

## ABSTRACT

CAREY, DENNIS JOHN. The Effects of Benzyladenine on Ornamental Crops. (Under the direction of Drs. Brian Whipker and Wayne Buhler).

A synthetic cytokinin, benzyladenine (BA), has recently been released in the U.S. as Configure<sup>®</sup> (2% liquid solution) for use on ornamental plants. Experiments were conducted to determine the efficacy of BA on various ornamental crops and to determine the optimal concentrations.

BA was trialed on petunias, succulents, *Paeonia*, *Salvia* 'Caradonna', and *Helleborus* ×*hybridus* and resulted in an increase in shoot number. Succulents (*Sempervivum*, *Echeveria*, *Jovibarba*, *Agave*, and *Aloe*) were the most reactive. The ideal foliar spray concentrations of 200 to 400 mg•L<sup>-1</sup> applied one time increased offset formation by two times in five *Sempervivum* cultivars and in *Echeveria*. The ideal foliar spray concentration of 1600 mg•L<sup>-1</sup> applied one time increased offset formation by two times in one cultivar of *Jovibarba*. BA foliar sprays applied two times were ineffective on three *Agave* cultivars and three *Aloe* cultivars.

Foliar sprays, drenches, fertigations, bulb soaks and plug dips in a range of concentrations, application numbers and timings were evaluated on an additional 48 annual and perennial species. Applications of BA had minor positive effects, no effects, or negative effects and the most promising commercial applications will be presented.

The Effects of Benzyladenine on Ornamental Crops.

by  
Dennis John Carey Jr.

A thesis submitted to the Graduate Faculty of  
North Carolina State University  
in partial fulfillment of the  
requirements for the Degree of  
Master of Science

Horticultural Science

Raleigh, North Carolina

2008

APPROVED BY:

---

Wayne Buhler, Ph.D.  
Co-Chair of Advisory Committee

---

Brian E. Whipker, Ph.D.  
Co-Chair of Advisory Committee

---

Mark Kistler, Ph.D

## DEDICATION

To my wife Eileen who has supported me through my career change, who has read every single paper I have ever written, and, inserted, commas, in, the, right, places.

## BIOGRAPHY

Dennis John Carey Jr. was born on 13 June, 1969 in Rockford, Illinois to Dennis and Kathryn Carey. In 1976 he moved to Cary, North Carolina. Dennis graduated from Cary High School in 1987. He went on to attend North Carolina State University and received a Bachelor of Science Degree in Electrical Engineering in December 1992 and a Bachelor of Science Degree in Computer Engineering in August 1993. He worked as a software engineer at Nortel Networks in RTP, NC until he was laid off in December 2002. He decided to change careers into Horticulture and went back to North Carolina State University and received a Bachelor of Science Degree in Horticulture Science in December 2004. He then worked at Plantworks Nursery in Rougemont, NC as a Section Grower until December 2006. In January 2007 he began a program of graduate study at North Carolina State University in Horticulture under the direction of Dr. Brian Whipker. Following the completion of the requirements for the degree of Master of Science in the floriculture program Dennis will find a job in the field of ornamental horticulture.

## ACKNOWLEDGMENTS

I would like to thank a number of people for their help and guidance throughout my graduate studies. I would like to thank Dr. Brian E. Whipker for his guidance and encouragement. Thank you to Eileen Carey for her time spent editing everything that I have ever written. Thanks to Ingram McCall for her help setting up experiments and taking data.

## TABLE OF CONTENTS

|  |     |
|--|-----|
| LIST OF TABLES .....                                 | xii |
| LIST OF FIGURES .....                                | xvi |
| Chapter 1 .....                                      | 1   |
| Literature Review and Introduction .....             | 1   |
| 1.1 The Need for Plant Growth Regulators .....       | 1   |
| 1.2 History of Plant Growth Regulators .....         | 2   |
| 1.3 Overview of Plant Growth Regulators.....         | 3   |
| 1.3.1 Growth Inhibition.....                         | 4   |
| 1.3.1.1 Anti-Gibberellins.....                       | 4   |
| 1.3.1.2 Anti-Auxins.....                             | 6   |
| 1.3.2 Branching Agents.....                          | 8   |
| 1.3.2.1 Ethylene Promoters .....                     | 8   |
| 1.3.2.1.1 Ethephon.....                              | 9   |
| 1.3.2.2 Methyl Esters of Fatty Acids.....            | 9   |
| 1.3.2.3 Dikegulac-sodium .....                       | 9   |
| 1.3.2.4 Cytokinins .....                             | 10  |
| 1.3.2.5 Anti-Auxins.....                             | 11  |
| 1.3.3 Growth Enhancers.....                          | 12  |
| 1.3.3.1 Gibberellins .....                           | 12  |
| 1.3.3.2 Auxins .....                                 | 12  |
| 1.3.4 Flowering Enhancers .....                      | 13  |
| 1.3.4.1 Gibberellins .....                           | 13  |
| 1.3.4.2 Cytokinins .....                             | 13  |
| 1.3.5 Senescence Interruption .....                  | 14  |
| 1.3.5.1 Cytokinins .....                             | 15  |
| 1.3.5.2 Anti-Ethylene Compounds.....                 | 15  |
| 1.3.5.2.1 1-MCP .....                                | 16  |
| 1.3.5.2.2 Silver Thiosulfate (STS).....              | 16  |
| 1.3.6 Stop Water Loss.....                           | 16  |
| 1.3.7 Research Focus of this Thesis.....             | 16  |
| 1.4 Overview of Cytokinins.....                      | 17  |
| 1.4.1 Description of Cytokinins .....                | 17  |
| 1.4.1.1 Cytokinin Effects in Plants.....             | 18  |
| 1.4.1.1.1 Cell Division.....                         | 19  |
| 1.4.1.1.2 Morphogenesis .....                        | 19  |
| 1.4.1.1.3 Lateral Bud Growth / Apical Dominance..... | 19  |
| 1.4.1.1.4 Flower Promotion or Inhibition.....        | 22  |
| 1.4.1.1.5 Leaf Expansion .....                       | 23  |
| 1.4.1.1.6 Delay Senescence .....                     | 23  |
| 1.4.1.1.7 Stomatal Opening .....                     | 24  |
| 1.4.1.1.8 Chlorophyll Biosynthesis .....             | 25  |
| 1.4.1.1.9 Flower Sex Ratios.....                     | 25  |

|   |    |
|---|----|
| 1.4.1.1.10 Vernalization .....  | 26 |
| 1.4.1.1.11 Parthenocarpy .....  | 26 |
| 1.4.1.1.12 Nutrient Signaling and Photosynthate Partitioning.....         | 26 |
| 1.4.1.1.13 Seed Development and Germination .....                         | 27 |
| 1.4.1.1.14 Cellular Differentiation.....                                  | 28 |
| 1.4.1.1.15 Maturation .....   | 28 |
| 1.4.1.1.16 Stress Resistance .....  | 29 |
| 1.4.1.1.17 Mycorrhizal Interactions.....                                  | 29 |
| 1.4.2 Cytokinin Biosynthesis .....  | 30 |
| 1.4.3 Cytokinin Absorption and Transport .....                            | 30 |
| 1.4.4 Cytokinin Metabolism .....  | 31 |
| 1.4.5 Cytokinin Reception and Binding.....                                | 32 |
| 1.4.6 Cytokinin Signal Transduction .....                                 | 32 |
| 1.4.7 Cytokinin Genetic Responses .....                                   | 33 |
| 1.4.8 Cytokinin Genetically Modified Crops.....                           | 33 |
| 1.4.9 Regulation of Cytokinin Production .....                            | 35 |
| 1.4.10 Cytokinin Forms .....  | 35 |
| 1.4.10.1 Free Base Forms.....   | 37 |
| 1.4.10.1.1 Isoprenoid Cytokinins.....                                     | 37 |
| 1.4.10.1.2 Aromatic Cytokinins.....                                       | 38 |
| 1.4.10.1.3 Substituted Urea Cytokinins .....                              | 38 |
| 1.4.10.1.4 Other Cytokinins .....   | 39 |
| 1.4.10.2 Storage and Transport Forms .....                                | 39 |
| 1.4.11 Cytokinin Reactions with Other Hormones.....                       | 40 |
| 1.4.11.1 Gibberellins .....   | 41 |
| 1.4.11.2 Abscisic Acid .....  | 41 |
| 1.4.11.3 Ethylene.....  | 42 |
| 1.4.11.4 Auxin.....   | 43 |
| 1.4.11.5 Phytochrome .....  | 44 |
| 1.4.12 Anticytokinins.....  | 45 |
| 1.4.13 Detection of Cytokinins .....                                      | 45 |
| 1.4.14 Factors Affecting Cytokinin Activity .....                         | 46 |
| 1.4.14.1 Activity Level of the Particular Cytokinin .....                 | 46 |
| 1.4.14.2 Amount of Cytokinin Present.....                                 | 46 |
| 1.4.14.3 Location of the Cytokinin Application.....                       | 47 |
| 1.4.14.4 Sensitivity / Responsiveness of the Tissue to Cytokinin .....    | 47 |
| 1.4.15 Current Uses of Cytokinins on Plants Outside of Floriculture ..... | 47 |
| 1.4.15.1 Fruit Orchards .....   | 47 |
| 1.4.15.2 Cotton Defoliant.....  | 48 |
| 1.4.15.3 Christmas tree Branching Agent .....                             | 48 |
| 1.4.15.4 Cut Flowers .....  | 48 |
| 1.4.15.5 Landscape Management .....                                       | 49 |
| 1.4.15.6 Turf Management.....   | 49 |
| 1.4.15.7 Tissue Culture .....   | 49 |
| 1.4.16 Cytokinin Based Products.....                                      | 50 |
| 1.4.17 Cytokinin Rates and Conversions.....                               | 52 |

|  |    |
|--|----|
| 1.4.18 Cytokinin Effects Useful for Floriculture Growers .....                                       | 53 |
| 1.4.18.1 Height Control / Growth Retardant .....   | 53 |
| 1.4.18.2 Shoot to Root Ratios .....  | 53 |
| 1.4.18.3 Height Enhancer .....   | 54 |
| 1.4.18.4 Branching Agent .....   | 54 |
| 1.4.18.5 Improve Branch Angles .....   | 55 |
| 1.4.18.6 Flower Enhancer / Promoter.....   | 55 |
| 1.4.18.7 Flower Inhibitor.....   | 56 |
| 1.4.18.8 Stress Resistance .....   | 57 |
| 1.4.18.8.1 Resist Oxidative Stress .....   | 57 |
| 1.4.18.8.2 Preserve Plant Quality during Drought or Salinity Stress.....                             | 57 |
| 1.4.18.8.3 Preserve Plant Quality during Production or Shipping.....                                 | 58 |
| 1.4.18.8.4 Recovery from Flooding.....   | 59 |
| 1.4.18.8.5 Prevent Nutrient Deficiency Symptoms .....  | 60 |
| 1.4.18.8.6 Prevent Quality Loss in Low Light Conditions .....  | 60 |
| 1.4.18.8.7 Prevent or Delay Quality Loss in Low Temperature Conditions.....                          | 61 |
| 1.4.18.8.8 Prevent or Delay Quality Loss in High Temperature Conditions.....                         | 61 |
| 1.4.18.8.9 Prevent or Delay Problems Caused by High Humidity .....                                   | 62 |
| 1.4.18.9 Improve Disease Resistance.....   | 62 |
| 1.4.18.10 Improve Insect Resistance.....   | 64 |
| 1.4.18.11 Prevent Loss of Quality in Crowded Conditions.....   | 65 |
| 1.4.18.12 Prevent or Reduce Transplant Shock .....   | 65 |
| 1.4.18.13 Alter Crop Timing .....  | 66 |
| 1.4.18.13.1 Accelerate Growth.....   | 66 |
| 1.4.18.13.2 Induce Early Flowering .....   | 66 |
| 1.4.18.13.3 Synchronize Flowering.....   | 66 |
| 1.4.18.13.4 Break Dormancy or Reduce Vernalization Requirements for Out of Season<br>Production..... | 67 |
| 1.4.18.14 Improve Propagation Results .....  | 68 |
| 1.4.18.14.1 Stock Plant Maintenance .....  | 68 |
| 1.4.18.14.2 Accelerate Flowering of Plants with Extended Juvenile Periods.....                       | 69 |
| 1.4.18.14.3 Improve Grafting Results .....   | 69 |
| 1.4.18.14.4 Increase Tuberization .....  | 70 |
| 1.4.18.14.5 Increase Bulb Offsets.....   | 70 |
| 1.4.18.14.6 Improve Seed Germination.....  | 70 |
| 1.4.18.14.7 Increase Plantlets that Form from Leaf Cuttings .....                                    | 72 |
| 1.4.18.15 Improve Vase Life and Quality of Cut Flowers .....   | 72 |
| 1.4.18.16 Effects on Fruiting.....   | 74 |
| 1.4.18.16.1 Increase Fruit Set or Seed Set.....  | 75 |
| 1.4.18.16.2 Increase Fruit Size .....  | 76 |
| 1.4.18.16.3 Delay Fruit Maturation and Ripening .....  | 76 |
| 1.4.18.16.4 Increase Postharvest Fruit Storage and Shelf Life .....                                  | 76 |
| 1.4.18.16.5 Thin Fruit for Even Cropping .....   | 77 |
| 1.4.19 Potential Side Effects of Cytokinins .....  | 77 |
| 1.4.20 How to Apply Cytokinins to Floriculture Crops.....  | 78 |
| 1.4.20.1 Concentration Responses .....   | 79 |
| 1.4.20.2 What Application Concentrations to Use.....   | 81 |
| 1.4.20.3 Application Timing and Number .....   | 82 |
| 1.4.20.4 Application Methods.....  | 83 |

|  |     |
|--|-----|
| 1.4.20.4.1 Applications Made in Conjunction with Pinching .....          | 84  |
| 1.4.20.4.2 Foliar Sprays .....   | 84  |
| 1.4.20.4.3 Substrate Drenches.....                                       | 86  |
| 1.4.20.4.4 Pre-plant Bulb Soaks.....                                     | 87  |
| 1.4.20.4.5 Seed Soak / Priming.....                                      | 87  |
| 1.4.20.4.6 Dips.....   | 88  |
| 1.4.20.4.7 Paste.....  | 88  |
| 1.4.20.4.8 Capillary String.....   | 89  |
| 1.4.20.4.9 Floral Cube .....   | 89  |
| 1.4.20.4.10 Cotton Swab .....  | 90  |
| 1.4.20.4.11 Droplets .....   | 90  |
| 1.4.20.4.12 Injection.....   | 90  |
| 1.4.20.4.13 Sub-Irrigation or Hydroponic Application .....               | 91  |
| 1.4.20.4.14 Pre-plant Substrate Spray .....                              | 91  |
| 1.4.20.4.15 Liner Dips.....  | 92  |
| 1.4.20.4.16 Sprench.....   | 92  |
| 1.4.20.4.17 Impregnated Granules or Stakes.....                          | 92  |
| 1.4.20.4.18 Paint.....   | 92  |
| 1.4.20.4.19 Sponge.....  | 93  |
| 1.4.20.4.20 Tubing .....   | 93  |
| 1.4.20.4.21 Vacuum Infusion .....  | 93  |
| 1.4.20.5 Combining Cytokinins with Other PGR Chemicals and Methods ..... | 93  |
| 1.4.20.5.1 Anti-Gibberellins .....                                       | 94  |
| 1.4.20.5.2 Gibberellins.....   | 94  |
| 1.4.20.5.3 Branching Agents.....   | 94  |
| 1.4.20.5.4 Anti-Ethylene Agents.....                                     | 95  |
| 1.4.20.5.5 Auxins.....   | 95  |
| 1.4.20.5.6 Anti-Auxins .....   | 95  |
| 1.4.20.5.7 Abscisic Acid.....  | 96  |
| 1.4.20.5.8 Water Level.....  | 96  |
| 1.4.20.5.9 Nutrition Level.....  | 96  |
| 1.4.20.5.10 Temperature.....   | 97  |
| 1.5 Conclusion .....   | 97  |
| 1.6 Bibliography .....   | 98  |
| Chapter 2.....   | 129 |
| Benzyladenine Affects Growth of Petunia .....                            | 129 |
| Abstract.....  | 131 |
| 2.1 Introduction.....  | 132 |
| 2.2 Materials and Methods.....   | 133 |
| 2.2.1 Experiment One .....   | 133 |
| 2.2.2 Experiment Two.....  | 133 |
| 2.2.3 Experiment Three.....  | 134 |
| 2.2.4 Experiment Four.....   | 135 |
| 2.3 Results.....   | 136 |
| 2.3.1 Experiment One .....   | 136 |
| 2.3.2 Experiment Two.....  | 136 |

|  |     |
|--|-----|
| 2.3.4 Experiment Three.....  | 137 |
| 2.3.4 Experiment Four.....   | 138 |
| 2.4 Discussion.....  | 138 |
| 2.5 Literature Cited.....  | 139 |
| Chapter 3.....   | 144 |
| The Effect of Benzyladenine Foliar Sprays on Offsetting of Succulents.....                 | 144 |
| Abstract.....  | 146 |
| 3.1 Introduction.....  | 147 |
| 3.2 Materials and Methods.....   | 147 |
| 3.2.1 Experiment One.....  | 147 |
| 3.2.2 Experiment Two.....  | 149 |
| 3.2.3 Experiment Three.....  | 149 |
| 3.2.4 Experiment Four.....   | 150 |
| 3.3 Results.....   | 151 |
| 3.3.1 Experiment One.....  | 151 |
| 3.3.2 Experiment Two.....  | 152 |
| 3.3.3 Experiment Three.....  | 152 |
| 3.3.4 Experiment Four.....   | 152 |
| 3.4 Discussion.....  | 153 |
| 3.5 Literature Cited.....  | 154 |
| Chapter 4.....   | 160 |
| Peony Rhizome Soaks in Benzyladenine Reduce Dormancy.....                                  | 160 |
| Abstract.....  | 162 |
| 4.1 Introduction.....  | 162 |
| 4.2 Materials and Methods.....   | 163 |
| 4.3 Results.....   | 164 |
| 4.4 Discussion.....  | 164 |
| 4.5 Literature Cited.....  | 165 |
| Chapter 5.....   | 168 |
| Benzyladenine Foliar Sprays Increase the Number of Flower Stalks in <i>Salvia nemorosa</i> |     |
| ‘Caradonna’.....   | 168 |
| Abstract.....  | 170 |
| 5.1 Introduction.....  | 170 |
| 5.2 Materials and Methods.....   | 171 |
| 5.3 Results.....   | 172 |
| 5.4 Discussion.....  | 172 |
| 5.5 Literature Cited.....  | 173 |
| Chapter 6.....   | 176 |

|   |     |
|---|-----|
| Benzyladenine Foliar Sprays Increase Shoot Number in <i>Helleborus</i> $\times$ <i>hybridus</i> ..... | 176 |
| Abstract .....  | 178 |
| 6.1 Introduction .....  | 178 |
| 6.2 Materials and Methods .....   | 179 |
| 6.3 Results .....   | 181 |
| 6.4 Discussion .....  | 181 |
| 6.5 Literature Cited .....  | 182 |
| Chapter 7 .....   | 186 |
| The Effect of Benzyladenine on Ornamental Plants .....  | 186 |
| Abstract .....  | 188 |
| 7.1 Introduction .....  | 189 |
| 7.2 Materials and Methods .....   | 189 |
| 7.3 Results .....   | 192 |
| 7.3.1 <i>Acalypha microphylla</i> .....   | 192 |
| 7.3.2 <i>Aquilegia flabellate</i> .....   | 192 |
| 7.3.3 <i>Begonia</i> $\times$ <i>hybrida</i> .....  | 193 |
| 7.3.4 <i>Catharanthus roseus</i> .....  | 194 |
| 7.3.4.1 Spray .....   | 195 |
| 7.3.4.2 Drench .....  | 195 |
| 7.3.4.3 Fertigation .....   | 196 |
| 7.3.4.4 Plug Dip .....  | 196 |
| 7.3.5 <i>Coreopsis grandiflora</i> .....  | 196 |
| 7.3.6 <i>Euphorbia pulcherrima</i> .....  | 197 |
| 7.3.7 <i>Exacum affine</i> .....  | 198 |
| 7.3.8 <i>Gerbera jamesonii</i> .....  | 199 |
| 7.3.9 <i>Heuchera micrantha</i> var. <i>diversifolia</i> .....  | 199 |
| 7.3.10 <i>Impatiens hawkeri</i> 'Fox Red' and 'Fox Pink' .....  | 200 |
| 7.3.11 <i>Impatiens hawkeri</i> 'Red Fox Riviera Bright Red' .....                                    | 201 |
| 7.3.12 <i>Ipomoea batatas</i> .....   | 201 |
| 7.3.13 <i>Iresine</i> hybrid .....  | 202 |
| 7.3.14 <i>Lantana camara</i> 'Miss Huff' .....  | 203 |
| 7.3.15 <i>Lantana camara</i> 'Lucky Red Hot Imp' .....  | 204 |
| 7.3.16 <i>Lantana camara</i> 'New Gold' .....   | 204 |
| 7.3.17 <i>Liatris spicata</i> .....   | 205 |
| 7.3.18 <i>Oenothera fruticosa youngii</i> .....   | 206 |
| 7.3.19 <i>Pentas lanceolata</i> .....   | 206 |
| 7.3.20 <i>Portulaca oleracea</i> .....  | 207 |
| 7.3.21 <i>Pseuderanthemum atropurpureum</i> .....   | 208 |
| 7.3.22 <i>Rudbeckia hirta</i> .....   | 208 |
| 7.3.23 <i>Salvia splendens</i> .....  | 209 |
| 7.3.24 <i>Scabiosa caucasica</i> .....  | 210 |
| 7.3.25 <i>Scutellaria</i> hybrid .....  | 211 |
| 7.3.26 <i>Senecio cineraria</i> .....   | 211 |
| 7.3.26.1 Spray .....  | 212 |
| 7.3.26.2 Drench .....   | 212 |
| 7.3.26.3 Fertigation .....  | 213 |

|   |     |
|---|-----|
| 7.3.27 <i>Solenostemon scutellarioides</i> 'Red Coat' .....                                   | 214 |
| 7.3.28 <i>Solenostemon scutellarioides</i> 'Mint Mocha' and 'Indian Summer' .....             | 214 |
| 7.3.29 <i>Sutera cordata</i> .....  | 215 |
| 7.3.30 <i>Verbena</i> hybrid.....   | 216 |
| 7.3.31 <i>Viola</i> × <i>wittrockiana</i> .....   | 216 |
| 7.3.32 <i>Zinnia elegans</i> .....  | 218 |
| 7.3.32.1 Spray – Part 1 .....   | 218 |
| 7.3.32.2 Drench .....   | 219 |
| 7.3.32.3 Fertigation .....  | 219 |
| 7.3.32.4 Spray – Part 2 .....   | 219 |
| 7.4 Discussion .....  | 221 |
| 7.5 Literature Cited .....  | 221 |
| APPENDIX .....  | 248 |
| A1. Summary of Research on the Effects of Cytokinins on Horticultural Crops.....              | 249 |
| A1.1 Summary of Research on the Effects of Cytokinins on Herbaceous Ornamental<br>Crops ..... | 250 |
| A1.2 Effects of Cytokinins on Postharvest / Cut Flower Ornamental Plants. ....                | 308 |
| A1.3 Effects of Cytokinins on Woody Ornamental Crops .....                                    | 318 |
| A1.4 Effects of Cytokinins on Non-ornamental Horticultural Crops.....                         | 334 |
| A2 Literature Cited .....   | 369 |

## LIST OF TABLES

|           |  |     |
|-----------|--|-----|
| Table 1.1 | Common cytokinin based products and their horticultural use area .....   | 51  |
| Table 1.2 | Molecular weights and conversion ratios for molar to milligrams per liter of the commonly used cytokinins .....  | 52  |
| Table 2.1 | Effects of benzyladenine foliar sprays on the number of branches of non-free-branching vegetative petunia ‘Improved Charlie’ .....   | 140 |
| Table 2.2 | Effects of single foliar sprays of 100 mg•L <sup>-1</sup> benzyladenine on ‘Wave Purple’ petunia at four different times (Expt. 3).....  | 140 |
| Table 2.3 | Effects of a single drench application of benzyladenine on ‘Wave Purple’ petunia (Expt. 3).....  | 141 |
| Table 2.4 | Main effects of a single foliar spray of a tank mix of benzyladenine (80, 120 mg•L <sup>-1</sup> ) with daminozide (2500, 5000 mg•L <sup>-1</sup> ) on ‘Wave Purple’ petunia (Expt. 3).....        | 141 |
| Table 3.1 | The effects of benzyladenine spray concentration on the number of offsets produced by <i>Sempervivum</i> ‘Red Heart’, <i>Sempervivum</i> ‘Green Wheel’ and <i>Echeveria setosa</i> (Expt. 1) ..... | 156 |
| Table 3.2 | The effects of benzyladenine spray concentration on the average number of flower stalks per plant on <i>Echeveria setosa</i> at 14 WAP (Expt. 1) .....   | 156 |
| Table 3.3 | The rooting quality of <i>Sempervivum</i> ‘Green Wheel’ as a function of offset size at harvesting (Expt. 1) .....   | 157 |
| Table 3.4 | The rooting quality of <i>Sempervivum</i> ‘Green Wheel’ offsets, greater than 1 cm in diameter, whose parent plants were treated with benzyladenine (BA) (Expt. 1) .....                           | 157 |
| Table 3.5 | The effects of benzyladenine spray (BA) concentration on the average number of flower stalks per plant produced by <i>Aloe</i> cultivar ‘Grassy Lassie’ (Expt. 3).....                             | 158 |
| Table 3.6 | The effects of benzyladenine spray concentration on the number of offsets produced by <i>Sempervivum</i> , <i>Jovibarba</i> and <i>Euphorbia suzannae</i> (Expt. 4) .....                          | 158 |
| Table 4.1 | The effects of benzyladenine rhizome soaks on the number of days to emergence of the last bud on Peony ‘Karl Rosenfield’ .....   | 167 |

|            |  |     |
|------------|--|-----|
| Table 5.1  | The effects of benzyladenine (BA) on the growth characteristics of <i>Salvia nemorosa</i> 'Caradonna' at 4 WAP .....   | 174 |
| Table 5.2  | The effects of benzyladenine (BA) on the flowering characteristics of <i>Salvia nemorosa</i> 'Caradonna' .....   | 174 |
| Table 6.1  | The effects of 6 foliar spray applications of benzyladenine on the number of shoots on <i>Helleborus ×hybridus</i> plants .....  | 183 |
| Table 7.1  | Description of the round azalea pot sizes used for this experiment.....  | 223 |
| Table 7.2  | Benzyladenine effect on <i>Acalypha microphylla</i> leaf size index .....  | 223 |
| Table 7.3  | The effect of a single foliar spray of benzyladenine on <i>Begonia ×hybrida</i> 'Dragon Wing Red' .....  | 224 |
| Table 7.4  | The effects of single foliar sprays of benzyladenine on <i>Catharanthus roseus</i> 'Pacifica Lilac' at 5.5 weeks after potting.....  | 224 |
| Table 7.5  | Effects of a single drench application of benzyladenine on <i>Catharanthus roseus</i> 'Pacifica Lilac' at 5.5 weeks after potting.....   | 225 |
| Table 7.6  | Fertigation applications of benzyladenine effects on <i>Catharanthus roseus</i> 'Pacifica Lilac' at 5.5 weeks after potting .....  | 225 |
| Table 7.7  | The effect of a single foliar spray of benzyladenine on the number of branches of <i>Impatiens hawkeri</i> 'Red Fox Riviera Bright Red' recorded at 4 weeks after spraying ..... | 226 |
| Table 7.8  | The effect of single foliar sprays of benzyladenine on the number of branches present at 5 WAP on <i>Iresine</i> hybrid 'Blazin Rose'.....                                       | 226 |
| Table 7.9  | The effect of foliar sprays of benzyladenine on the number of branches present at 5 WAP on <i>Lantana camara</i> 'New Gold'.....   | 227 |
| Table 7.10 | The effect of a single foliar spray of benzyladenine on the branching of <i>Portulaca oleracea</i> 'Rio Yellow'.....   | 227 |
| Table 7.11 | The effect of a single foliar spray of benzyladenine on the growth characteristics of <i>Rudbeckia hirta</i> 'Becky Mix' .....   | 228 |
| Table 7.12 | The effect of a single foliar spray of benzyladenine on the number of branches of <i>Salvia splendens</i> 'Dancing Flame' .....  | 228 |

|            |   |     |
|------------|---|-----|
| Table 7.13 | The effect of a single foliar spray of benzyladenine on the growth characteristics of <i>Senecio cineraria</i> .....  | 229 |
| Table 7.14 | The effect of drench applications of benzyladenine on the growth characteristics of <i>Senecio cineraria</i> .....  | 229 |
| Table 7.15 | The effect of fertigation applications of benzyladenine on the growth characteristics of <i>Senecio cineraria</i> .....   | 230 |
| Table 7.16 | The effect of a single foliar spray application of benzyladenine on the growth characteristics of slow-growth-rate viola cultivars.....   | 230 |
| Table 7.17 | The effect of a single foliar spray application of benzyladenine on the growth characteristics of medium-growth-rate pansy cultivars.....   | 231 |
| Table 7.18 | The effect of a single foliar spray application of benzyladenine on the growth characteristics of fast-growth-rate pansy cultivar.....  | 232 |
| Table 7.19 | The effect of a single foliar spray application of benzyladenine on the growth characteristics of <i>Zinnia elegans</i> ‘Dreamland Scarlet’ .....   | 233 |
| Table 7.20 | The effect of a single drench application of benzyladenine on the growth characteristics of <i>Zinnia elegans</i> ‘Dreamland Scarlet’ .....   | 234 |
| Table 7.21 | The effect of fertigation applications of benzyladenine on the growth characteristics of <i>Zinnia elegans</i> ‘Dreamland Scarlet’ .....  | 234 |
| Table 7.22 | The effect of multiple foliar spray applications of benzyladenine on the growth characteristics of <i>Zinnia elegans</i> ‘Dreamland Scarlet’ .....  | 235 |
| Table 7.23 | The effect of multiple foliar spray applications of benzyladenine on the ratios of growth variables of <i>Zinnia elegans</i> ‘Dreamland Scarlet’ indicate that multiple sprays increase branching and decrease average node length..... | 236 |
| Table 7.24 | Summary of the effects of benzyladenine on the plants tested in this experiment.....  | 237 |
| Table A1   | Research efforts for exogenous cytokinins on herbaceous ornamental crops .....  | 250 |
| Table A2   | Research efforts for exogenous cytokinins on cut flower crops .....   | 308 |
| Table A3   | Research efforts for exogenous cytokinins on woody plants.....  | 318 |

Table A4      Research efforts for exogenous cytokinins on non-ornamental crops .....334

## LIST OF FIGURES

|            |   |     |
|------------|---|-----|
| Figure 1.1 | Major steps in gibberellin biosynthesis highlighting the locations where anti-gibberellin plant growth regulators inhibit the process. Figure compiled from text and figures in (Sponsel and Hedden 2004) and (Sakakibara 2004).....  | 7   |
| Figure 1.2 | Adenine form cytokinins.....  | 36  |
| Figure 1.3 | Phenylurea form cytokinins .....  | 37  |
| Figure 1.4 | Hypothetical concentration response curve for exogenous cytokinins.....   | 80  |
| Figure 2.1 | Top views of control, 10, 20, 40, 80, 160 mg•L <sup>-1</sup> benzyladenine on ‘Improved Charlie’ petunia.....   | 142 |
| Figure 2.2 | Slight phytotoxicity of 160 mg•L <sup>-1</sup> benzyladenine on ‘Improved Charlie’ petunia appears as yellowish spots near the leaf tips of new foliage.....  | 142 |
| Figure 2.3 | Effects of benzyladenine foliar sprays on the average diameter (cm) of vegetative petunias. (A), One and two foliar sprays onto ‘Red Fox Surprise Blue Vein Improved’, (B) ‘Red Fox Surprise White, and (C) ‘Red Fox Surprise Red’. Average diameter calculated as width at the widest point + width after turning 90° / 2. ♦ - Single foliar spray • - Two foliar sprays .....   | 143 |
| Figure 2.4 | Side and top views of control plants and 2 spray applications of 160 mg•L <sup>-1</sup> benzyladenine on (top) ‘Red Fox Surprise Blue Vein Improved’, (middle) ‘Red Fox Surprise White’, and (bottom) ‘Red Fox Surprise Red’ petunias .....   | 143 |
| Figure 3.1 | Comparison of <i>Sempervivum</i> ‘Green Wheel’ at benzyladenine concentrations of 0 and 400 (mg•L <sup>-1</sup> ) highlighting the difference in the size of the offsets (Expt. 1) .....  | 159 |
| Figure 4.1 | Benzyladenine rhizome soaks on Peony ‘Karl Rosenfield’ hasten the time for the later buds to emerge resulting in larger plants at the end of production. Shown here are plants on May 20 that had been treated the previous fall with benzyladenine at concentrations (from left to right) of 0, 200, 400, 800, and 1600 mg•L <sup>-1</sup> . The largest plant (circled) is the 400 mg•L <sup>-1</sup> plant. It is larger because its shoots emerged an average of 35 days earlier than the control ..... | 167 |

|            |  |     |
|------------|--|-----|
| Figure 5.1 | Benzyladenine (BA) at 1600 mg•L <sup>-1</sup> causes slight phytotoxicity in the form of leaf edge necrosis indicated by the arrows .....  | 175 |
| Figure 5.2 | The effect of benzyladenine (BA) at concentrations of (from left to right) 0, 100, 200, 400, 800, or 1600 mg•L <sup>-1</sup> on the height and flowering of <i>Salvia nemorosa</i> 'Caradonna'. Photo taken 4 WAP .....  | 175 |
| Figure 6.1 | Number of shoots versus weeks after potting (WAP) of the control (■) and the 800 mg•L <sup>-1</sup> treatment (◆) for spray applications of benzyladenine on <i>Helleborus ×hybridus</i> plants. Shoot number significantly different after 6 weeks ( $P \leq 0.05$ ) .....                            | 184 |
| Figure 6.2 | <i>Helleborus ×hybridus</i> control plant (left) and the 800 mg•L <sup>-1</sup> spray plant (right) .....  | 184 |
| Figure 6.3 | Leaf morphology changes on <i>Helleborus ×hybridus</i> plants sprayed with benzyladenine. A) Untreated plant. B) Narrow leaf segments. C) Feathered leaf margin. D) Increased number of segments per leaf .....  | 185 |
| Figure 7.1 | The effect of benzyladenine on <i>Acalypha microphylla</i> leaf size. Pictured here (left to right) are 0, 100, 200, and 400 mg•L <sup>-1</sup> . Note the reduction in leaf size with increasing concentrations of benzyladenine .....  | 240 |
| Figure 7.2 | A single foliar spray of benzyladenine at a concentration of 1600 mg•L <sup>-1</sup> causes minor phytotoxicity on <i>Aquilegia flabellate</i> in the form of minor leaf edge necrosis .....   | 240 |
| Figure 7.3 | The effect of single foliar sprays of benzyladenine on the branching of <i>Begonia ×hybrida</i> 'Dragon Wing Red'. Photo taken at 6 WAP. From left to right is the control versus the 80 mg•L <sup>-1</sup> concentration .....  | 241 |
| Figure 7.4 | Effects of a single drench application of benzyladenine on branching of <i>Catharanthus roseus</i> 'Pacifica Lilac'. Measurements taken at 5.5 WAP. From left to right – Control versus 15 mg ai at 3 WAP. Note the increased number of small branches at the base .....                               | 241 |
| Figure 7.5 | Phytotoxicity caused by 2 benzyladenine foliar sprays spaced one week apart on <i>Exacum affine</i> at 400 mg•L <sup>-1</sup> . The plant was chlorotic, the apical meristems were killed, the new growth was very small, and flowering was inhibited during the entire length of the experiment ..... | 242 |
| Figure 7.6 | Phytotoxicity caused by a single benzyladenine foliar spray at 4 WAP on <i>Heuchera micrantha</i> var. <i>diversifolia</i> 'Palace Purple' at 1600 mg•L <sup>-1</sup> . Note the crinkled leaves, necrotic spots and edge necrosis .....   | 243 |

|             |  |     |
|-------------|--|-----|
| Figure 7.7  | Phytotoxicity caused by a single benzyladenine foliar spray on <i>Impatiens hawkeri</i> 'Red Fox Riviera Bright Red' at 1600 mg•L <sup>-1</sup> . Note the edge chlorosis .....                                    | 244 |
| Figure 7.8  | Phytotoxicity caused by a single benzyladenine foliar spray on <i>Iresine</i> hybrid 'Blazin Rose' at 3200 mg•L <sup>-1</sup> . Note the leaf cupping.....   | 245 |
| Figure 7.9  | Phytotoxicity caused by a single benzyladenine foliar spray on <i>Oenothera fruticosa youngii</i> at 1600 mg•L <sup>-1</sup> . Note the leaf cupping.....  | 245 |
| Figure 7.10 | A single foliar spray of benzyladenine affects growth index and height of <i>Rudbeckia hirta</i> 'Becky Mix'.....  | 246 |
| Figure 7.11 | Phytotoxicity symptoms of a single foliar spray of benzyladenine at 1600 mg•L <sup>-1</sup> on <i>Scabiosa caucasica</i> 'Perfecta alba'. Note the leaf crinkling and the leaf edge chlorosis.....                 | 246 |
| Figure 7.12 | Phytotoxicity caused by a single foliar spray of benzyladenine at 800 mg•L <sup>-1</sup> on pansy cultivar 'Delta Pure Rose'. Note the severe yellowing on the new growth.....                                     | 247 |
| Figure 7.13 | Phytotoxicity symptoms of a single foliar spray of benzyladenine at 800 mg•L <sup>-1</sup> applied at 3 WAP on <i>Zinnia elegans</i> . Note the leaf crinkling and the leaf edge chlorosis on the new leaves ..... | 247 |

## **Chapter 1**

### **Literature Review and Introduction**

#### **1.1 The Need for Plant Growth Regulators**

Commercial ornamental plant growers have to satisfy both aesthetic and practical requirements in order to deliver a high quality plant to buyers. Ornamental requirements include the presence of flowers at shipping time, deep green leaf color, freedom from pests and disease, and proper size proportion between the plant and its pot. Practical considerations include everything that makes the plant easier to house, package, ship, and survive the retail environment. Growers sometimes have to produce plants based on calendar dates that do not always follow the natural schedule of the plant. In order to produce quality plants, ornamental growers use a variety of cultural practices and chemical products to influence plant growth. Cultural practices used by growers involve manipulating environmental factors such as light, temperature, water, and nutrients. Sound cultural practices are the single most important factor in influencing plant growth and quality (Keever, 1994b). However, manipulating the environment is not always possible due to factors such as cost or the presence of mixed crop types in a single greenhouse. One alternative method that growers use to manipulate plant quality involves physically altering the shape of a plant via staking, pruning, and pinching. This is very expensive as it is not conducive to automation and requires manual labor (Puglisi, 2002). Thus ornamental growers may decide to use chemical applications in order to manipulate plant characteristics. These chemicals are called plant growth regulators (PGRs). Proper PGR use improves plant quality and yield. However, improper PGR use can delay flowering, ruin growth habit or cause phytotoxicity. Plant

growth regulators are used by ornamental plant growers to assist with plant propagation by improving seed germination, improving the rooting of cut stems, and triggering the growth of plant tissue cultures. Plant growth regulators are also used during production to reduce or increase the growth rate of plants, chemically pinch plants, induce buds to break dormancy, break apical dominance, and to delay senescence of buds, flowers, or leaves.

### **1.2 History of Plant Growth Regulators**

The first generation of plant growth regulators for use by the ornamental plant industry were released from the 1920s to the 1950s (Agranova, 1997) and consisted primarily of natural or synthetic auxins and gibberellins. Some of these older chemicals are no longer available because they are toxic or there are newer, more effective compounds. The first of the modern generation of ornamental PGRs, chlormequat (Cycocel), was commercially available in the 1960s (Albrecht and Tayama, 1992). This was soon followed by daminozide (B-Nine) and ethephon (Ethrel, Florel). In the 1970's ancymidol (A-Rest) and dikegulac-sodium (Atrimmec) were released. In the 1980's, the triazine type PGRs paclobutrazol (Bonzi) and uniconazole (Sumagic) were released along with flurprimidol (Cutlass) and prohexadione-calcium (Apogee). The 1990s saw the release of cyclanilides (Finish). In the 2000's many new products have become available including generic forms of older chemicals (Dazide, Piccolo, Concise), new bedding plant registrations for existing chemicals (Tiburon, Topflor, Configure) and novel modes of action such as with abscisic acid (s-ABA).

PGR sales for all agricultural applications represent 3 to 4% of the total pesticide market and in 2002 totaled \$0.9 to \$1.2 billion per year (Menendez, 2002). Ornamental plant growth control is one of the smallest areas of PGR use. The largest uses of PGRs are for

cotton defoliation, fruit and nut ripening, and vegetative growth control of cereals and grasses.

Ornamental plant growers now have a large toolbox of PGRs that they can use on their plants. Each new product provides a new price point, a new set of application restrictions, or a new mode of action. This allows ornamental growers flexibility in application timing and method, and allows them to make more money by providing higher quality products to their customers at lower cost.

### **1.3 Overview of Plant Growth Regulators**

PGRs are chemicals that are applied in low doses, absorbed into the plant through the epidermis, and transported to a site of action. They are then recognized and bound to a receptor which amplifies the signal by activating a secondary messaging system to trigger or inhibit a cellular activity. In this regard PGRs are similar to plant hormones (Puglisi, 2002) and some PGRs are plant hormones. If the concentration is too low, is mal-absorbed, or if the plant is not able to perceive the chemicals then the PGR application will not have the desired effect. Thus PGR activity depends on environmental factors that influence absorption and on the physiological status of the plant.

Modern PGRs have a variety of modes of action and affect plants in different ways. Some PGRs are synthetic versions of plant hormones and mimic their actions. Other PGRs inhibit the biosynthesis, reception, or metabolism of plant hormones and thus block the activity of plant hormones.

Each specialty area of horticulture (fruit trees, turf management, cut flowers, weed science, floriculture, and nursery) has its own requirements and its own set of PGRs. The

chemicals may be used in more than one area of horticulture, but they may be sold under different brand names, percentage of active ingredient, and have different registration restrictions. In the ornamental pot crop and bedding plant industry, growers typically have the following needs.

### **1.3.1 Growth Inhibition**

Growth inhibition is the most common reason that ornamental plant growers use PGRs. Commercially produced plants are grown in crowded conditions with ideal levels of water, fertilizer, temperature, and light. As a result the plants grow quickly and have a tendency to stretch. Growers often use growth inhibiting PGRs in combination with an environmental change to slow down the growth of a crop or hold it after it is finished. The growth inhibitors fall into two classes, the anti-gibberellins and the anti-auxins. Both restrict stem elongation by reducing the plant hormones that trigger cell expansion, or cell elongation.

#### **1.3.1.1 Anti-Gibberellins**

The gibberellin (GA) biosynthesis inhibitors (anti-gibberellins) are by far the most widely used by ornamental plant growers for growth inhibition. Blocking GA biosynthesis reduces cell elongation. At the whole plant level this causes the plant to grow more slowly or not at all. There are a large number of products in this class. The anti-GAs include chlormequat, daminozide, ancymidol, paclobutrazol, uniconazole, flurprimidol, mepiquat and prohexadione calcium. Each interrupts GA biosynthesis at a different location in the GA biosynthetic pathway and so there may be some synergy through tank mixing these products. Tank mixes of chlormequat and daminozide are common, and mixes of paclobutrazol and daminozide, or ancymidol and daminozide are possible. All of the anti-GAs can be applied

via a foliar spray. In addition, paclobutrazol, uniconazole, flurprimidol, chlormequat, and ancymidol may be applied as a substrate drench (Albrecht and Tayama, 1992). Care must be taken as bark based substrates reduce the activity of these chemicals and 10 to 25% more chemical is needed to have the same degree of control. Paclobutrazol and uniconazole may be applied to the substrate surface before planting via a method called pre-plant surface treatment. Paclobutrazol may also be applied via sub irrigation, but there is limited published research in this area.

Anti-gibberellins vary greatly in activity and persistence. The least active and shortest lived is daminozide which is safe on the greatest variety of ornamental plants and is active for about 10 days. It can be applied only via a foliar spray as it breaks down quickly in the substrate. It is very mobile and moves to all parts of the plant after being applied which is advantageous if the crop has a tight canopy. Daminozide is commonly applied at concentrations of 1250 to 5000 mg·L<sup>-1</sup>. Chlormequat has an activity level on par with daminozide. Chlormequat may be applied as a spray or drench and is commonly applied at concentrations of 400 to 3000 mg·L<sup>-1</sup>. Chlormequat sprays frequently cause yellow chlorotic spots when applied at concentrations above 1500 mg·L<sup>-1</sup>, or when the plant is stressed. However, drench applications do not. Daminozide and chlormequat are water soluble and take a long time (more than six hours) to move through the waxy cuticle of the plant. They need to be applied at a time when the leaf surface will stay wet for several hours, such as in the morning, evening, in humid conditions, or on cloudy days. Ancymidol has activity levels greater than chlormequat or daminozide, but less than the triazole chemicals. Ancymidol can be applied as a spray or drench at 10 to 200 mg·L<sup>-1</sup>. It may cause some phytotoxic spots at

temperatures above 70F. It is commonly used as a foliar spray on plugs or a drench on bulb crops, but its use is limited due to its high price. Flurprimidol is normally applied at 20 to 80 mg·L<sup>-1</sup> with foliar sprays and 1 to 8 mg·L<sup>-1</sup> via drench. It has an activity level similar to paclobutrazol when used as a spray and uniconazole when used as a drench. The triazole chemicals paclobutrazol and uniconazole have the highest activity level and persist for many weeks in some plants, several months in others and can be active for several years in some woody species. They may be applied as a spray or a drench. Spray applications must be made carefully because the triazoles have limited mobility when applied to leaves. Applicators must take care to get the triazoles onto the stems of the plants for proper effect. Paclobutrazol is commonly applied at 15 to 90 mg·L<sup>-1</sup>. Uniconazole is usually applied at concentrations of 5 to 10 mg·L<sup>-1</sup>. These products must be used carefully to avoid overdoses and avoid a carryover of their effects outside of the nursery. Ancymidol, paclobutrazol and uniconazole are fat soluble and so they are absorbed through the plant cuticle in as little as 5 minutes.

Interrupting GA biosynthesis may cause a shift in the precursor substances into alternate biosynthetic pathways which may lead to an increase in the production of cytokinins, brassinosteroids, and abscisic acid (Figure 1.1). Thus the anti-GAs may have secondary effects on the plants as well.

#### **1.3.1.2 Anti-Auxins**

These substances work by halting the biosynthesis of auxin or by interrupting its transport to sites of action. There are several substances in this class that are available to ornamental plant growers including maleic hydrazide (Fair Plus, Sprout-Stop and others), cyclanilides (Tiburon), TIBA (tri-iodobenzoic acid), clofibric acid, PCIB (p-

chlorophenoxyisobutyric acid) and NPA (N-(1-naphthyl)thalamic acid). These PGRs will inhibit growth and will also break apical dominance in the plant and stimulate branching which in turn prevents a plant from growing taller. In addition, the interruption of auxin movement prevents cell enlargement and cell division, thus slowing overall growth rates.

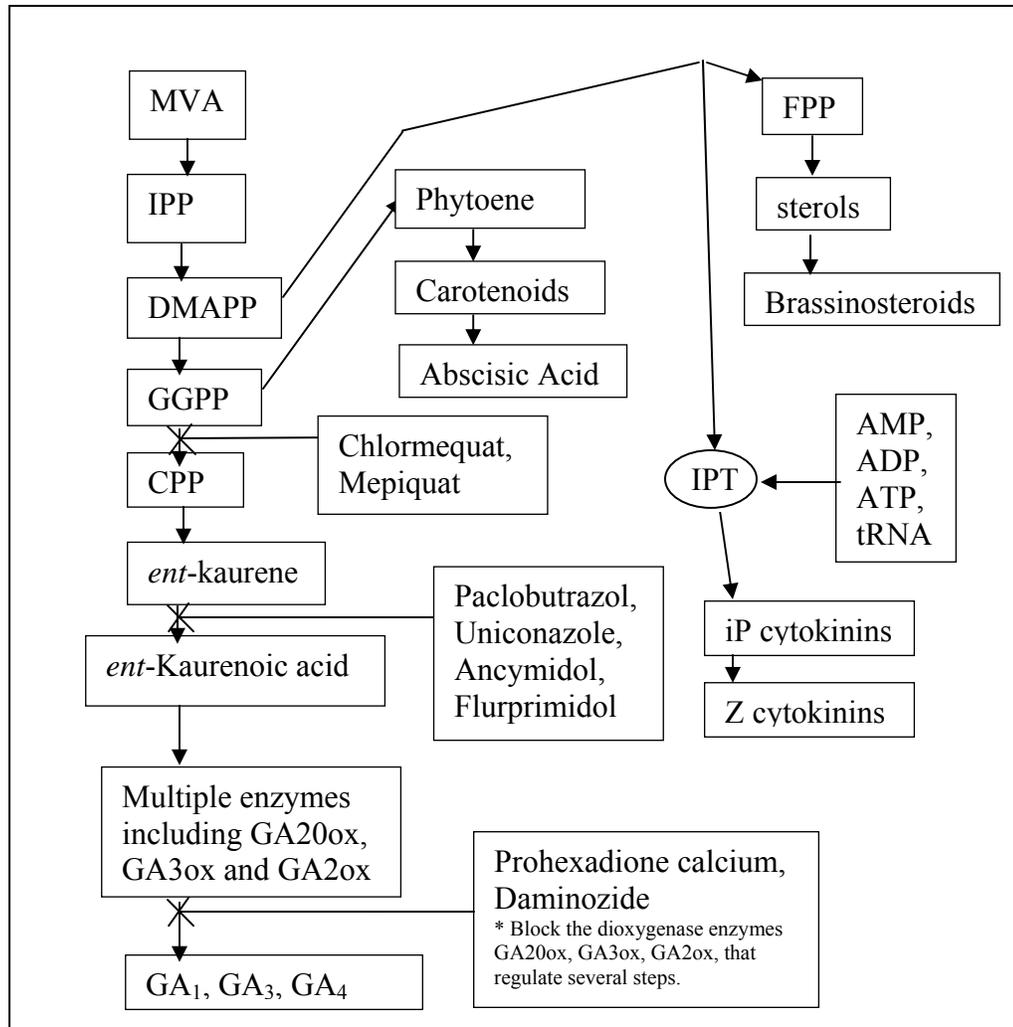


Figure 1.1 Major steps in gibberellin biosynthesis highlighting the locations where anti-gibberellin plant growth regulators inhibit the process. Figure compiled from text and figures in (Sponsel and Hedden, 2004) and (Sakakibara, 2004).

The cyclanilides are somewhat new in the ornamental plant industry, but they have been used in turf grass management and cotton production for years. They may be tank mixed with other chemicals for combined effect (as in Reign SC Plant Regulator).

### **1.3.2 Branching Agents**

Ornamental plant growers often need to encourage branching in certain crops that form long runners such as verbena, English ivy, and lantana or in stock plants to be used as sources for cuttings. The PGRs that are used for this are collectively known as branching agents. They work by interrupting apical dominance, which triggers lateral buds to grow and fill in the plant. Branching agents may also be used to inhibit upward growth due to the fact that a plant which is expending energy on branching has less energy for upward growth.

Apical dominance can be interrupted in several ways. One way is to reduce the internal ratio of auxin to cytokinin by applying external cytokinins. A second way is to apply a chemical that inhibits auxin production or transport. A third way is to kill the apical meristem which halts auxin production (Bangerth et al., 2000).

#### **1.3.2.1 Ethylene Promoters**

Ethylene promoters cause ethylene to be generated inside the plant, which has many possible effects. Ethylene can cause flower, fruit, and leaf abscission (Pederson et al., 2006), leaf epinasty, fruit-ripening, reduce stem growth, and can break apical dominance (Kwon and Criley, 1991). It can induce flowering in bromeliads such as pineapples. Ethylene generally has the effect of delaying flowering for 2 weeks or more (Styer, 2002). By breaking apical dominance, ethylene is able to stimulate branching, and trigger flower buds to break. Ethylene may be applied directly, but it is a gas and so there are application challenges such

as keeping the plants in an air tight chamber during the application period. Ethylene may also be applied to plants by using chemicals that stimulate ethylene production inside of the plant.

#### **1.3.2.1.1 Ethephon**

Ethephon (Florel, Pistill) is applied to crops via foliar spray and gets converted into ethylene inside the plant (Reid, 1994). Ethephon requires an acidic solution below pH 5 (Styer, 2002), and should not be tank mixed with chemicals that require higher pH levels such as cytokinins. It is generally not tank mixed with other chemicals, but there is a pre-mixed product called Finish that consists of ethephon and cyclanilides (Pederson et al., 2006) used as a cotton defoliant.

#### **1.3.2.2 Methyl Esters of Fatty Acids**

Off-Shoot-O is a methyl ester of fatty acids that kills terminal meristems, thus releasing apical dominance. It delays plant growth by several weeks and causes phytotoxicity on many plants (Richards and Wilkinson, 1984).

#### **1.3.2.3 Dikegulac-sodium**

Dikegulac-sodium is sold under the trade name Atrimmec or Atrinal and is registered for a few ornamental crops as a chemical pincher. It is applied via a spray application and travels to the shoot apices where it inhibits DNA synthesis and thus inhibits cell division and new growth (Arzee et al., 1977). This has the effect of preventing apical meristems from growing and thus it breaks apical dominance and stimulates lateral buds to break. This results in denser and generally shorter plants. It can cause some foliar chlorosis and can delay resumption of growth by 2 to 4 weeks. It is only labeled for use on 8 ornamental crops and is

applied at concentrations of 0.5 to 3 oz / gallon. There are no reports of tank mixes with Atrimmec.

#### **1.3.2.4 Cytokinins**

Cytokinins are plant hormones and, along with auxins, are part of the plants' hormonal mechanism of enforcing apical dominance. Cytokinins are formed in the roots and are in balance with auxins moving downward from the shoot tips. Growers can apply exogenous cytokinins to interrupt the balance in favor of cytokinins, which can result in lateral buds escaping apical dominance and breaking. Most exogenous cytokinins are quickly metabolized in the plant which means that they have little carryover. The phenylurea cytokinins (Thidiazuron, DPU, and CPPU) are resistant to being metabolized and thus have a longer influence. In addition, thidiazuron (TDZ) inhibits the cytokinin oxidase enzyme (CKX) from metabolizing endogenous cytokinins as well (Lalouem and Fox, 1989). Cytokinins do not affect the apical meristems in any long term fashion which means that once the lateral buds start to grow, the plant can return to its prior balance of auxin and cytokinins. Subsequent lateral bud growth is optimal in the presence of auxin.

Cytokinins have been used for decades in research laboratories, tissue culture, turf management, pomology, woody plant production and the cut flower industry, but they have been used sparingly in commercial floriculture pot crops and bedding plants. Cytokinins induce branching on some plant species, but the concentrations and effects vary widely among species.

One cytokinin product registered for use on ornamental plants is Configure; a benzyladenine (BA) based PGR. It is labeled only for Hosta, Echinacea and Christmas cactus,

but its expanded use label allows for it to be trialed on any ornamental plant (Whipker, 2008. pers. comm.). It can be applied as a foliar spray or a substrate drench at concentrations from 1 to 3000 mg·L<sup>-1</sup>. The useful application concentration differs greatly among ornamental plants and is generally unknown. There is evidence that cytokinin tank mixes with anti-GAs may have synergistic effects on branching (Werbrouk et al., 1996). There is also evidence that cytokinin mixes with anti-ethylene products may have synergistic effects on preventing senescence. However, mixes with other PGRs are not common. Another BA based product called ProShear was used in the past to stimulate lateral branching in woody plants (Crovetti and Shafer, 1989), but production was discontinued in the early 1990's (Bailey, 1992). There are also products containing a mixture of cytokinins and gibberellins (Fascination, Fresco, Promalin) that are used to prevent leaf yellowing and bud blasting in Easter Lilies and tulips.

Cytokinins are also reported to substitute for manual pinching (Marczynski et al., 1979; Richards and Wilkinson, 1984) and can thus save growers money. However, the results are not always ideal. In the case of grafted roses, cytokinins increased branching, but some of the branches occurred at the graft union. When cytokinins are used on stock plants to create more cuttings, they sometimes have the effect of reducing the ability of the cuttings to form roots (Day and Loveys, 1998; Carpenter and Beck, 1972; Jeffcoat, 1977; Maene and Deburgh, 1982; Accati et al., 1979).

#### **1.3.2.5 Anti-Auxins**

The auxin biosynthesis and transport inhibitors described above also work as branching agents because they interrupt the auxin to cytokinin balance which interrupts apical dominance (Bangerth, 1993).

### **1.3.3 Growth Enhancers**

In some cases, ornamental plant growers want to encourage top growth or root growth in their crops. Some ornamental crops (poinsettia, fuchsia) are grown as standards which have long un-branched trunks with a well branched plant at the top. Growers use growth enhancers to quickly produce the long stem. Growers that produce ornamental tree liners also use growth enhancers to produce tall, straight, un-branched liners. In some cases, overdoses of growth inhibitors can be overcome with applications of growth enhancers (Runkle, 2006). Plant propagators use growth enhancers to stimulate root growth in stem cuttings, and landscapers use them to stimulate root growth to help landscape plants overcome transplant shock (Arteca, 1982).

#### **1.3.3.1 Gibberellins**

Gibberellins (GAs) are commonly used as growth enhancers because they cause cell elongation in the plant. ProGibb and GibGro are commonly used in the ornamental plant industry for this. They can be used to partially overcome dormancy, increase flower size, flower number, flower uniformity, and to create standards. They may also be used to help overcome anti-GA PGR overdoses. When using GA's to overcome PGR overdoses, it is important to apply very small doses and watch the crops closely for an effect. A gibberellin overdose will result in a spindly unmarketable plant (Runkle, 2006).

#### **1.3.3.2 Auxins**

In the ornamental plant industry, auxins are used primarily to induce root formation on cuttings (Van Bragh et al., 1976) and in tissue culture. They are also used to induce

rooting in transplanted shrubs (Rhizopon Researcher, 1992) and have been studied for improving graft success (Yates and Sparks, 1992).

### **1.3.4 Flowering Enhancers**

Some growers use PGRs to enhance flowering. The chemicals used for this can increase the number of flower buds (Boyle, 1992), increase the size of flowers (Midcap et al., 1999), promote earlier flowering (Sakai et al., 1979), delay flower senescence (Paulin and Muloway, 1979), prevent bud blasting (Moe, 1979), alter sex ratios in imperfect flowered plants (Amrutavalli, 1980), and induce parthenocarpy (Hayata et al., 1995).

#### **1.3.4.1 Gibberellins**

Gibberellins have been used to increase the size and number of flowers on plants, but timing is critical. Gibberellin increases flower size by stimulating an increase in cell size. Gibberellin causes early flowering by partially overcoming cold requirements in some species. Gibberellins may be used for many ornamental plants such as *Aquilegia* (Gianfagna and Merritt, 2000), petunia, sweet pea, cyclamen and others (Itakura et al., 1957; Lindstrom and Wittwer, 1957). Gibberellins are most commonly used on camellias to induce early flowering and increase flower size via a process called 'gibbing' (Midcap et al., 1999). Gibberellin has also been shown to alter sex ratios of dioecious plants in favor of male flowers (Khryanin, 2002).

#### **1.3.4.2 Cytokinins**

Endogenous cytokinin levels have been observed to fluctuate during floral induction (Bernier et al., 1993). They do not trigger flowering, but they do regulate events such as cell division that occur when flowering has been triggered. Benzyladenine (BA) has been used to

promote flower bud formation on Easter cactus when applied during the floral initiation phase of plant growth (Boyle, 1992). BA increases the number of buds that form and when managed properly, growers can easily double the number of flower buds. Benzyladenine and BA + GA mixes have also been used to thin the flowers on apples to avoid uneven fruit yield. In this case it is sprayed on flowering trees in heavy years to cause flowers to drop off (Western Plant Growth Regulator Society, 2000). Cytokinins have been studied on many other plants to determine their effect on flowering. The results are inconsistent. On many plants, BA delays flowering, but on some plants, it increases bud set and induces flowering.

BA has also been used in the vegetable crop industry to alter flower sex ratios of monoecious and dioecious plants to increase the number of female flowers available to produce fruit (Khryanin, 2002). Benzyladenine has also been used to prevent bud blast in tulips (de Munk and Gijzenberg, 1977) and delay flower senescence lilies (Ranwala and Miller, 1998).

There is also some evidence that cytokinins can help increase the flower size of some plants. Cytokinins increased the size of petunia flowers (Nishijima et al., 2006) (ref. Chapter 2).

### **1.3.5 Senescence Interruption**

Pot crops, cut flowers and bedding plants are often stressed during the process of shipping, holding, retail display, and post sales treatment. The stress can manifest itself as bud or flower drop, leaf, bract, or flower discoloring and wilting. Growers can use PGRs to combat these problems so that the plant looks good until the stressors are removed (Hare et al., 1997).

### **1.3.5.1 Cytokinins**

Cytokinins have been studied extensively in this area. In the 1960s there was extensive research into using cytokinins to increase the post-harvest life of vegetables such as celery, endive (Guzman, 1963), and lettuce (Wittwer and Dedolph, 1962). Others later applied this knowledge to cut flowers like calla lily (Skutnik et al., 2001), Easter lilies (Han, 1995) and carnations (Heide and Oydvin, 1969). Cytokinins can delay senescence in flowers and prevent age-induced, stress-induced or cold-induced yellowing of leaves. Cytokinins are effective in many cases, but are often not as effective as a mix of cytokinin + gibberellin (Fascination, Fresco, Chrysal BVB), GA-alone, or ethylene blockers such as STS and 1-MCP. Very little work has been done on combinations of 1-MCP and cytokinins, but there is some evidence that they act additively in preventing senescence (Çelikel et al., 2002). Cytokinins prevent senescence primarily by reducing the plants' sensitivity to ethylene (Pech et al., 2004), by blocking ethylene biosynthesis within the plant and by antagonizing the effect of abscisic acid on triggering tissue senescence (Halmann, 1990). High endogenous carbohydrate levels and low light levels negatively regulate cytokinins ability to prevent senescence (Drüge, 2000).

### **1.3.5.2 Anti-Ethylene Compounds**

Ethylene inhibitors are chemicals that prevent ethylene from binding to receptors in the plant. They are used to delay leaf senescence in pot crops and flower senescence in pot crops and cut flowers. Only certain cut-flowers will senesce in the presence of ethylene. These are referred to as 'ethylene-sensitive' or 'climacteric' flowers. Only these plants will benefit from applied ethylene inhibitors (Blankenship, 2001).

#### **1.3.5.2.1 1-MCP**

1-MCP (1-methylcyclopropane) (e.g., Floralife) is a gaseous ethylene inhibiting PGR that is applied in a closed environment such as a tight greenhouse or a closed truck (Blankenship, 2001).

#### **1.3.5.2.2 Silver Thiosulfate (STS)**

STS is a liquid PGR that is placed in the vase solution with cut flowers. It has been used on many cut flower and post harvest applications, but its use is on the decline due to environmental concerns (Serek and Reid, 1993). It has also been used in conjunction with BA applications to enhance vase life and the effects were synergistic (Yamane et al., 1997).

#### **1.3.6 Stop Water Loss**

Recently, abscisic acid (s-ABA) has gained popularity with greenhouse growers and retailers because of its ability to close stomata and thus reduce drought stress and increase the retail window for bedding crops (Blanchard et al., 2007).

#### **1.3.7 Research Focus of this Thesis**

In conclusion, PGRs have become a vital part of an ornamental grower's tool kit. However, there are many other possible uses for PGRs that remain to be explored such as new modes of action for existing chemicals. The basis of the research for this thesis was to explore the use of a cytokinin based PGR on floriculture crops such as landscape annuals, landscape perennials, and indoor pot crops under commercial production time frames and conditions and with application methods that are commonly used by commercial growers.

## **1.4 Overview of Cytokinins**

Cytokinins have many potential uses as PGRs in floriculture. However, they are only widely used in tissue culture, and by Easter lily, apple, grape, and cotton growers (Carlson and Croveti, 1990). In the past, cytokinins have been considered to be too expensive to use on ornamental plants (Duan et al., 2006) and to have too few commercial applications (Thomas, 1982). Early research into cytokinins on intact plants was largely unsuccessful (Wittwer and Dedolph, 1963). The recent release of a cytokinin product (Configure) for ornamental plants has opened the door to ornamental growers, but the range of potential uses is not fully appreciated. The next section will discuss the details of cytokinin use in plants, identify potential uses of exogenous cytokinins to the floriculture industry and provide a summary of the research done with cytokinins on horticultural crops.

### **1.4.1 Description of Cytokinins**

Cytokinins are plant hormones derived from adenine and characterized by their ability to induce cell division in tissue culture (Davies, 2004a). Cytokinins are produced in all plants, some mosses, fungi, and bacteria. They are active in regulating the cell division cycle in both plants and animals (van Staden and Crouch, 1996). There are many natural and synthetic forms of cytokinins and cytokinin conjugates. They are used in a wide variety of plant processes and ornamental plant growers may be able to take advantage of these and use cytokinins in plant production.

Cytokinins were discovered in the 1955 in the lab run by Folke Skoog (Strong et al., 1955) in their effort to find growth substances that stimulated cell division in tissue culture. The first cytokinin that Skoog's team discovered was kinetin, a synthetic cytokinin. Very

soon after this discovery and the elucidation of its structure, they started creating new substances that had cytokinin activity. Benzyladenine (BA) was the first of the substances created (Armstrong, 2002). Skoog's lab also discovered the natural cytokinins Zeatin in 1964 and 2iP in 1966. Although cytokinins contribute to many plant processes, they are not yet widely used in horticulture outside of a few specialized areas such as tissue culture and apple production. They have historically been expensive to produce compared to other PGRs and that has limited their use (Thomas, 1982). Many attempts have been made over the years to register cytokinin products in horticulture (Carlson and Croveti, 1990).

Benzyladenine+GA<sub>4+7</sub> was first registered in the late 1970's for agricultural crops and PBA was registered in the late 1970's for use on ornamentals. In the 1970s, a BA product called ProShear was registered for use on promoting fascicular bud development in conifers, but was never widely used for this purpose. Currently, the major horticultural uses of cytokinins are as shoot promoters in tissue culture, as defoliant in the cotton industry, and as thinning agents and yield enhancers in certain tree fruit crops (Carlson and Croveti, 1990). There is a minor market for cytokinins as senescence inhibitors in potted plants and cut flowers. Cytokinins have the potential to be used in greenhouse plant production because they contribute to many plant processes.

#### **1.4.1.1 Cytokinin Effects in Plants**

Cytokinins are utilized in many different ways within plants. In new tissues, they regulate cell growth, cell division and morphogenesis. In callus and wound tissue they regulate the formation of vascular elements. In mature tissues they stimulate chlorophyll biosynthesis, regulate nutrient partitioning, open stomata and delay senescence. In flowers

they regulate sex determination and pollination. In seeds and fruits they regulate dormancy, germination, and senescence.

#### **1.4.1.1.1 Cell Division**

Cytokinins are involved in regulating the cell division cycle (Halmann, 1990; Davies, 1994). When exogenous cytokinins are added to plant tissue cultures in the presence of auxin, they induce cell division. In addition, research indicates that cytokinins also induce cell division on *en-vivo* plants (McCarthy and Bünemann, 1981).

#### **1.4.1.1.2 Morphogenesis**

Cytokinins stimulate shoot formation and vascular differentiation in plants and bud formation in mosses. They are also involved with gall formation in crown gall disease. At high levels, cytokinins inhibit root formation, but they promote it at low concentrations (Auer, 1996; Zhang and Hasenstein, 1999). Thus, cytokinin levels are manipulated in tissue culture to induce root formation (low levels), induce callus growth (medium levels), or induce shoot formation (high levels). There is also some evidence that cytokinins are involved with regulating phyllotaxy in plants (Giulini et al., 2004) and with regulating meristem function (Kurakawa et al., 2007).

#### **1.4.1.1.3 Lateral Bud Growth / Apical Dominance**

Cytokinins are involved with breaking apical dominance and the growth of lateral buds. Cytokinins act in balance with auxins to control apical dominance (Sachs and Thimann, 1967; Bangerth et al., 2000). Plants that receive exogenous cytokinins or transgenic plants that overproduce cytokinins display weakened apical dominance and display enhanced lateral bud development. Auxins are produced primarily at the top of the

plant by the dominant growing points (buds) and are transported basipetally into the roots. The downward movement of auxins from dominant buds serves to inhibit the growth of lateral buds that subtend the dominant bud.

Cytokinins are produced primarily in the root tips and move acropetally to the axillary meristems. The level of cytokinins produced in the roots is regulated by shoot derived auxins (Bangerth et al., 2000). A decrease in auxin production due to the removal of the growing point or environmental cues causes an increase in cytokinin production. Cytokinins move from the roots to the dominated lateral growing points and act as auxin antagonists (Bangerth, 1993) thus releasing the lateral buds from apical dominance and stimulating them to grow. As the new buds grow they start producing and exporting their own auxin which travels to the roots and down-regulates cytokinin production. The effect of cytokinins on apical dominance has been shown experimentally (Bangerth et al., 2000). Cytokinins that are applied to dominant terminal shoots do not induce lateral bud break and only reinforce apical dominance by stimulating growth in the dominant bud. However, cytokinins applied to lateral shoots stimulate their growth and can even cause a formerly dominated shoot to become the dominant shoot by stimulating them to produce and export more auxins than the terminal bud.

Apical dominance in dicots has four identifiable stages, and two of them are regulated by cytokinins (Cline, 1997). Apical dominance stage 1 consists of the formation of lateral buds within the meristem. Stage 2 consists of the imposition of apical dominance on the new lateral buds by the apical meristem. Stage 3 consists of the initiation of outgrowth of the lateral buds following meristem decapitation or some other releasing event. Stage 4 consists

of the outgrowth and development of the lateral bud into a branch. The degree of apical dominance imposed by the plant varies from species to species. In weakly inhibited species such as coleus, lateral buds grow immediately after forming. In partially inhibited species such as petunia, lateral bud outgrowth occurs weakly or sporadically. In strongly inhibited species such as sunflower, no lateral outgrowth occurs without some releasing event such as decapitation. Plants generally move from stage 1 to stage 4, but plants can revert from stage 3 or 4 back to stage 2. Stage 1 is promoted by cytokinins. Stage 3 is also promoted by cytokinins and is inhibited by auxins. Stage 4 is promoted by auxins and gibberellins. This knowledge provides some insight to the use of cytokinins on plants. Cytokinins may potentially be used to increase the number of lateral buds that form in stage 1. They may also potentially be used to release lateral buds from inhibition in stage 3. However, other phytohormones may be needed to promote the growth of the released buds in stage 4. During stage 3, exogenous cytokinins show reduced effectiveness on weakly dominated plants and enhanced effectiveness on strongly dominated plants. However both types of plants may be amenable to increased lateral bud formation in stage 1 by cytokinins.

Other environmental factors that modify the apical dominance effect include the sensitivity of the taxa to the promotive affects of cytokinin and the inhibitory effects of auxin (Cline and Dong-II, 2002). Other plant hormones also affect apical dominance. ABA promotes bud dormancy and gibberellins promote bud growth. Light quality, photoperiod, temperature, water availability, and nutrient status also regulate apical dominance to some extent (Bangerth, 1993). Root constriction can reduce the amount of cytokinins that are produced and result in plants with reduced lateral shoot growth (Haver and Schuch, 2001).

Lateral root formation also appears to be under the influence of the cytokinin/auxin balance (Zhang and Hasenstein, 1999). There is not a complete model for apical dominance, but auxins and cytokinins appear to be the key components.

#### **1.4.1.1.4 Flower Promotion or Inhibition**

Cytokinins may be involved with the photoperiod response of plants (Grayling and Hanke, 1992; Metzger, 1995). They appear to stimulate flowering in some short day (SD) and long day (LD) plants, but not in others. Endogenous levels of cytokinins have been observed to increase at the start of short days in the SD *Perilla*, *Begonia* (Hansen et al., 1988), *Chenopodium* (Ullmann et al., 1985), and *Mercurialis* (Chang et al., 1999) as well LD plants such as *Sinapis*. However, some plants such as *Xanthium*, sunflower, lupine, and tomato show a drop in endogenous cytokinin levels during floral initiation (Letham, 1994). Transgenic *Arabidopsis* plants (a LD plant) that are deficient in cytokinins flower later than normal while those that are enriched in cytokinins flower earlier than normal (Bernier and Perilleux, 2005).

Exogenous cytokinin applications can reduce the number of short days required to initiate flowering in SD *Perilla* (Grayling and Hanke, 1992), but will not trigger flowering in *Perilla* under LDs. Exogenous cytokinins have been observed to promote flowering of other SD plants when applied during the floral induction period such as Christmas cactus (Boyle, 1992) and *Pharbitis* (Ogawa and King, 1980). Exogenous cytokinin applications to the apical meristems of LD *Rudbeckia hirta* plants failed to affect flowering (Harkess and Lyons, 1994). Exogenous cytokinin applications partially stimulated a LD petunia to flower under non-inductive SDs (Das et al., 1977). Exogenous applications of cytokinins were not observed to

reduce the time to flower in facultative SD gerberas grown under SDs, day neutral (DN) New Guinea impatiens grown under LDs, or the cold temperature followed by LD (Cold→LD) plant *Coreopsis grandiflora* grown under LDs without a cold pretreatment (ref. Chapter 7).

Thus there appear to be few specific rules governing which plants are stimulated and which are not. However, in those plants that are receptive to exogenous cytokinins, a low concentration applied during the floral initiation phase appears to accelerate flowering or increase bud formation. Cytokinins generally do not stimulate flowering of plants in non-inductive photoperiods, but there are a few exceptions.

#### **1.4.1.1.5 Leaf Expansion**

Cytokinins promote leaf expansion (Mok, 1994) when applied to individual leaves. They do this by regulating assimilate partitioning, cell division, and cell wall extensibility. Exogenous applications of cytokinins to individual leaves have resulted in larger than normal leaves. However, exogenous foliar applications of cytokinins to whole plants has sometimes reduced leaf size (ref. Chapter 7), presumably by interrupting normal photosynthate partitioning to specific tissues. Greenhouse growers do not have the ability to inexpensively apply cytokinins to specific organs on a plant and so this effect has limited use to growers. Transgenic plants that overproduce cytokinins also have altered photosynthate partitioning and thus reduced growth in newer leaves (Jordi et al., 2000).

#### **1.4.1.1.6 Delay Senescence**

Cytokinins can delay tissue senescence. When cytokinins are applied to excised leaves, they stay green (Mok, 1994). Cytokinins are commonly used in Easter lily production to prevent lower leaf yellowing that occurs in crowded greenhouse crops and chilled crops.

In the cut flower industry benzyladenine has been reported to delay the senescence of carnation petals (van Staden and Joughin, 1988) and other cut flowers by several days. This senescence delay effect has also been indirectly correlated to increased yield of cereal crops because the plants have more time to fill out the grains (Halmann, 1990) and in grapes (Retamales et al., 1995). Exogenously applied cytokinins appear to reduce respiration rates of leaves of some plants (Franco and Han, 1997) which is one of the contributing factors in its ability to reduce foliar senescence. However, they increase respiration in other plants such as *Helianthus*, *Phaseolus*, *Citrullus*, and *Nicotiana* (Musgrave, 1994).

Cytokinins are used in the cut flower industry because they cause the flowers to be less sensitive to ethylene. Some cut flower petals senesce rapidly in the presence of ethylene and cytokinins delay this effect (Jaroenkit and Paull, 2003; Upfold and Van Staden, 1992; Lucaszewska et al., 1995).

There are potential uses of senescence delay by cytokinins in ornamental plant production. They could be used during holding (Clark et al., 1991), shipping (Emino et al., 2002; King et al., 1982) or retail display to reduce bud blast (de Munk and Hoogeterp, 1975; Moe, 1979; de Munk and Gijzenberg, 1977; Vonk and Ribot, 1982) or leaf yellowing (Carow and Bahnemann, 1980; Funnell and Heins, 1998; van Doorn et al., 1992; Philosoph-Hadas et al., 1996; Kaufman and Ringel, 1961).

#### **1.4.1.1.7 Stomatal Opening**

Cytokinins can reverse stomata closure caused by ABA (Rulcová and Popíšilová, 2001) and by high levels of CO<sub>2</sub> (Blackman and Davies, 1984). Under drought stress, cytokinin levels drop which de-inhibits ABA from closing the stomata. Once drought stress

is relieved, cytokinin levels rise and reverses the ABA mediated closure of stomata. By themselves, cytokinins do not affect stomata in young leaves (Blackman and Davies, 1984). However, in fully expanded leaves, cytokinins are able to cause stomata to open without the presence of ABA. Thus exogenously applied cytokinins increase transpiration rates of plants (Blackman and Davies, 1985), but the response varies based on the age of the leaf and the plant species.

During drought stress, the lack of cytokinin movement in the plant may result in poor quality plants. Exogenous applications of cytokinins during re-irrigation following a drought event can result in reduced plant injury due to drought stress (Halmann, 1990). Cytokinins may also reduce injury due to the lack of water movement in high humidity situations.

#### **1.4.1.1.8 Chlorophyll Biosynthesis**

Exogenous cytokinins can promote an accumulation of chlorophyll and promote the conversion of etioplasts into chloroplasts (Davies, 2004a) even in dark grown seedlings. This may appear as a greening effect on ornamental crops which may be perceived as an increase in quality in green leaved crops and a decrease in quality in crops with other leaf colors.

#### **1.4.1.1.9 Flower Sex Ratios**

Cytokinins can alter flower sex ratio in species with imperfect flowers. Cytokinins generally, increase the ratio of female flowers to male flowers which has implications for fruit production (Halmann, 1990). In ferns however, cytokinins appear to induce maleness in the gametophytes (Menendez et al., 2006).

#### **1.4.1.1.10 Vernalization**

Cytokinins can alter the vernalization requirements of certain plants to reduce or eliminate the cold requirement that induces flowering. The ability of cytokinins to reduce the vernalization requirement has been reported in wheat (Pogna, 1979; Csepely and Barabás, 1979), *Gypsophila* (Davies et al., 1996), and *Ornithagalum* (Wang and Walter, 2006).

#### **1.4.1.1.11 Parthenocarpy**

Parthenocarpy is the formation of fruits without seeds in the absence of pollination. Cytokinins can trigger parthenocarpy in some plants such as watermelon (Huitron et al., 2007) and gourd (Yu, 1999) which has implications for fruit production when a pollinator is not available. This effect may be useful in greenhouse crops where pollinators may be excluded.

#### **1.4.1.1.12 Nutrient Signaling and Photosynthate Partitioning**

Cytokinins can influence the allocation of nutrients and assimilates in the plant towards the tissues where cytokinins are concentrated (Beck, 1996). Thus foliar applications of cytokinins, onto individual leaves, tend to draw nutrients toward the leaf that it is applied to. Cytokinins are also involved in nitrate management within the plant (Schmulling, 2002).

Low nitrate levels negatively regulate the amount of cytokinins synthesized in the roots (de Groot et al., 2004). The drop in cytokinins exported out of the roots reduces cell division in the upper portion of the plant. This in turn negatively regulates nitrate reductase activity in the shoot and so the top portion of the plant uses less nitrate and stops growing. However, roots are sensitive to much lower levels of cytokinins than shoots are and thus root cells continue to divide in the presence of lower cytokinin and nitrate levels. In this way the

plant is able to manage the root/shoot ratio so that the top of the plant does not outgrow the root system. As the roots grow and find new nitrate sources, nitrate levels rise and cytokinin production increases which leads to higher cell division rates in the upper portions of the plant. However, root growth is inhibited by the increased cytokinins and thus root cell division slows in favor of top growth when nitrate levels are higher. Thus when nitrates are sufficient, the plant uses cytokinins to signal the top to grow, but as nitrate levels drop, the plant uses cytokinins to stop top growth and signal the roots to grow.

There is also some evidence that cytokinins and their response regulators are regulated by soil phosphorus and sulfate levels (Ferriera and Kieber, 2005; Camacho et al., 2008; Hirose et al., 2008). However, other mineral nutrients such as ammonium or potassium (Wang et al., 2003) do not appear to regulate cytokinins.

#### **1.4.1.1.13 Seed Development and Germination**

Cytokinins appear to play a role in seed germination (Walker et al., 1989). Cytokinin levels in *Acer saccharum* seeds rise at the same time that ABA levels are falling during cold stratification. Cytokinins appear to be generated as a signal that seed dormancy is complete and germination can begin. Cytokinin levels in non-stratified seeds did not follow this pattern. Walker theorizes that the mode of action of the cytokinins is to antagonize ABA levels (and other germination inhibitors) which in turn allows the seed to respond to increased gibberellin production and grow.

Cytokinins can satisfy the seeds' light requirements in species such as tobacco (Spaulding and Steffens, 1969). Cytokinins appear to overcome thermodormancy in celery seeds (Biddington and Thomas, 1978; Palevitch and Thomas, 1974). Research into priming

seeds with cytokinins has shown that they induce more even and rapid germination in production (Finch-Savage et al., 1991a, 1991c; Persson, 1993).

Cytokinins do not appear trigger germination in lilac (Junttila, 1970), *Picea* (Shibakusa, 1980), *Elaeagnus* (Hamilton and Carpenter, 1976) or lirioppe (Fagan et al., 1981).

#### **1.4.1.1.14 Cellular Differentiation**

Cytokinins are involved with the differentiation of vascular tissues during growth. They have been shown to regulate the growth of xylem fibers and sieve tube elements in coleus (Aloni et al., 1990). This effect could be useful in accelerating the formation of a graft union and thus improving graft take percentages.

#### **1.4.1.1.15 Maturation**

The control or influencing of plant maturation is an important concept in horticulture. Many woody plants do not start to flower for decades. This can greatly delay breeding efforts. Other plants root at much higher rates from juvenile wood.

There are many methods to induce a plant to flower early or to determine plant sexual characteristics before they flower (Meilan, 1997). In one case, cytokinins have been reported to initiate flowering in juvenile plants. PBA has also induced flowering in juvenile grapes (Srinivasan and Mullins, 1981).

Endogenous cytokinin levels are high in juvenile plants and decrease as the plant matures (Andres et al., 2002). In addition, mature plants that are rejuvenated will exhibit an increased production of cytokinins. Several researchers have tried to use exogenous cytokinins to induce rejuvenation in plants with success in pines (Zhang et al., 2003) and failure in ivy (Rogler and Hackett, 1975).

Cytokinin levels change throughout the year as the new plant tissues age. Cytokinin levels are low in dormant plants, rise in the spring when dormancy is released and fall again in the summer as summer dormancy occurs. There is another rise in the late summer and fall prior to a second flush of growth (Smith and Schwab, 1980). Finally, there is a drop at the beginning of winter. The levels of cytokinins vary in individuals of the same species and affect the individual's proclivity for sylleptic branching (Cline and Dong-Il, 2002).

The ratio of cytokinins also appears to change based on maturity. Juvenile plants have a higher ratio of 2iP to Z and the ratio falls as plants mature. In addition, the ratio of active cytokinins to storage form cytokinins falls as plants mature (Day et al., 1995)

#### **1.4.1.1.16 Stress Resistance**

Cytokinins seem to be involved with many types of stress resistance mechanisms in plants (Hare et al., 1997) including drought (Chernyad'ev, 2005; Rulcová and Popíšilová, 2001), high temperatures (Liu et al., 2002; Ervin et al., 2006; Xu and Huang, 2007; Schrader, 2005), cold (Ranwala and Miller, 2005; White and Schmidt, 1989, 1990), herbicides (Durmus and Kadioglu, 2005), and shipping (Emino et al., 2002; King et al., 1982; Beach, 2005; Jaroenkit and Paull, 2003). Thus, exogenous cytokinins could be used to protect plants during stressful production conditions.

#### **1.4.1.1.17 Mycorrhizal Interactions**

Cytokinins appear to regulate some plant / mycorrhizal interactions (Barker and Tagu, 2000). Arbuscular mycorrhiza (AM) appear to exude cytokinins in order to suppress certain plant defenses to allow hyphae to penetrate the root epidermis.

### **1.4.2 Cytokinin Biosynthesis**

Cytokinins exist in nanomolar concentrations within plants (McGaw, 1994). Endogenous cytokinins are synthesized from adenosine-(mono, di, tri)-phosphate (AMP, ADP, ATP) which provide the adenine and from dimethylallyl pyrophosphate (DMAPP) which provides the isoprenoid side chain (Morris, 1988). In the presence of the enzyme isopentyltransferase (IPT) these substrates are converted into the mono, di, or triphosphate nucleotide forms of the cytokinin isopentyladenine (iPMP, iPDP, iPTP). These forms may then be conjugated in the presence of microsomal hydroxylase into the *trans*-zeatin forms (tZRMP, tZRDP, tZRTP). There are other minor pathways that utilize other substrates to form the iP and Z type cytokinins also. Cytokinins may be produced in any plant tissue, but the majority are produced in root tips, seeds, and growing fruits. They are used by the metabolically active parts of the plant including meristems, fruits, storage organs, and seeds. The rate of cytokinin production in the roots is regulated by auxins generated in the shoot tips which travel to the roots and inhibit production. A drop in auxin flow to the roots causes an increase in cytokinin production.

### **1.4.3 Cytokinin Absorption and Transport**

Cytokinins are transported from the roots to the growing points via the xylem (McGaw, 1994). They also move via phloem in a source-sink relationship to any structure that needs them. Cytokinins are not transported in their active (free base) form. They are converted from the ribotide forms (created in biosynthesis) into riboside transport forms before moving. These forms do not bind efficiently to cytokinin receptors and so are much less active.

Exogenous cytokinins can be applied to plants via foliar sprays or drenches and are absorbed through the cuticle (Shafer, 1990; Bukovac, 1990; Canal et al., 2000; Zhu and Matsumoto, 1987). The plants can take up the cytokinins through the leaf or root epidermis and transport them to the growing points. It is likely that younger tissues with thinner epidermis layers would absorb more cytokinins than older tissues. Plants, even in the same species, absorb exogenous cytokinins at different rates (Auer et al., 1992) which accounts for some of the varietal variability in cytokinin response.

Free base cytokinins applied via a drench are not conjugated into riboside transport forms before transport (van Staden and Crouch, 1996). Therefore, drenches must be made carefully as roots are more sensitive to free base cytokinins than shoots and they may inhibit root growth at high rates.

#### **1.4.4 Cytokinin Metabolism**

There are three types of cytokinin metabolism; irreversible oxidation, irreversible conjugation, and reversible conjugation (van Staden and Crouch, 1996). The enzyme cytokinin oxidase/dehydrogenase (CKX) irreversibly inactivates the isoprenoid purine cytokinins. There is mixed evidence on whether or not it also metabolizes kinetin, and benzyladenine or whether some unrecognized enzyme does (van Staden and Crouch, 1996). It may be that CKX is able to metabolize aromatic cytokinins in some plants such as wheat (Galuzska et al., 2000), but not in others. The production of CKX is up regulated by the presence of cytokinins (including aromatic cytokinins) and can triple in amount only 8 hours after an exogenous cytokinin application (Galuzska et al., 2000). Despite the rapid up-regulation of CKX, exogenous cytokinin applications can lead to an increase in endogenous

cytokinins presumably by saturating CKX (Auer et al., 1999). Thus, exogenous cytokinins could have direct effects on the plant and also indirect effects. This is important because some plants are sensitive to different types of cytokinins (Galuzska et al., 2000). Plants, even in the same species, metabolize exogenous cytokinins at different rates into different metabolites (Auer et al., 1992) which accounts for some of the varietal variability in cytokinin response.

Plants may also irreversibly conjugate cytokinins with alanine or glucose, thus rendering them inactive. The resulting molecules have very weak cytokinin activity. There are also reversible conjugations into ribotide and riboside storage forms. There are dozens of conjugate forms that vary based on the location of the conjugation and the molecule that is added (Auer, 1997).

#### **1.4.5 Cytokinin Reception and Binding**

Cytokinins bind to a series of plasma trans-membrane histidine kinase receptors called CRE1, AHK2 and AHK3 (Deruère and Kieber, 2002). The free base forms of cytokinins bind to the receptors much more readily than the storage or transport forms. In response, a receptor moiety inside the cell goes through a phosphorylation sequence that transfers a phosphate to a signaling intermediate called a histidine phosphotransmitter (AHP).

#### **1.4.6 Cytokinin Signal Transduction**

Cytokinin signal transduction is a two component relay system similar to that in prokaryotic cells. The first signaling intermediate AHP moves from the membrane receptors in the cytosol into the nucleus where it transfers the phosphate group to a family of more than 20 related proteins called response regulators (ARRs) (Deruère and Kieber, 2002). The ARRs

in turn de-inhibit the translation many genes, activate proteins, and interact with other receptors. The production of ARR proteins is regulated by cytokinins and by other factors such as light.

There is also evidence that  $\text{Ca}^{2+}$  also acts as a signal transducer for cytokinins (Saunders, 1992). Cytokinins can increase  $\text{Ca}^{2+}$  uptake 65 times above background levels starting only minutes after application and lasting for several hours. It is hypothesized that the  $\text{Ca}^{2+}$  accumulation in the cytosol acts as a messenger and subsequently triggers many internal responses such as enhanced ethylene production, delayed leaf senescence, increased hypocotyl dry weight, membrane protein phosphorylation, betacyanin synthesis and cell division. Ethylene production is  $\text{Ca}^{2+}$  dependent and cytokinins stimulate  $\text{Ca}^{2+}$  uptake into the cytosol.  $\text{Ca}^{2+}$  may also regulate cytokinin biosynthesis.

#### **1.4.7 Cytokinin Genetic Responses**

Cytokinins induce transcription of many genes on their own or in conjunction with auxin (Rashotte et al., 2005), light (Zheng et al., 2006), or ABA (Schmulling et al., 1997). Among these are genes for cytokinin oxidase (Taniguchi et al., 2007), cytochrome P450, disease response proteins, nitrate reductase, and chloroplast proteins (Brault et al., 1997).

#### **1.4.8 Cytokinin Genetically Modified Crops**

There have been several cytokinin biosynthesis genes characterized. The primary gene that is used in genetically modified plants is the isopentyltransferase (IPT) gene, which is a rate limiting catalyst in cytokinin biosynthesis (Duan et al., 2006). The IPT gene has been controlled by constitutive, tissue-specific, and inducible promoters and has been shown to alter endogenous cytokinin levels.

Transgenic plants that over produce cytokinins grow larger flowers (Verdonk et al., 2008), produce a higher number of lateral shoots, have shorter internodes, have greater adventitious shoot formation, have altered source-sink relationships, exhibit delayed senescence, and a resistance to stress. However, some also had delayed or reduced flowering, and morphological differences. Some have poor root growth. Transgenic plants that over-produce cytokinins often grow better than normal plants with exogenously applied cytokinins.

Several plants have been genetically modified to overproduce or under produce cytokinins (Duan et al., 2006) including petunia and tobacco. Plants have been transformed with constitutive promoters of the gene for IPT production and also with various inducible promoters such as senescence specific promoters (Chang et al., 2003), cold-inducible promoters, light inducible promoters (Thomas et al., 1995), heat-shock inducible promoters (Ainley et al., 1993), Tetracycline inducible promoters, copper inducible promoters (Dodd, 2005), and flower inducible promoters (Verdonk et al., 2008). These inducible promoters give researchers a control mechanism for preventing excessive endogenous cytokinin production or delaying production until it is needed. Transgenic plants that under-produce CKX have phenotypes similar to plants that over-produce cytokinins.

There has also been some work with transgenics that increase CKX production and thus reduce endogenous cytokinins. The resulting plants have stunted shoots, smaller apical meristems, reduced leaf cell production, and increased root elongation and branching. Transgenic tobacco plants that overproduced the CKX enzyme produced well branched root systems and exhibited reduced shoot growth (Ferriera and Kieber, 2005).

### **1.4.9 Regulation of Cytokinin Production**

Cytokinin production is regulated by many factors, but is primarily regulated by auxin levels. High auxin levels inhibit cytokinin production and low auxin levels cause an increase in cytokinin production. The increase in cytokinin production stimulates bud growth which thus increases auxin levels which then inhibit cytokinin production. Cytokinins also negatively regulate their production. However, in some *in-vitro* scenarios, cytokinins appear to positively regulate their own production (Meins, 1988). This positive feedback only occurs in callus cultures. Plants grown from these cultures eventually revert back to a negative feedback regulation system.

### **1.4.10 Cytokinin Forms**

The first chemical that was determined to have cytokinin activity was a synthetic form called kinetin, which was discovered in the early 1950's. Since then, over 40 substances have been identified that have some level of cytokinin activity in bioassays (Shaw, 1994). Only a handful of these have been derived from plants. They are known as the natural cytokinins. The others have been created in the lab by altering side chains of known cytokinins and measuring the cytokinin response. Kinetin is used as the baseline bioassay response. All cytokinin bioassay responses are compared to kinetin and reported in terms of their activity levels compared to kinetin.

Cytokinins fall into two general categories, the adenine (aka purine) group (Figure 1.2) and the phenylurea (aka substituted urea) group (Figure 1.3)(Shudo, 1994). All of the natural plant cytokinins are in the adenine group and consist of a free base of adenine with a side chain substitution at the N<sup>6</sup> terminal. The substitutions consist of either an

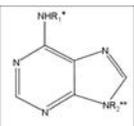
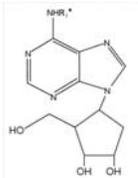
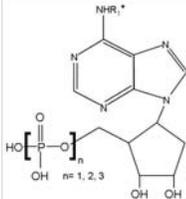
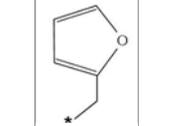
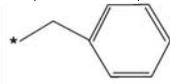
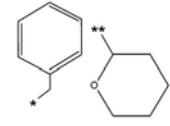
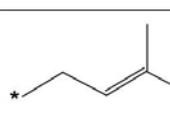
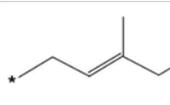
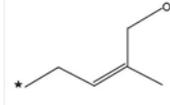
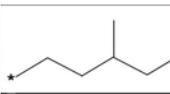
| Adenine based Cytokinins  |                            | Free Base   | Nucleoside   | Nucleotide  |
|---|----------------------------|---|--|---|
| R <sub>1</sub> Substitution Group   |                            |  |  |  |
|    | kinetin (K)                | kinetin riboside (KR)   | kinetin riboside 5'-monophosphate (n=1) (KRMP)                                     |   |
|    | benzyladenine (BA)         | benzyladenine riboside (BAR)  | benzyladenine riboside 5'-monophosphate (n=1) (BARMP)                              |   |
|    | pyranylbenzyladenine (PBA) | --  | --   |   |
|    | isopentyladenine (iP)      | isopentyladenine riboside (iPR)   | isopentyladenine riboside 5'-(mono, di, tri) phosphate (n=1, 2, 3)                 |   |
|   | <i>trans</i> -zeatin (tZ)  | <i>trans</i> -zeatin riboside (tZR)   | <i>trans</i> -zeatin riboside 5'-monophosphate (tZRMP)                             |   |
|  | <i>cis</i> -zeatin (cZ)    | <i>cis</i> -zeatin riboside (cZR)   | <i>cis</i> -zeatin riboside 5'-monophosphate (cZRMP)                               |   |
|  | dihydrozeatin (DZ)         | dihydrozeatin riboside (DZR)  | dihydrozeatin riboside 5'-monophosphate (DZRMP)                                    |   |

Figure 1.2 Adenine form cytokinins.

isoprene derived chain (isoprenoid cytokinins) or an aromatic derivative (aromatic cytokinins). A few of these isoprenoid substitution groups have isomers that vary greatly in activity.

The phenylurea-group of cytokinins have urea as a base and a substitution group at one end (Shudo, 1994). They vary in activity level, but some of the synthetic phenylureas have activity levels that are much higher than BA. The phenylurea cytokinins are not

metabolized by CKX and thus have a long period of effect which contributes to their high activity level. However, they are so strong that they can very easily cause toxic effects in the plant. Thidiazuron is used as a cotton defoliant and others are used as herbicides (Karanov et al., 1992).

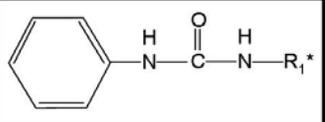
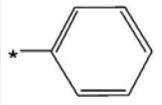
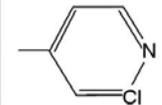
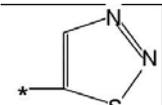
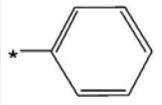
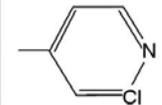
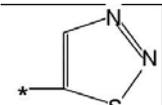
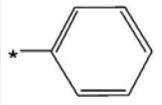
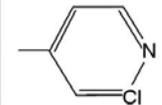
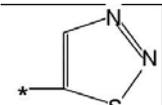
| Phenylurea based cytokinins  |   |   |                                |   |   |  |   |
|--|---|---|--------------------------------|---|---|--|---|
| Base   | R <sub>1</sub> Substitution groups  |   |                                |   |   |  |   |
|   | <table border="0"> <tr> <td></td> <td><i>N, N'</i>-phenylurea (DPU)</td> </tr> <tr> <td></td> <td><i>N</i>-pheny-<i>N'</i>-(2-chloro-4-pyridyl)urea (CPPU)</td> </tr> <tr> <td></td> <td><i>N</i>-pheny-<i>N'</i>-(1,2,3-thiadiazol-4-yl)urea (TDZ)</td> </tr> </table> |  | <i>N, N'</i> -phenylurea (DPU) |  | <i>N</i> -pheny- <i>N'</i> -(2-chloro-4-pyridyl)urea (CPPU) |  | <i>N</i> -pheny- <i>N'</i> -(1,2,3-thiadiazol-4-yl)urea (TDZ) |
|   | <i>N, N'</i> -phenylurea (DPU)  |   |                                |   |   |  |   |
|   | <i>N</i> -pheny- <i>N'</i> -(2-chloro-4-pyridyl)urea (CPPU)   |   |                                |   |   |  |   |
|  | <i>N</i> -pheny- <i>N'</i> -(1,2,3-thiadiazol-4-yl)urea (TDZ)   |   |                                |   |   |  |   |

Figure 1.3 Phenylurea form cytokinins.

#### 1.4.10.1 Free Base Forms

The free base forms of cytokinins are the active forms of the chemical. The free bases are formed from the transport forms near the site of activity and bind to the cytokinin receptors. The free base forms exist as isoprenoid forms or aromatic forms (Sakakibara, 2004).

##### 1.4.10.1.1 Isoprenoid Cytokinins

The isoprenoid cytokinins consist of an adenine base with an isoprenoid substitution group. These tend to be the most abundant cytokinins within the cell. The most active of these is called zeatin (Z). It has 2 isomeric forms. The *trans*-zeatin (tZ) form is 100x more

active than the *cis*-zeatin (cZ) form (Kulaeva et al., 1995). Zeatin can be hydrolyzed into the second type called dihydrozeatin (DZ) which has low activity. A third form is called isopentyladenine (iP, 2iP). Of the isoprenoid cytokinins, 2iP is used in research most often because zeatin is very expensive (Sakakibara, 2004).

#### **1.4.10.1.2 Aromatic Cytokinins**

The aromatic cytokinins consist of an adenine base with benzyl substitution group (van Staden and Crouch, 1996; Jones et al., 1996). These are not very abundant in the cell, but generally have a higher activity level than zeatin. In addition, they are metabolized more slowly and thus have a longer period of effect. Today, the most widely used of these is benzyladenine (BA) (CAS 1214-39-7) because it has a high activity level, is stable, and relatively inexpensive to produce. Others include pyranylbenzyladenine (PBA), kinetin (K), and topolin (T). These substances are considered to be synthetic cytokinins because they are not present in high levels in most plants. However, some of these (BA, T) are produced in high levels in certain plants and are therefore natural.

#### **1.4.10.1.3 Substituted Urea Cytokinins**

The substituted urea based cytokinins include the naturally occurring diphenylurea (DPU), and the synthetic chemicals forchlorfenuron (CPPU), and thidiazuron (TDZ) (Halmann, 1990). The substituted urea based cytokinins often have a much higher activity level than the aromatic or isoprenoid cytokinins. For example, TDZ is active at  $10^{-13}$  to  $10^{-8}$  molar in the standard tobacco callus bioassay as compared to  $3 \times 10^{-8}$  M for BA (Shudo, 1994).

#### **1.4.10.1.4 Other Cytokinins**

There are many other natural and synthetic substances that have cytokinin activity (as measured in cytokinin bioassays), but they are generally much weaker or more toxic than those listed above. A few such as topolin (Buban, 2000), 9-Benzyladenine (Yamaji and Tomioka, 1980), triacanthine (Ogawa and King, 1980; Skoog, 1994), 6-Chloroprine (Shaw, 1994), 4PU (Zhang and Hasenstein, 1999)) have variable activity and been used rarely in research. In addition, there are many other chemicals that have partial cytokinin activity. They produce one or a few cytokinin-like responses, but not all of them. The herbicides imidazole and benzimidazole as well as other chemicals such as N-substituted ureas, thio-ureas, and pyrimidines are examples of chemicals that have some cytokinin-like activity. Some research has used adenine as a cytokinin-like substance presumably because it serves as a rate limiting substance in endogenous cytokinin production.

In practice, the most commonly used purine cytokinin is benzyladenine (van Staden and Crouch, 1996). Benzyladenine is more active than kinetin, 2iP, and zeatin (in some tests). It is more stable in storage than 2iP and zeatin. It is less expensive than zeatin to produce. Benzyladenine is also metabolized more slowly than any other purine cytokinin. The most commonly used substituted urea cytokinins are TDZ and CPPU because they have very high activity levels and are metabolized very slowly.

#### **1.4.10.2 Storage and Transport Forms**

All of the adenine based cytokinins can be conjugated into inactive forms for storage or transport (McGaw and Burch, 1995). The storage and transport conjugations are reversible. One conjugate form is called the nucleoside form and is characterized by a ribose sugar being

attached to N9 on the adenine (Shaw, 1994). These are denoted using the following acronyms: trans-zeatin-riboside (tZR), isopentyladenine-riboside (iPR), benzyladenine-riboside (BAR). The riboside forms are commonly found in xylem and phloem exudates and are considered to be the translocation forms. The second conjugate form is called the nucleotide form and is characterized by one or more phosphates being attached to the ribose sugar. These are denoted using the following form: trans-zeatin-riboside-5' monophosphate (tZRMP), isopentyladenine-riboside-5'(mono, di, tri)phosphate (iPRMP, iPRDP, iPRTP), benzyladenine-riboside-5' monophosphate (BARMP). There are other conjugate forms characterized by glucose, ribose, or alanine units being attached to C2, N3, N7, or N9, positions on the adenine. These are collectively termed the N-glucoside (riboside, alanyl) forms and they have very little activity. There are also conjugate forms characterized by glucose or xylose being attached to the end of the side chain which are termed the O-glucoside forms. The O-glucoside forms are considered to be the storage forms of cytokinins in the cell since they are resistant to CKX and have very little activity (Jameson, 1994). These storage forms serve as reservoirs of cytokinins as they can be readily transformed into active forms when they are needed.

#### **1.4.11 Cytokinin Reactions with Other Hormones**

It may be possible to use other PGRs in combination with cytokinins in order to produce a desired result. However, it is important to consider the following interactions between these substance and cytokinins before using them.

#### **1.4.11.1 Gibberellins**

Gibberellins and cytokinins are mutually antagonistic to each other. Cytokinin inhibits gibberellin formation and gibberellin inhibits cytokinin responses (Weiss and Ori, 2007). GA may be inhibitory to the activity of cytokinin on floral induction (Even-Chen et al., 1979), root and shoot elongation, cell differentiation, and shoot regeneration (Weiss and Ori, 2007) in some plants. However, BA and GA are often used together as a senescence inhibitor (e.g., Fascination, Fresco). Benzyladenine+GA is commonly studied as a branching agent and a flower enhancer. There is some evidence that BA and GA act synergistically on some plant processes such as releasing azalea flowers from dormancy (Furuta and Straiton, 1965). There may also be applications for applying cytokinin and GA in a sequential manner. For example, cytokinins could be applied in order to stimulate lateral buds to break and a week later, GAs could be applied in order to stimulate the released buds to grow.

#### **1.4.11.2 Abscisic Acid**

Abscisic acid (ABA) inhibits seed germination, stimulates ethylene production and causes stomata to close (Kumar and Sastry, 1974). Cytokinin inhibits the activity of ABA on all of these processes. Despite this inhibition, there may be uses for this combination of chemicals if they are applied sequentially so that growers get the benefit of one chemical for a period of time, followed by the benefit of the other. For example, cytokinins could be applied to prevent senescence during shipping and then ABA could be applied to prevent desiccation during retail display or after transplant.

### 1.4.11.3 Ethylene

Cytokinins have been shown to inhibit ethylene induced senescence of many plants. Cytokinins appear to reduce the sensitivity of the plant to ethylene (Chang et al., 2003). However, cytokinins (in conjunction with auxins) also appear to up-regulate the production of ethylene (Rashotte et al., 2005). Thus, cytokinins stimulate ethylene production while simultaneously making plants less sensitive to ethylene.

The response of a flower or fruit to ethylene depends on if it is a climacteric plant or not. Climacteric plant organs undergo a sudden increase in respiration and ethylene production at the start of ripening and senescence while non-climacteric plants have a gradual decrease in respiration and ethylene production during senescence (Serek et al., 2006). Cytokinins interact with this response in a species dependent manner. In apples (a climacteric fruit) the application of BA before the onset of ripening (pre-climacteric) depressed respiration levels. However, BA applied to post-climacteric fruit increased respiration and ethylene production. Kinetin applied to pre-climacteric banana slices increased respiration and ethylene production, but had no effect on the pre-climacteric avocado fruit. Nor did it inhibit ethylene production in olive (Tsantili et al., 2002).

Conversely, ethylene influences the activity of cytokinins by reducing auxin levels and thus reducing the auxin to cytokinin ratio which is important for maintaining apical dominance (Haver and Schuch, 2001). The effect is transitory though as a reduced auxin level stimulates the production of cytokinins which in turn up-regulates auxin production. At high enough levels cytokinins decrease the activity of the auxin oxidase (Hemberg, 1972). There is also evidence that ethylene triggers an increase in cytokinin metabolism within

plants (Taverner et al., 1999). Ethylene and cytokinin may also interact due to crosstalk at the genetic level (Bishopp et al., 2006).

#### **1.4.11.4 Auxin**

Cytokinin and auxins together maintain apical dominance in a balancing act (Cline, 1997). An increase in the ratio of cytokinins to auxin breaks apical dominance. In tissue culture, both cytokinins and auxins are required to promote growth in callus, but the ratio is important. When cytokinin levels are high relative to auxin, shoot formation is promoted. A low cytokinin to auxin ratio promotes root formation. In cultures that contain only cytokinin or only auxin, there is generally only limited callus growth with no differentiation into roots or shoots. Auxins tend to antagonize the effect of cytokinins on delaying senescence. Auxins also inhibit cytokinin production (Zhang et al., 1996). This can be observed experimentally by decapitating a dominant shoot (Bangerth et al., 2000). Within 6-10 hours of decapitation researchers have seen a substantial increase in, presumably root derived, cytokinins in xylem sap. These new cytokinins break the effect of auxin on inhibiting the growth of lateral (dominated) buds, fruit, and shoots. However, by breaking apical dominance and stimulating growth cytokinins also stimulate the production of new sources of auxin which then move to the roots and inhibit cytokinin production. Auxins also appear to inhibit the conversion of 2iP into zeatin (Tamas et al., 1992).

Despite this interaction, there may be uses for this combination of chemicals if they are applied sequentially. For example, cytokinins could be applied to induce lateral branching and a week later, auxins could be applied to induce growth of the new branches. Conversely,

cytokinins could be applied simultaneously with anti-auxins (TIBA, cyclanilides) to stimulate branching or prevent senescence.

#### **1.4.11.5 Phytochrome**

Cytokinins may be the signaling mechanism that plants use when phytochrome is altered by red light. The evidence for this is that endogenous cytokinin levels rise in plant roots in day-length sensitive plants once the day length or night length meets exceeds certain critical limits. Other evidence for the interaction is that exogenous cytokinins replace the need for red-light in bean hypocotyl expansion, and lettuce seed germination (Miller, 1956). Cytokinins also appear to partially counteract low light levels on flower bud development in roses (Mor and Halevy, 1984). Dark grown seedlings that are moved into light have an increase in cytokinin production. Cytokinins can induce the light mediated transition to flowering, but do not induce flowering on their own (Rashotte et al., 2005). In ferns it has been observed that cytokinins induce light regulated morphogenesis in dark grown gametophytes which implies that cytokinins are the signaling agent in some light responses (Spiro et al., 2004).

The light induced responses of cytokinins appear to be conserved in dicots, monocots, gymnosperms, ferns and mosses. Cytokinin mutants that over express cytokinin signal transduction response proteins (ARRs) are hypersensitive to red light and mutants that under express them have reduced sensitivity to red light (Ferriera and Kieber, 2005). One of the cytokinin response regulators (ARR4) helps stabilize the far-red form ( $P_{fr}$ ) of phytochrome B which implies that increased cytokinin levels help make plants more sensitive to red light (Rashotte et al., 2005). Together, phytochrome and cytokinins regulate the circadian rhythm

of the plant which in turn regulates many physiological processes in the plant (Zheng et al., 2006).

Thus, cytokinins could be used during long periods of low light levels (e.g., clouds, winter) that may delay flower initiation. Similarly, cytokinins may be used to induce or prevent early flowering in day-length sensitive plants.

#### **1.4.12 Anticytokinins**

There are five classes of cytokinin antagonists that are used in laboratories to test substances for cytokinin activity. These anticytokinins are all substituted pyrimidines (Arima et al., 1995) that are similar in structure to purine cytokinins. The activity levels of these substances are tested by combining them with cytokinins in bioassays and measuring the lack of response (Alexieva et al., 1994). Some interfere only with the purine cytokinins while others will antagonize purine and substituted urea cytokinins. There may be potential for these substances to be used as PGRs to enhance rooting of cuttings, prevent an early release from dormancy or to close stomata.

#### **1.4.13 Detection of Cytokinins**

Cytokinins are detected by several different methods. There are several bioassays that test for one or more cytokinin-like properties. Assays include tests for callus formation and cell growth (tobacco pith callus, soybean callus, radish hypocotyl expansion), and metabolic processes (betacyanin synthesis in *Amaranthus*, chlorophyll retention in oats) (McGaw, 1994). High performance liquid chromatography (HPLC) can be used to detect cytokinins and their conjugates as can mass spectroscopy and gas chromatography (McGaw, 1994). There are ELISA tests that can be used to detect many forms and isomers of cytokinins

(Jones et al., 1996). There are even florescent cytokinins that can be used as probes in biological systems (Sprecker et al., 1976).

#### **1.4.14 Factors Affecting Cytokinin Activity**

The effects of cytokinins in plants depend on a variety of factors, including:

##### **1.4.14.1 Activity Level of the Particular Cytokinin**

Each type of natural and synthetic cytokinin has a different activity level. The activity levels are measured with bioassays that compare each substance to a known standard (kinetin). There are multiple bioassays for cytokinins and the various cytokinins perform differently in each one. In general, kinetin is the weakest of the commonly used cytokinins, followed by 2iP, zeatin, benzyladenine, thidiazuron, and then CPPU (Davies, 2004b).

##### **1.4.14.2 Amount of Cytokinin Present**

Cytokinins are rapidly metabolized into inactive and storage forms (conjugates). The amount of exogenous cytokinins that a plant “sees” thus depends on the amount applied and how long the chemical is present before being metabolized or conjugated. *In vitro* applications of cytokinins to the explant substrate provide a low, but long term dosage of exogenous cytokinins. For example, 2.2 $\mu$ M BA applied in the explant substrate improves shoot formation better after 10 days of exposure than for 2 to 8 days (Auer et al., 1992). Exogenous applications onto potted plants during production are likely to also be influenced by how much cytokinin gets absorbed and how long they are active before being metabolized. Thus, it is important to consider factors that influence absorption of exogenous cytokinin applications such as, light, wind, humidity, canopy cover, and cuticle thickness (Bailey and Whipker, 1998).

#### **1.4.14.3 Location of the Cytokinin Application**

Cytokinins are synthesized in the roots and transported to the active growing points (Bangerth et al., 2000). High levels of cytokinins in root tissues inhibit root growth, whereas high levels in the shoots stimulate bud growth and lateral stem formation (Auer, 1996). Thus drench applications may be an efficient way to apply cytokinins, but may also negatively affect root growth. Foliar applications may be applied at higher concentrations, but may not penetrate the canopy and be absorbed by the axillary meristems.

#### **1.4.14.4 Sensitivity / Responsiveness of the Tissue to Cytokinin**

In order for a tissue to respond to cytokinin, it requires the presence of cytokinin receptors and signal-transduction chain components. The levels of these may vary due to tissue age, stress, environment, stage of plant development or other conditions and thus a particular tissue may or may not be competent to recognize the presence of cytokinins. Sensitivity to cytokinin levels is also species specific. Some species display necrosis at doses that do not affect other species. Some species respond to different types of cytokinins more or less strongly. For example, Ericaceous plants respond more strongly to 2iP cytokinins than to BA (Norton and Norton, 1985).

#### **1.4.15 Current Uses of Cytokinins on Plants Outside of Floriculture**

Understanding the current uses of cytokinins outside of floriculture may provide some insight as to their potential uses by commercial ornamental plant growers.

##### **1.4.15.1 Fruit Orchards**

Cytokinins have multiple uses in the apple industry (Baker, 2001; Buban, 2000). They are most commonly used in a 1:1 ratio with Gibberellin<sub>4+7</sub> in a product called Promalin and

similar products. When applied to flowering trees they promote bloom thinning which promotes even production from year to year. When sprayed onto young fruit they improve the shape of the fruit and increase the size. They are used on young apple trees to promote lateral bud break and improve crotch angles. They are also used on pear trees, and nut trees for similar reasons. These products may also be used on table grapes to increase the size of the fruits.

#### **1.4.15.2 Cotton Defoliant**

There are various products that use cytokinins to defoliate cotton plants in order to make harvesting the bolls easier. The main cytokinin used in these products is thidiazuron (Dropp, Freefall) or a mix of TDZ with other substances (Dropp Ultra, Ginstar) (Baker, 2001).

#### **1.4.15.3 Christmas tree Branching Agent**

The cytokinin product Pro-Shear (2% BA) was used on white pines until the 1990's to increase lateral bud set in the year of application and to increase branch development in the following year (Baker, 2001). However, Pro-Shear is no longer produced.

#### **1.4.15.4 Cut Flowers**

Cytokinins are currently used in floral preservation products (Chrysal BVB) to increase the vase life of flowers that senesce in the presence of ethylene. Cytokinins help reduce the flower tissue sensitivity to ethylene and thus increase vase life (Leonard and Nell, 2004). Examples of flowers that are affected include *Iris*, *Lilium*, *Alstroemeria*, *Anemone* and *Nerine*.

#### **1.4.15.5 Landscape Management**

Cytokinins are currently used in landscaping and gardening in products containing low doses of many plant hormones and nutrients as a tonic to stimulate root growth and thus reduce transplant shock (Arteca, 1982; Rhizopon Researcher, 1992; Smith and Schwab, 1980).

#### **1.4.15.6 Turf Management**

Cytokinins are currently used in turf management to prevent the degradation of the appearance of the grass in stressful environments, such as extreme heat, cold, and during shipping (White and Schmidt, 1989, 1990; Taylor et al., 1994; King et al., 1982; Carroll et al., 1996; Liu et al., 2002; Xu and Huang, 2007; Morales-Payan, 2004; Borden and Campbell, 1985).

#### **1.4.15.7 Tissue Culture**

Cytokinins were first discovered by Folke Skoog and his team at the University of Wisconsin (Skoog, 1994). They were looking for ways to grow plants in tissue culture. The majority of research on cytokinins since then has been in the area of tissue culture. Cytokinins are used to stimulate branching in callus tissue at concentrations of 0.1 to 10 mg·L<sup>-1</sup>. The most commonly used cytokinins in this area are Kinetin, BA, and 2iP. Zeatin is used occasionally, but is cost prohibitive. Different plants respond best to different cytokinins. For example Ericaceous species respond best to 2iP (Norton and Norton, 1985), while Rosaceous (Norton and Boe, 1982) plants respond better to BA than 2iP. Benzyladenine tends to be metabolized more slowly than the other adenine based cytokinins. Phenylurea cytokinins such as CPPU (Kapchina-Toteva et al., 2000), and TDZ are used because they

have a higher activity level than most adenine based cytokinins and they are metabolized even more slowly and thus last longer.

The basic formula for using cytokinins in tissue culture is to use an even ratio of cytokinins to auxins to promote callus growth. Then shift to a high cytokinin to auxin ratio to promote shoot initiation. Finally, shift to a low cytokinin to auxin ratio to promote root growth. The actual ratios of cytokinins and auxins vary for each plant species as well as the type of cytokinins used and their timing (Hartmann et al., 2001).

#### **1.4.16 Cytokinin Based Products**

There are many products that contain cytokinins (Table 1.1). Some are not labeled for use in every state or country. The following table lists the most common cytokinin products and the area of horticulture that they are primarily used in.

The most common cytokinin used in PGRs is BA. Technical grade BA is only slightly soluble in water (Little, 1984; Wittwer and Dedolph, 1963) at concentrations up to 76 mg·L<sup>-1</sup> (EPA, 1994). Other cytokinins are also fairly insoluble in water. However, there is a reference to at least one highly active water soluble cytokinin called 6-{N-[2-(N-Methoxy-N-methylamino)ethyl]amino}purine (Maruyama et al., 1993). Benzyladenine mixtures thus require an organic solvent such as isopropanol (BA soluble up to 3960 mg·L<sup>-1</sup>), chloroform (soluble up to 288 mg·L<sup>-1</sup>), HCL, KOH, DMSO, propylene glycol, ethoxylated tallowamines, ammonium hydrozide, sodium hydrozide, methanol or ethanol and a surfactant such as Tween. Benzyladenine can also be dissolved in hot water and then cooled to a supersaturated solution (Ogawa and King, 1980). Two separate guides to preparing a liquid solution of BA

from crystalline BA, HCl, ethanol, and water for use as a foliar spray has been published (Fooshee and Henny, 1985; Wang, 1988).

Table 1.1 Common cytokinin based products and their horticultural use area.

| <b>Area of Horticulture</b>              | <b>Product (EPA, 2007; Scorecard, 2008)</b>   |
|--|---|
| Fruit trees and Fruit crops              | Paturyl, Promalin, Accel (discontinued), Perlan, Exilis Plus, MaxCel, Bongrow, Lift, Prestige, Sitofex  |
| Cut flowers                              | Chrysal BVB, Fascination, Fresco, Verdan  |
| Bedding plants, pot crops, Nursery crops | Configure, BAP-10, ProShear (discontinued), Fascination, Fresco   |
| Vegetable crops                          | Seaweed extracts, Verdan  |
| Turf                                     | Seaweed extracts, Biostimulants: Burst, Cytex, Agralife, Algistim, AZOMIN, Bio Pac Vital, Cytozyme, Early Harvest PGR, Flourish, Foundation RM, Goemar, IAT Foliar Spray, IAT Seed Treat, Soil Triggrr  |
| Landscaping                              | Seaweed extracts, Biostimulants   |
| Research                                 | Technical grade crystalline powders of BA, CPPU, TDZ, K, Z, 2iP. Liquid formulations of these chemicals have been produced and given temporary names. They may be referred to in the literature by these names: E.g., ABG-2062, ABG-3182, ABG-3182, ABG-3207, SD-4901, SD-8339, NC5392, FAL-456, FAL-457. |

BA can cause foliar phytotoxicity in plants on its own or as a result of being mixed with these substances. Benzyladenine is relatively non-toxic (EPA category III or IV in all areas) and is approved for use on food crops when it is applied more than 40 days before harvest at concentrations of less than 20 g ai per acre. It has been placed in EPA toxicity category II for PPE and given a 12hr REI (EPA, 1994).

Cytokinins are also available as seaweed extracts to home gardeners and vegetable growers for use as yield enhancers. These substances contain many ingredients including small amounts of cytokinins. It is unclear how much of their benefit is derived from the cytokinins that they supply. Also, the type and amount of cytokinins tends to vary from batch to batch and so they may not be appropriate for research use.

#### 1.4.17 Cytokinin Concentrations and Conversions

Researchers have used both molar and  $\text{mg}\cdot\text{L}^{-1}$  (ppm) notations in their experiments.

Table 1.2 lists the conversion rates for the free bases of commonly used cytokinins.

Table 1.2 Molecular weights and conversion ratios for molar to milligrams per liter of the commonly used cytokinins.

| Cytokinin                  | Molecular weight | molar to $\text{mg}\cdot\text{L}^{-1}$  | $\text{mg}\cdot\text{L}^{-1}$ to molar  |
|----------------------------|------------------|---|---|
| Benzyladenine (BA)         | 225.25           | $1\mu\text{M} = 0.22525 \text{ mg}\cdot\text{L}^{-1}$<br>$1\text{mM} = 225.25 \text{ mg}\cdot\text{L}^{-1}$ | $1 \text{ mg}\cdot\text{L}^{-1} = 4.43951 \mu\text{M}$<br>$1 \text{ mg}\cdot\text{L}^{-1} = 4.43951 \cdot 10^{-3} \text{ mM}$ |
| CPPU                       | 247.68           | $1\mu\text{M} = 0.24768 \text{ mg}\cdot\text{L}^{-1}$<br>$1\text{mM} = 247.68 \text{ mg}\cdot\text{L}^{-1}$ | $1 \text{ mg}\cdot\text{L}^{-1} = 4.03746 \mu\text{M}$<br>$1 \text{ mg}\cdot\text{L}^{-1} = 4.03746 \cdot 10^{-3} \text{ mM}$ |
| DPU                        | 212.25           | $1\mu\text{M} = 0.21225 \text{ mg}\cdot\text{L}^{-1}$<br>$1\text{mM} = 212.25 \text{ mg}\cdot\text{L}^{-1}$ | $1 \text{ mg}\cdot\text{L}^{-1} = 4.71142 \mu\text{M}$<br>$1 \text{ mg}\cdot\text{L}^{-1} = 4.71142 \cdot 10^{-3} \text{ mM}$ |
| Isopentyladenine (2iP)     | 203.25           | $1\mu\text{M} = 0.20325 \text{ mg}\cdot\text{L}^{-1}$<br>$1\text{mM} = 203.25 \text{ mg}\cdot\text{L}^{-1}$ | $1 \text{ mg}\cdot\text{L}^{-1} = 4.92004 \mu\text{M}$<br>$1 \text{ mg}\cdot\text{L}^{-1} = 4.92004 \cdot 10^{-3} \text{ mM}$ |
| Kinetin (K)                | 215.21           | $1\mu\text{M} = 0.21521 \text{ mg}\cdot\text{L}^{-1}$<br>$1\text{mM} = 215.21 \text{ mg}\cdot\text{L}^{-1}$ | $1 \text{ mg}\cdot\text{L}^{-1} = 4.64662 \mu\text{M}$<br>$1 \text{ mg}\cdot\text{L}^{-1} = 4.64662 \cdot 10^{-3} \text{ mM}$ |
| Pyranolbenzyladenine (PBA) | 309.37           | $1\mu\text{M} = 0.30937 \text{ mg}\cdot\text{L}^{-1}$<br>$1\text{mM} = 309.37 \text{ mg}\cdot\text{L}^{-1}$ | $1 \text{ mg}\cdot\text{L}^{-1} = 3.23237 \mu\text{M}$<br>$1 \text{ mg}\cdot\text{L}^{-1} = 3.23237 \cdot 10^{-3} \text{ mM}$ |
| Thidiazuron (TDZ)          | 220.25           | $1\mu\text{M} = 0.22025 \text{ mg}\cdot\text{L}^{-1}$<br>$1\text{mM} = 220.25 \text{ mg}\cdot\text{L}^{-1}$ | $1 \text{ mg}\cdot\text{L}^{-1} = 4.54029 \mu\text{M}$<br>$1 \text{ mg}\cdot\text{L}^{-1} = 4.54029 \cdot 10^{-3} \text{ mM}$ |
| Zeatin (Z)                 | 219.24           | $1\mu\text{M} = 0.21924 \text{ mg}\cdot\text{L}^{-1}$<br>$1\text{mM} = 219.24 \text{ mg}\cdot\text{L}^{-1}$ | $1 \text{ mg}\cdot\text{L}^{-1} = 4.56121 \mu\text{M}$<br>$1 \text{ mg}\cdot\text{L}^{-1} = 4.56121 \cdot 10^{-3} \text{ mM}$ |

### **1.4.18 Cytokinin Effects Useful for Floriculture Growers**

Cytokinins have many effects on plant growth that have been highlighted above.

Commercial floriculture businesses can use knowledge of these effects to use cytokinins in the production of plants. The following sections suggest several areas that cytokinins may be used in commercial production.

#### **1.4.18.1 Height Control / Growth Retardant**

Cytokinins stimulate branching and therefore may competitively limit upward growth. Cytokinins may be used in tank mixes with other growth inhibitors, but no working combination is commonly used yet. Cytokinins may potentially be used in conjunction with a reduction in nutrient levels to control height as cytokinins can help prevent leaf yellowing or senescence in nutrient deficiency situations (Erdei and Mastumoto, 1991).

#### **1.4.18.2 Shoot to Root Ratios**

Cytokinins alter the shoot to root ratios of plants in favor of shoots. Thus cytokinins could be used to stimulate top growth when needed, and then removed in order to stimulate root growth. Since cytokinins have been associated with nitrate nutrient signaling, applying nitrates in combination with exogenous cytokinins may increase the growth rate on the shoot system of the target plant beyond nitrates or cytokinins alone. Conversely, it may be possible that withholding nitrates in combination with exogenous foliar cytokinins may encourage root growth while inhibiting senescence of the shoots. However, the rate of cytokinin would be critical as the root/shoot ratios under low nutrition may be altered by foliar cytokinins in favor of the shoot at some concentrations (Kuiper et al., 1988).

#### **1.4.18.3 Height Enhancer**

Cytokinins may increase the height of some plants. This effect has been observed in free-branching petunias (Carey et al., 2007). Cytokinins altered the branch structure in such a way that the plants were more upright. Cytokinins also increased the size of Rudbeckia (ref. Chapter 7) at very low concentrations.

#### **1.4.18.4 Branching Agent**

Plants that traditionally produce few branches during production can be encouraged to branch with cytokinins. This effect was measured in several ornamental plants such as *Petunia*, *Sempervivum*, and *Salvia* (Carey et al., 2007, 2008), but many ornamental plants did not react to cytokinins during a typical production time frame (ref. Chapter 2, 3, 7). This effect could possibly be enhanced by a tank mix of BA with an anti-auxin product such as cyclanilide or a chemical pincher such as ethephon, or dikegulac sodium.

Many plants have to be pinched, pruned, sheared or disbudded during production in order to stimulate branching. This is a time-consuming and thus expensive procedure. Cytokinins have been studied as a replacement for pinching in many crops with mixed results. Cytokinins have been shown to be somewhat effective in replacing the need for shearing in Christmas trees (Little, 1985, 1984), for pinching in *Clematis* (Puglisi, 2002), carnation (Accati et al., 1979), holly (Wright, 1975; Keever and Foster, 1990), but not in *Caladium* (Whipker et al., 2005).

Some young woody plants do not form branches in the first year of production. Cytokinins have been used to improve branch production (feathering) on sweet cherry trees

(Hrotkó et al., 1999; Magyar and Hrotkó, 2005; Neri et al., 2004) and there is potential to use this effect on ornamental plants.

#### **1.4.18.5 Improve Branch Angles**

Cytokinins have been observed to improve branch angles in some narrow angled woody crops such as Bradford pear (Keever et al., 1993). This effect could apply to other ornamental woody plants to improve branch angles during production and thus enhance retail quality and landscape performance.

#### **1.4.18.6 Flower Enhancer / Promoter**

Cytokinins have been known to promote faster flower development and shorten time to anthesis in short day (SD) and long day (LD) plants such as *Perilla*, *Chenopodium*, *Wolffia*, and *Pharbitis* (Evans, 1975). The method that appears to work best is to apply the cytokinins to the plant during the floral induction phase or just after it. For example, if a SD plant requires four SDs to induce flowering, add the cytokinins sometime during the four short days. The concentrations required and methods of application will differ from species to species. There is mixed evidence that cytokinins can inhibit flowering in LD plants and that cytokinins have no effect on day neutral plants. There have been inconsistent effects and therefore, therefore it is impossible to predict how a photoperiodic plant will react to exogenous cytokinins.

BA has been observed to increase the number of flower buds that form in the SD plant Christmas cactus if it is applied during the floral initiation phase (Boyle, 1992; Ho et al., 1985; Whipker, 2007. unpublished). Cytokinins appeared to stimulate additional flower buds when applied during the floral initiation period of the plant. The effect was positively

correlated to cytokinin concentration and some rates triggered eight or more buds to form on phylloclades where normally only two or three would form.

BA has also been observed to increase or accelerate flower production in *Echeveria setosa* (Carey et al., 2008) and to potentially accelerate flowering in Dragon Wing Begonia and Zinnia (ref. Chapter 7). Cytokinin sprays in the spring increased the number of flower stalks that formed during the summer.

In addition, cytokinins reduce flower sensitivity to ethylene which means that individual flowers will last longer on the plant. This has been studied extensively in the cut flower industry, but less so for pot crops. However, there is a study that demonstrates that pollinated flowers of cytokinin treated Petunia last longer, because they do not senesce as quickly (Chang et al., 2003). Cytokinins have also been observed to extend flower life on daylilies too (Gulzar et al., 2005). There is a possibility that cytokinins applied simultaneously with 1-MCP or STS would synergistically delay senescence on pot crops.

Cytokinins have also been observed to increase flower size in transgenic *Petunia* (Nishijima et al., 2006). There were indications that this may also be possible in foliar sprayed petunias (ref. Chapter 2) but the evidence was not conclusive.

#### **1.4.18.7 Flower Inhibitor**

In perennial crops, flower elimination or reduction may allow for more vegetative growth during production and thus shorten production times. This effect can be seen in the apple industry where cytokinins are used to thin blooms on apple trees in order to promote increased flowering in the next season (Wertheim, 2000). There has been no research in this area on ornamental plants. Cytokinins may be used in this manner on ornamental plants that

have a heavy flowering period and a multi-year production schedule such as flowering cherry or crabapple to increase plant growth at the expense of flowering during production.

Cytokinins delay flowering in some crops such as lily (Zhang et al., 1990), pansy (ref. Chapter 7) and *Salvia* (ref. Chapter 5). There may be a commercial application for this if growers are trying to bulk up plants prior to letting them flower or to time the market.

#### **1.4.18.8 Stress Resistance**

Cytokinins can increase a plant's stress tolerance and its recovery from many forms of stress (Chernyad'ev, 2005; Durmus and Kadioglu, 2005; Liu et al., 2002; Hare et al., 1997).

The following section details some possible uses of this in ornamental plant production.

##### **1.4.18.8.1 Resist Oxidative Stress**

BA pre-treatments can reduce the oxidative stress caused by the herbicide paraquat. Benzyladenine reduced the herbicides effect on chlorophyll and carotenoid degradation and increased peroxidase activity (Durmus and Kadioglu, 2005). Thus, BA pretreatments could have uses in commercial systems to prevent or reduce oxidative stress from herbicide drift or other causes.

##### **1.4.18.8.2 Preserve Plant Quality during Drought or Salinity Stress**

Cytokinins have been studied as a drought stress tolerance mechanism in plants (Chernyad'ev, 2005). Drought stress causes cytokinin levels to drop which allows ABA to close the stomata to conserve water (Rulcová and Popíšílová, 2001). However, lower cytokinin levels lead to lower photosynthesis via lower chlorophyll and photosynthetic protein production, and lower electron transport rates. The drop in cytokinin levels thus leads

to senescence where the plant drops leaves in order to conserve water. However, in ornamental production, growers may be able to add exogenous cytokinins to prevent senescence even in the presence of drought stress in order to inhibit the decrease of a crop's visual quality.

Plants that receive a drought stress may have suppressed photosynthesis levels for a long time after the drought is over. Rulcová hypothesized that cytokinins could help a plant return to normal photosynthesis levels more quickly, but only a slight benefit of spraying with BA on drought stressed beans occurred (Rulcová and Popíšilová, 2001).

Cytokinins have also been implicated as a messenger of salinity stress in plants. Salt stressed plants show reduced endogenous cytokinin levels and a concomitant reduction in growth. Exogenous cytokinins applied to salt stressed plants can reduce the drop in growth rates (Hare et al., 1997; El-Keltawi and Croteau, 1987). This effect could help organic growers reduce the effects of sodium accumulation in plants fertilized with sodium nitrate.

#### **1.4.18.8.3 Preserve Plant Quality during Production or Shipping**

Some plants tend to senesce leaves, buds, or flowers if they are held for too long under crowded conditions, very hot or cold temperatures, or dark conditions. This may occur when a crop is finished, but its shipment is delayed, or when a plant is shipped over a very long distance. These types of conditions lead to the production of ethylene which triggers senescence. Cytokinins tend to decrease a plants' sensitivity to ethylene and can thus potentially combat quality loss.

Cytokinins can reduce lower leaf yellowing in Easter lily under crowded conditions and cool storage (Ranwala and Miller, 2000). Cytokinins have reduced leaf yellowing in geranium cuttings during shipping (Emino et al., 2002) as well as potted roses (Clark et al., 1991). However it was not effective on potted *Zinnias* (Pinto et al., 2005). Cytokinins could be used on plants that traditionally lose flowers (blasting) during shipping such as *Salvia splendens*, and geranium. There is some evidence that cytokinins combined with other anti-ethylene compounds may have a synergistic effect in plants such as lilies (Çelikel et al., 2002).

In vegetable production, cytokinins have been proven to improve storage and transport characteristics of several species including endive, celery (Guzman, 1963), asparagus, brassicas, watercress, spinach (Wittwer and Dedolph, 1962), onion (Nowak, 1980), olive (Tsantili et al., 2002), and betel leaves (Venkata-Rao and Narasimham, 1977). However some vegetables such as lettuce show inconsistent results (Lipton and Ceponis, 1962; Fonseca, 2004; Aharoni et al., 1975; Halevy et al., 1965; Wittwer and Dedolph, 1962). The storage life of some vegetables was not impacted by cytokinins including snap beans, summer squash, corn (Wittwer and Dedolph, 1962), and mushrooms (Halevy et al., 1965).

#### **1.4.18.8.4 Recovery from Flooding**

Cytokinins also decrease epinasty (Jackson and Campbell, 1979) and senescence in flooding situations (Duan et al., 2006). Transgenic plants that over-produce cytokinins recover more quickly from flood conditions (including complete submergence), and show less senescence. This could potentially be used to help nurseries recover from floods or help

reduce problems caused by over-watering crops or growing them in a substrate that holds too much water.

#### **1.4.18.8.5 Prevent Nutrient Deficiency Symptoms**

Nutrient deficiencies may affect growth because some nutrients do not readily move into meristems. Cytokinins are involved with nutrient partitioning (Jordi et al., 2000). Thus they could possibly be used to improve growth or flowering in nutrient poor situations. For example, pansy plugs grown in very hot humid conditions may exhibit calcium deficiencies in the terminal meristem. Cytokinins may be able to relieve this problem by opening up the stomata thus increasing transpiration, and also by triggering a reallocation of assimilates to the growing points (Blackman and Davies, 1984). Cytokinins can also reduce some of the effects of calcium deficiency in cucumber (Erdei and Mastumoto, 1991). Cytokinins may be able to help with other nutrient deficiency problems such as tulip stem topple (Nelson et al., 2003).

#### **1.4.18.8.6 Prevent Quality Loss in Low Light Conditions**

Cytokinins can decrease senescence in dark grown plants (Duan et al., 2006) or in plants shipped in dark containers (Wijeratnam et al., 1995). Transgenic plants that over-produce cytokinins stay green during prolonged dark storage. This could be helpful with preventing senescence during shipping, distribution, or retailing. It may also help during prolonged periods of low light during the winter or during exceptionally cloudy weather.

#### **1.4.18.8.7 Prevent or Delay Quality Loss in Low Temperature Conditions**

Cytokinins can decrease senescence in low temperature situations (Duan et al., 2006). Transgenic plants that over-produce cytokinins stay green longer. Bermuda grass that has been sprayed with cytokinins stays green longer during cold temperatures than untreated grass (White and Schmidt, 1989). Cytokinins have also been used to prevent lower leaf yellowing and flowering senescence of Easter lily during cold storage (Han, 1995). This effect has potential applications for enhancing plant quality during shipping and for extending the sales season of outdoor grown plants.

#### **1.4.18.8.8 Prevent or Delay Quality Loss in High Temperature Conditions**

Cytokinins can improve plant responses during periods of high temperatures. They combated thermodormancy by promoting *Aquilegia*, *Platycodon*, *Thalictrum*, *Verbena*, and *Nicotiana* seed germination (Persson, 1993) and celery seed germination (Biddington and Thomas, 1978) under abnormally high temperatures. Cytokinins had no effect on germination rates at normal temperatures though. Cytokinins prevent leaf yellowing in turf under heat stress (Liu et al., 2002; Ervin et al., 2006; Xu and Huang, 2007). Cytokinins could potentially be used to combat leaf or flower senescence caused by high temperatures during commercial production. However, since cytokinins also tend to open up stomata they may actually cause other problems such as wilting.

Potential applications include using cytokinins to help reduce the delay in flowering in poinsettias caused by heat or cold or to reduce splitting caused by high night temperatures. Research into this has been inconclusive (Siraj-Ali et al., 1990).

#### **1.4.18.8.9 Prevent or Delay Problems Caused by High Humidity**

Cytokinins could potentially be used to combat problems caused by high humidity. For example, BA could be used to open stomata and reduce edema in ornamental sweet potatoes that occurs during late winter production in humid greenhouses. It could potentially help reduce boron or calcium deficiency in pansy plugs caused by growing in a hot humid environment. High humidity environments reduce transpiration and thus reduce the amount of xylem transported nutrients that reach growing point and flower buds. This can result in bud blasting, retardation of bud growth, or malformed buds and leaves. Cytokinins could possibly help this situation by opening stomata and thus inducing higher transpiration rates. And they could trigger nutrient and photosynthate partitioning to the growing point if applied via a spray.

#### **1.4.18.9 Improve Disease Resistance**

There has been extensive research into the role of exogenous cytokinins and plant disease. Cytokinins can help plants resist virus infections (Jameson and Clarke, 2002). They appear to help prevent certain virus infections only when they are applied pre-inoculation. Post-inoculation cytokinin applications appear to increase virulence. The theory is that cytokinins are involved with triggering systemic acquired resistance (SAR). *In vitro* studies show that pre-inoculation with BA appears to help prevent the appearance of tomato spotted wilt virus (TSWV) lesions *in-vitro* *Petunia* (Jameson and Clarke, 2002). Benzyladenine reduced the progress of bract necrosis in poinsettia (McAvoy and Bible, 1998), but not Botrytis (Sammons et al., 1981). However, BA applied to *Nicotiana rustica* after inoculation with tomato spotted wilt virus (TSWV) actually increased the number of lesions that formed

(Aldwinkle and Selman, 1967). There has not been any research into determining if the pre-inoculation effect is useful on a commercial scale.

Kinetin and the substituted urea cytokinin 4-PU-30 can also reduce the contamination progression of the single celled parasitic fungus *Phlyctidium scenedesmi* (Karanov et al., 1992). In addition, cytokinin is a known inhibitor of ABA (Cowan et al., 1999). Therefore ABA-producing plant diseases such as *Botrytis cinerea* (gray mold) and *Cercospora rosicola* may also be impacted (Norman et al., 1983; Rademacher, 2006). Researchers have looked at controlling gray mold in various plant types and the results varied from almost complete control, to no control at all (Elad, 1993).

Researchers have studied controlling powdery mildew in roses and begonias with cytokinins, but there was no effect (Sammons et al., 1981). However cytokinins did reduce powdery mildew incidence in barley (Liu and Bushnell, 1986). So there may be species, timing, concentration, or methodology limitations. Exogenous cytokinins can also reduce postharvest damage of apples by blue mold (Yu et al., 2008).

Although exogenous cytokinins may be used to reduce some diseases, they may help others. Cytokinins are implicated in reducing the hypersensitive response (Smigocki et al., 1992) which could reduce the ability of a plant to resist diseases. Enhanced cytokinin levels caused by mycorrhizal interactions can lead to increased susceptibility to some viruses (Barker and Tagu, 2000). Enhanced cytokinin levels caused by protist interactions can lead to clubroot disease in Brassicaceae (Siemans et al., 2006). In addition, the virulence of *Cornyebacterium fascians*, which causes witches brooms, is positively correlated to

cytokinin levels (Eason, 1992), as is the fasciation causing *Rhodococcus* bacteria (Eason et al., 1996) and the *Rhodococcus* leaf gall bacteria (Agrios, 1997).

Some pests exude cytokinins as part of their pathogenicity, but it is unclear if exogenous cytokinins make the problem worse. Nematodes exude cytokinins when they invade plants (de Meutter et al., 2003) as does the crown gall causing bacteria *Agrobacterium tumefascians* (Sakakibara et al., 2005) and the symbiotic nodule forming bacteria *Rhizobium* (Frugier et al., 2008). On the other hand, exogenous cytokinins could combat cytokinin-using organisms if the organism is using cytokinins to alter assimilate partitioning or nutrient flow towards it. In such cases, exogenous cytokinins applied to the whole plant may interrupt assimilate partitioning or nutrient flow to the pest and reduce its ability to injure the host plant.

#### **1.4.18.10 Improve Insect Resistance**

There is some evidence that cytokinins can be used to manage insects. Transgenic petunias that over produced cytokinins inhibited the development of green peach aphid nymphs and tobacco hornworm (Duan et al., 2006). Extracts from transgenic *Nicotiana* plants that over-produced cytokinins were shown to kill eggs, larva and in-stars of sugar beet root maggot, tobacco hornworm and green peach aphid (Smigocki et al., 1992). When these pests were placed on the transgenic plants, they ate 90% fewer leaves. The process by which this happens is not well studied, but it appears that cytokinins trigger a build up of secondary metabolites that have insecticidal properties.

Cytokinins have also been shown to directly affect insects. Kinetin has been observed to increase the life span of fruit flies by 20% (Sharma et al., 1995). Kinetin directly increases

the duration of each of the larva and pupa stages of the insect. This knowledge may be useful in controlling insects as longer immature stages may help increase the time exposure to insecticides.

#### **1.4.18.11 Prevent Loss of Quality in Crowded Conditions**

Cytokinins are theorized to up-regulate nitrogen use in the tissues where they accumulate. They are also theorized to up-regulate assimilate partitioning into the tissues where they accumulate which may explain plant growth habits in crowded conditions (Pons et al., 2001). Higher leaves are exposed to more light which increases transpiration. More cytokinins (and nutrients and assimilates) are delivered via the transpiration stream to higher leaves than to lower shaded leaves. The higher cytokinin levels trigger nitrate and assimilate partitioning to the higher leaves. The lower cytokinin levels in the lower leaves reduce nitrate and assimilate partitioning to them. In addition, the lower cytokinin levels are less able to inhibit ABA and ethylene mediated senescence and abscission in the lower leaves. Thus as the plant grows taller, the lower leaves stop growing, become chlorotic and abscise. In crowded commercial production systems, lower leaf yellowing is a major issue. Cytokinins are already used to combat lower leaf yellowing in Easter Lilies during the final and most crowded stage of production (Han, 1995). There is a possibility for cytokinins or cytokinin + GA mixes to help prevent lower leaf yellowing in other crops as well.

#### **1.4.18.12 Prevent or Reduce Transplant Shock**

Under certain circumstances, cytokinins stimulate root growth, delay senescence, and promote mycorrhizal pairing (Barker and Tagu, 2000). Thus, cytokinins could be used in commercial production or landscape installation to reduce transplant shock by encouraging

new root formation and accelerating mycorrhizal pairing. There are already products called root stimulators that contain very small amounts of cytokinins in them that are marketed for this purpose (EPA, 2007).

#### **1.4.18.13 Alter Crop Timing**

Cytokinins may possibly be used to alter crop timings. They could promote early flowering or growth in some crops and may promote synchronized flowering in other crops. Therefore, cytokinins have the potential to reduce production times and increase greenhouse throughput in the ornamental plant industry.

##### **1.4.18.13.1 Accelerate Growth**

Fall applications of Cytokinins have been shown to promote spring growth of hostas (Wilton et al., 1994). Many leaves emerged simultaneously which resulted in full plants earlier than normal.

##### **1.4.18.13.2 Induce Early Flowering**

Cytokinins induced early flowering in *Selenicereus* (2 weeks), *Hylocereus* (1.5 months)(Khaimov and Mizrahi, 2006), and Christmas cactus (Ho et al., 1985). Thus cytokinins could be used on certain crops to accelerate production. However, on short term crops such as New Guinea Impatiens, cytokinins have not accelerated flowering enough to make a difference in production scheduling (ref. Chapter 7). In many crops such as *Exacum*, pansy, and New Guinea impatiens, cytokinins may delay flowering (ref. Chapter 7).

##### **1.4.18.13.3 Synchronize Flowering**

Cytokinins used as bud dormancy breakers also tend to cause flowering to occur sooner (Alvarado-Raya et al., 2000) . This is important in the fruit industry for even-cropping,

but could also be important for crop scheduling of bedding plants. A few ornamental crops, such as gerberas, do not bloom simultaneously. Crop scheduling could possibly be improved by applying cytokinins so that bench runs become possible. However, initial trials on gerbera were unsuccessful (ref. Chapter 7).

#### **1.4.18.13.4 Break Dormancy or Reduce Vernalization Requirements for Out of Season Production**

Cytokinins applied during the early stages of winter dormancy (pre-dormancy or paradormancy) or in the late stages of dormancy (post-dormancy or s-endodormancy) can induce plants to be released from dormancy earlier (Faust et al., 1997). Cytokinin applications may be useful for high-chill crops grown in low-chill areas. This is currently done for fruit crops such as apple, plum, and peach (Alvarado-Raya et al., 2000) and could be applied to ornamental crops such as peony, tulip, or lilac. This effect has been demonstrated on azalea. Buds sprayed with cytokinins bloomed under shorter cold treatments than unsprayed plants (Nell and Larson, 1974). Benzyladenine also triggered gladiolus corms to sprout in the absence of a cold treatment (Ginzburg, 1973). Peonies treated with BA sprouted 20 days earlier than normal (ref. Chapter 4). This could be used by southern growers to produce plants for northern markets.

This ability of cytokinins to reduce the vernalization requirement has been reported in wheat (Pogna, 1979; Csepely and Barabás, 1979), *Gypsophila* (Davies et al., 1996), and *Ornithogalum* (Wang and Walter, 2006).

#### **1.4.18.14 Improve Propagation Results**

Cytokinins have long been used for tissue culture propagation (Skoog, 1994), but there are some macropropagation uses as well. Cytokinins can be used for stock plant maintenance, grafting, seed germination, leaf cuttings and bulb propagation.

##### **1.4.18.14.1 Stock Plant Maintenance**

Research has occurred using cytokinin applications to manage stock plants to enhance macropropagation. Generally, the cytokinin is applied several weeks prior to harvesting cuttings in order to stimulate branching. This has been studied on a variety of plants such as poinsettia (Witaszek, 1989), *Cordyline*, grape (Preece, 1987), *Gerbera* (Kamínek et al., 1987), *Tillandsia* (Bessler, 1997) and *Sempervivum* (Carey et al., 2008). Care needs to be taken because cytokinins can increase branching, but reduce the ability of the cuttings to form roots. This has been observed in rose (de Vries and Dubois, 1988), chrysanthemum (Carpenter and Carlson, 1972), *Cordyline* (Maene and Deburgh, 1982), *Dracaena* (Criley, 1980), and occasionally in geranium (Emino et al., 2002; Steinitz et al., 1987), carnation (Accati et al., 1979; Mynett, 1977), and poinsettia (Kamínek et al., 1987; Carpenter et al., 1971). This is also a problem in tissue culture systems (Werbrouk et al., 1995). Root inhibition can be managed by timing the applications so that the cytokinins are fully metabolized prior to taking cuttings as was seen in *Sempervivum* (Carey et al., 2008). This generally means that the cytokinin applications need to be made several weeks prior to taking cuttings. If that is not possible, then growers could increase the amount of rooting hormones used on the cuttings to offset the cytokinins.

Cytokinins can reduce senescence in cuttings that were shipped long distances and the reduction help the cuttings root at a higher percentage after shipping (Emino et al., 2002).

Cytokinins can also induce more keikis on orchid flower stems (Smeltz, 1995). Orchids are generally propagated via tissue culture, but this technique could be used on low volume cultivars without using tissue culture.

In some plants, cytokinins may influence maturation in a way that could enhance propagation. Some mature plants could be rejuvenated with cytokinins in order to produce cuttings that root better such as sycamore (Land et al., 1995). Since endogenous cytokinins fluctuate throughout the year, and may influence bud break, exogenous cytokinins could be employed to stimulate bud break during a time of year when it could be advantageous to collect cuttings.

#### **1.4.18.14.2 Accelerate Flowering of Plants with Extended Juvenile Periods**

Cytokinins could be used to induce flowering in juvenile plants in order provide seed more quickly. This effect has also been observed in grapes (Srinivasan and Mullins, 1981).

#### **1.4.18.14.3 Improve Grafting Results**

Since cytokinins are involved with assimilate movement, cellular differentiation and xylem formation, grafts treated with cytokinins could survive at a higher percentage or heal more quickly. Exogenous cytokinins can induce phloem regeneration and callus formation in coleus wounds (Aloni et al., 1990), cause camellia grafts heal faster (Stanley, 1976), and cause ivy rootstocks to move more assimilates to scions (Clark and Hackett, 1980).

Cytokinins have also improved graft success in Picea (Beeson and Proebsting, 1989),

improved scion bud sprouting in some citrus (Nauer and Boswell, 1981) and improved graft success in *in-vitro* graft experiments (Parkinson and Yeoman, 1982). However, (Hartmann et al., 2001) caution that cytokinins do not provide uniform results. For example, rose grafts tended to sucker below the graft union more when treated with cytokinins (Marczynski et al., 1979).

#### **1.4.18.14.4 Increase Tuberization**

There is mixed evidence that cytokinins can improve tuber formation in plants. In *Dahlia*, cytokinins had no effect on tuberization (Biran et al., 1974). Cytokinins reduced tuber formation in purple nutsedge (Edenfield et al., 1999). In potatoes, cytokinins have had no effect (Drozdov and Volkova, 1975; Badizadegan et al., 1972) on tuber formation or increased tuber number while decreasing tuber size (Artamonov, 1975).

#### **1.4.18.14.5 Increase Bulb Offsets**

Cytokinins have been used successfully to increase the number of viable bulblets and similar structures on geophytes. Bulb soaks increased the number of bulblets produced by lily (Simmonds and Cumming, 1976), *Achimenes* (Deutch, 1973), and *Muscari* (Puchalski et al., 1979), but not tulip (van Bragt and van Gelder, 1979) or hyacinth (Pierik and Steegmans, 1975). Cytokinins increased the size of Narcissus bulbils and the percentage that sprouted (Hanks and Rees, 1977a).

#### **1.4.18.14.6 Improve Seed Germination**

Cytokinins have been used successfully to promote germination in several species. Cytokinins improved germination in lily by 20% (Roh and Sim, 1996) and improved *Verbena* germination (Finch-Savage et al., 1991b). Cytokinins improved germination

percentages of celery, columbine, *Platycodon*, *Thalictrum*, *Nicotiana*, *Verbena* and lavender at very high and very low temperatures, but not at normal temperatures (Biddington and Thomas, 1978; Persson, 1993). Cytokinins improved the germination of sunflowers by inhibiting the suppressive effects of ABA on germination (Kumar and Sastry, 1974). They improved the germination of dark sown impatiens and *Primula* (Finch-Savage et al., 1991a), but not seeds sown under light (Finch-Savage et al., 1991c). Cytokinins did not effect germination of liriopse (Fagan et al., 1981) and delayed germination of petunia, *Salvia* (Finch-Savage et al., 1991c) lilac (Junttila, 1970), and Sakhalin spruce (Shibakusa, 1980). Cytokinins had promotive or inhibitory effects on germination in tobacco depending on concentration (Spaulding and Steffens, 1969). Cytokinins are sometimes better than other germination stimulators such as gibberellins and sometimes worse.

Cytokinins can substitute for cold stratification in some plants (Hagon, 1976). Therefore, they could potentially be used to reduce cold stratification times for seed germination. Cytokinins could be applied to newly harvested seed or partially stratified seeds could be treated with cytokinins. It may even be possible that cytokinins could replace one or more cold stratification periods in seeds that require multiple stratification periods. Mixtures of BA and GA (e.g., Promalin) may remove inhibition and simultaneously promote seedling growth.

Thus cytokinins could be used on ornamental crops that are germinated off-season to improve germination percentages. For example, pansies (Kessler and Behe, 1998) are often germinated during the summer and germination percentages may suffer from due to the heat at that time. Cytokinins could also be used to stimulate germination of weed seeds out of

season in order to reduce the survivability of the seedlings or to synchronize germination in order to improve the effect of herbicides. This method has been researched for controlling purple nutsedge (Teo et al., 1973; Teo and Nishimoto, 1973).

#### **1.4.18.14.7 Increase Plantlets that Form from Leaf Cuttings**

Cytokinins have been used to increase the number of plants that form from leaf cuttings in *Sedum* (Boe et al., 1972) and African violet (Sanderson and McGuire, 1988), but inhibited plantlet formation in *Kalanchoe* (Jaiswal and Sawhney, 2006) leaves.

#### **1.4.18.15 Improve Vase Life and Quality of Cut Flowers**

Cytokinins have been studied extensively by cut flower researchers as postharvest aids. Despite the many research papers that report the beneficial effects of cytokinins, their use has not become widespread in the cut flower industry (Goszczyńska et al., 1985). Only a few floral preservatives contain cytokinins (Verdan, Chrysal BVB) (EPA, 2007). Cytokinins help delay the senescence of ethylene sensitive flowers and leaves in the cut flower industry by delaying the onset of the climacteric rise in respiration and ethylene production that occurs when senescence begins (Wawrzyńczak and Goszczyńska, 2003). Exogenously applied cytokinins appear to substitute for the decrease in endogenous cytokinins that occur during the climacteric period. However, experiments have shown that different climacteric species sometimes do not show a decrease in endogenous cytokinins. As with potted plants, some cut flowers are strongly affected by cytokinins, some are weakly affected by them and some show no effect or negative effects.

There are many application methods that have been trialed. Pre-harvest plants have been sprayed or drenched with cytokinins to observe the effect on the cut flowers. Post-

harvest flowers have been sprayed with cytokinins (stem sprays) (Paull and Chantrachit, 2001), dipped into cytokinins for a short period (pulsed dips) (Heide and Oydvin, 1969), stored in cytokinin solutions (continuous dip) (Dai and Paull, 1991), and entire flower stems have been soaked in cytokinin solutions (immersion) (Paulin and Muloway, 1979). Bulbs have been treated with cytokinins to induce flowering out of season (Goh, 1979). Stock plants have been treated with cytokinins to increase overall flower production or prevent blasting, especially during times when the environment is not conducive to flower production (winter). Cut flower researchers have combined cytokinins with other substances to look for synergistic effects and this has generally been successful. Cytokinins and STS have proven to be synergistic (Systema, 1986). Together they improve the vase life of cut flowers. Other synergistic combinations are cytokinins plus cycloheximide (CHI) (Gulzar et al., 2005), cytokinins plus sugars (Huang and Chen, 2002), and cytokinins plus AOA (Harkema et al., 1991).

Cytokinins that are used as dips have to travel up the flower stem before they can prevent senescence in the flower and they can be metabolized along the way. Longer flower stems mean that less cytokinin makes it to the flower (Upfold and Van Staden, 1992). This means that stem dip doses ought to be correlated to stem length. For example, in 10 cm stems, cytokinins amounts after 24 hr dips peaked at 23% of applied cytokinins, but in 40 cm carnation stems, cytokinin amounts had peaked at 15%. This also implies that pre-harvest cytokinin drench applications or postharvest sprays may be more useful on long stemmed flowers.

#### **1.4.18.16 Effects on Fruiting**

Cytokinins have a long history of use in the apple industry. The knowledge gained there may provide some insight as to the use of cytokinins on fruiting ornamental plants such as ornamental peppers, Jerusalem cherry, hollies, pumpkins and gourds.

Cytokinins are currently registered for use on apples (Accel, Promalin) and sweet cherries (Promalin) as fruit thinners, to improve “typiness”, and to induce lateral branching and bud break (Western Plant Growth Regulator Society, 2000). Fruit thinners are needed because apples naturally tend to produce alternate bearing crops where they produce many fruit in one year and only a few the next year. The fruit tend to be small in the heavy years. Cytokinins and other chemicals are used to thin the fruit on the heavy years and even out production from year to year (Williams and Fallahi, 1999). Cytokinins do not work on all types of apples. Certain cultivars such as ‘Gala’ and ‘Delicious’ are more responsive to cytokinins than others. The application timing is very important as cytokinins have little effect on thinning when applied outside of the window of opportunity. Even so, the effect is complicated by weather and so varies from year to year. Cytokinins generally improve branching of apples which in turn increases fruit yield. Individual cytokinins (BA, CPPU, TDZ) have also been studied as fruit thinners with some success. Cytokinins are promising as fruit thinners because they are not harmful to beneficial insects (as carbaryl thinners are) and also promote branching and flowering the following year. The cytokinin thinners tend to cause asymmetric fruit and high concentrations can cause russetting, insufficient red color formation and promote vegetative growth. Benzyladenine + carbaryl mixes work well in difficult to thin cultivars (Wertheim, 2000). Cytokinins have also been studied as a way to

release apples from dormancy. They work in this regard, but only when applied very early in winter during pre-dormancy and very late in winter during post-dormancy (Faust et al., 1997). Thus the timing of cytokinin applications will vary for low chill and high chill apples.

#### **1.4.18.16.1 Increase Fruit Set or Seed Set**

Cytokinins increase fruit or seed set in several ways. Cytokinins can be used to induce flower or fruit drop in order to reduce nutrient competition for the remaining flowers and fruits. This reduces subsequent fruit drop and increases fruit size, thus increasing yield. This effect is common in apples (Williams and Fallahi, 1999), pears (Stern and Flaishman, 2003) and has been seen in citrus (Dayuan, 1981).

Cytokinins also increase fruit set by inducing parthenocarpy in crops such as watermelon (Huitron et al., 2007) and gourds (Yu, 1999). Cytokinins can also alter flower sex ratios in imperfect flowered crops and increase the number of female or perfect flowers. This effect has been observed in crops such as castor bean (Sindagi and Puttarudrappa, 1972), mango (Utsunomiya et al., 1995), luffa (Takahashi et al., 1980), cilantro (Amrutavalli, 1980), pine (Wakushima, 2004) and grapes (Hopkins et al., 2005). The effect on flower sex was not seen in *Ilex opaca* (Milbocker, 1967). However, in ferns, cytokinins have the opposite effect and ‘masculinize’ the gametophytes (Menendez et al., 2006).

Cytokinins increase branching in strawberry which leads to higher fruit set, but lower fruit weight (Pritts et al., 1986). Other plants that have shown yield increases include soybean (Nagel et al., 2001), olives (Antognozzi and Proietti, 1995; Antognozzi et al., 1993), pea (Saxena et al., 1987), and Japanese black pine (Wakushima, 2004).

Cytokinins could be used to enhance the fruiting of ornamental fruit crops such as holly berries, or ornamental peppers. In crops where the female flower is more attractive, cytokinins could improve the appearance of the flower display.

#### **1.4.18.16.2 Increase Fruit Size**

Cytokinins have been shown to increase fruit size in a variety of fruits when sprayed onto the plant canopy after fruit set. Cytokinins have been observed to work on kiwi (Patterson, 1993; Xing et al., 2007), peppers (Nowak, 1980), pecans (Herrera et al., 1987), and melons (Hayata et al., 2000), but not citrus (Dayuan, 1981). Ornamental growers could use cytokinins on certain ornamental fruit crops such as ornamental peppers or holly to increase fruit size.

#### **1.4.18.16.3 Delay Fruit Maturation and Ripening**

There is some evidence that cytokinins may delay fruit ripening in Japanese persimmon (Itai et al., 1995). This could be due to the fact that cytokinins delay senescence in plants. This is important for storage of edible fruits. However, cytokinins may not be beneficial for ornamental fruit growers as markets generally require ornamental fruit to be ripe as early as possible.

#### **1.4.18.16.4 Increase Postharvest Fruit Storage and Shelf Life**

Cytokinins can increase storage life of fruits such as olive (Tsantili et al., 2002), pomegranate and grape (Zabadal and Bukovac, 2006). This could have implications for improving shelf life of ornamental fruits such as pumpkins, gourds, mistletoe, or cut holly stems.

#### **1.4.18.16.5 Thin Fruit for Even Cropping**

Fruits often produce large crops one year and small crops the next. This is due to the fact that the large crops out compete next years buds for nutrients and inhibit them from fully forming. Cytokinins are used to thin fruit and flowering in crops so that next years buds form more fully and thus produce more evenly from year to year. Cytokinins have been used successfully in apples, pistachio (Daoudi et al., 2002), sweet cherry (Guak et al., 2005), almond (Sotomayor and Castro, 1998), grapes (Zabadal and Bukovac, 2006; Hopkins et al., 2005), sunflower (Beltrano et al., 1994; Uppar and Kulkarni, 1989).

Some ornamental plants suffer from alternate bearing such as yellowwood (Olsen et al., 2002). Cytokinins could potentially benefit them as well.

#### **1.4.19 Potential Side Effects of Cytokinins**

Cytokinins are by no means a panacea for growers. Their effects vary from species to species. Many ornamental species will show no reaction to exogenous cytokinins when applied using common growing techniques such as spraying or drenching. Foliar sprays can cause phytotoxicity and may limit growth of lateral buds (Jeffcoat, 1977).

The foliar phytotoxicity manifests as chlorosis, necrosis, and leaf cupping. This has been reported in many crops such as tomato (Selman and Sandanam, 1972), soybean (Hodgson and Snyder, 1988), pecan (Worley, 1989), viburnum (Schoene and Yeager, 2005), azalea (Bell et al., 1997), *Picea* (Duck et al., 2004), indian hawthorn, *Ilex glabra* (Oates et al., 2005a), *Nandina* (Keever and Morrison, 2003), balsalm fir (Little, 1984), lily (Tabuchi et al., 2005; Iizuka et al., 1978), rose (Ohkawa, 1984), geranium (Murch et al., 1997), *Ornithagalum* (Wang and Walter, 2006), hosta (Findley et al., 1994), clematis (Puglisi et al.,

2002) , coreopsis (Das et al., 1977), dieffenbachia (Henny, 1986), dianthus (Messinger and Holcomb, 1986), *Boronia* (Richards, 1985), *Anthurium* (Imamura and Higaki, 1988), pansy, *Exacum*, petunia, ornamental sweet potato, *Iresine*, *Zinnia*, dusty miller, *Heuchera*, columbine, *Scabiosa*, (ref. Chapter 7), gaillardia, calendula, aster, columbine, candytuft, *Lobelia*, *Physostegia*, *Astilbe* (Lieth and Dodge, 2004), *Zinnia*, poinsettia, fuchsia and chrysanthemum (Jeffcoat, 1977). Cytokinins even have an herbicidal effect in some plant families such as the Malvaceae (Hodgson and Snyder, 1988).

Most plants only show phytotoxicity at high concentrations. However, some plants are very sensitive at low concentrations including pansy and *Exacum* (ref. Chapter 7). Pansies exhibit yellowing at foliar spray concentrations above  $100 \text{ mg}\cdot\text{L}^{-1}$ , while petunias show it at about  $160 \text{ mg}\cdot\text{L}^{-1}$ . Dieffenbachia may not develop phytotoxicity until  $500 \text{ mg}\cdot\text{L}^{-1}$ . Coleus and hosta appear to be very tolerant of cytokinins at concentrations of  $1600 \text{ mg}\cdot\text{L}^{-1}$  and higher (ref. Chapter 7) (Keever, 1994a).

#### **1.4.20 How to Apply Cytokinins to Floriculture Crops**

The most important step in using cytokinins on ornamental crops is determining how to apply them, how much to apply, and how often to apply. The research in this area has focused more on determining the effect of cytokinins rather than on the proper application of them. Researchers have tried dozens of application methods, concentrations and timings. The most common application method has been foliar spraying.

The concentrations and timings used have been greatly influenced by the researcher's own area of specialty. Researchers who specialize in tissue culture usually apply frequent low concentrations of cytokinins as that gives them the most control over the amount of

cytokinins absorbed by the plant. Common application concentrations range from 0.1 to 10 mg·L<sup>-1</sup> (BA) which correspond to the concentrations used in tissue culture media.

Researchers who specialize in commercial production usually apply much higher concentrations, once or twice at 1 to 2 week intervals as that is how commercial growers want to apply PGRs. They usually apply concentrations from 50 mg·L<sup>-1</sup> to 5000 mg·L<sup>-1</sup>. Appendix 1 contains a synopsis of cytokinin PGR research done for ornamental, woody, cut flower, and non-ornamental plant species that highlights the method of application, concentrations, timings, and goals of the research.

The following sections highlight the important factors in determining how to apply cytokinins to floriculture crops, how much to apply, and how often to apply.

#### **1.4.20.1 Concentration Responses**

Plants are likely to have a concentration response to exogenous cytokinins of the form shown in Figure 1.4.

An example of a cytokinin concentration response curve similar to this has been reported by (Karanov et al., 1992) for BA, 4-PU-30, Kinetin, and PSPPU *in-vitro*. A similar response model has also been suggested for endogenous cytokinins (Ferreira and Kieber, 2005) and for plant hormones in general (Davies, 1994). The slope of the curve and the magnitude of the effect are moderated by tissue sensitivity, competence, and receptivity.

There is a low response range where the plants do not react to exogenous applications. This could be due to mal-absorption, or tissue insensitivity to concentrations below a certain level.

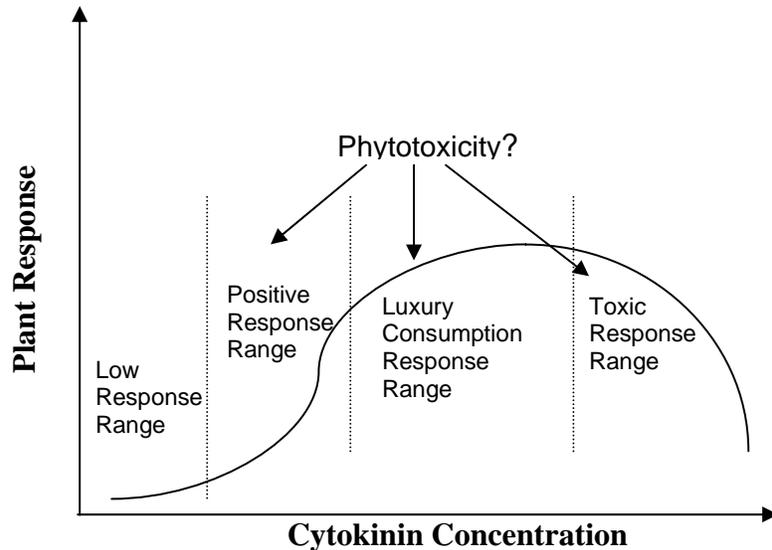


Figure 1.4 Hypothetical concentration response curve for exogenous cytokinins.

Next is a positive response range where there is roughly a positive linear or quadratic concentration response (branching, flowering etc.). This is the zone that ornamental plant growers want to use and the zone that researchers should try to identify. The next zone is the luxury consumption response range where an additional dose of cytokinins does not elicit any additional response from the plant. Last, there is the toxic zone where the desired response is actually inhibited by the addition of more cytokinins. This response curve may exist on a logarithmic scale. Thus, researchers may need to do log transformations of their response data in order to observe it. The *in-vitro* studies report that the response curve usually covers 2 or 3 powers of 10 from the low concentration to the high concentration. Due to the limitations of commercial applications of cytokinins, the concentration curve may be much narrower.

Phytotoxicity may appear as leaf chlorosis, necrosis, or puckering, or root inhibition at any application concentration. Unfortunately, the concentration that is toxic on one tissue may also be the concentration that is beneficial to another. Some plants will exhibit leaf phytotoxicity before they exhibit any other useful positive responses in the buds or flowers. The range of doses is different for every single plant and probably every single cultivar. Roots seem to react more strongly to cytokinins than shoots in that root growth is promoted at very low concentrations of cytokinins and inhibited at high concentrations, while shoot growth is stimulated at these same high concentrations.

#### **1.4.20.2 What Application Concentrations to Use**

Application concentrations for ornamental plants vary widely with plant species. Assuming that the grower only wants to spray once or twice, the effective concentrations of BA for *Hosta* has been reported to be 2000 to 3000 mg·L<sup>-1</sup> (Keever, 1994a). The effective concentration for *Sempervivum* has been reported to be 400 mg·L<sup>-1</sup> (Carey et al., 2008). The effective concentration on *Petunia* has been reported to be only 160 mg·L<sup>-1</sup> (Carey et al., 2007). Finding the effective concentration of BA is difficult and involves trial and error. If the application concentration for a plant is unknown, it may be better to start at a low concentration and work up as that will help the researcher find the positive response zone sooner. The active concentration of BA inside the plant is about 10<sup>-8</sup>M. If the researcher assumes that 10% of the cytokinins applied to the tissue of interest are absorbed and assumes that only 0.1% of the solution will come in contact near the tissue of interest (usually the buds), it is not unreasonable to use concentrations starting at 10<sup>-4</sup>M and working up. For BA this translates to about 22 mg·L<sup>-1</sup>, which based on the plants listed above is too low to elicit a

response. Since the concentration response curve is logarithmic, it may be useful to initially set trial concentrations over two orders of magnitude from the base concentration. In the example above, that means the initial screening concentration should be from 22 mg·L<sup>-1</sup> to 2200 mg·L<sup>-1</sup> which includes the active concentrations for all of the plants listed above.

#### **1.4.20.3 Application Timing and Number**

Although some plants respond well to a single application of cytokinins (Carey et al., 2008), there is evidence that multiple applications are more beneficial for stimulating lateral branching over the long term (Jeffcoat, 1977; Carey et al., 2007) (ref. Chapter 7), but the ideal number of applications is likely to be species dependent. This makes sense as many cytokinins are generally metabolized quickly in the plant. Thus application timing should occur at intervals close to the metabolic consumption of cytokinins (10 to 14 days for BA) unless the researcher wants to divide a large dose over several applications. A large single dose may cause temporary toxic responses that can be avoided by multiple doses.

There is evidence that the developmental stage of the plant dictates how it reacts to BA (Oates et al., 2005b). Plants with tender new growth have thinner cuticles and are more likely to show phytotoxicity than plants with hardened growth. Plants that are metabolically active will tend to form more branches from cytokinin applications than quiescent plants. Plants with strictly enforced apical dominance such as sunflower may have a stronger reaction to exogenous cytokinins than plants with weak apical dominance such as coleus.

If cytokinins are used to influence flowering then a single application during the floral induction phase may work better than multiple applications that occur before or after floral induction. Thus there is a window of opportunity for cytokinins to affect flowering which

means that the grower will have to be fully aware of the floral induction periods of every cultivar that they grow in order to fully take advantage of it.

There may also be a window of opportunity to positively influence branching when cytokinins are used in conjunction with pinching. Several experiments have reported that cytokinins should be applied at the same time as a pinch in order to maximize subsequent branching. The window of opportunity may be as little as a few days to maximize branching with a combination pinch + cytokinin. Cytokinins may inhibit subsequent rooting of the cuttings if applied too close to harvest time so it is generally better if there is a one week or longer gap in between application and harvest.

Timing is also very important for cytokinin based apple fruit thinning, and influencing fruit shape. Benzyladenine must be applied in the time period from 80% full bloom to 10 mm fruit size in order to be effective in increasing fruit size. Promalin is applied from 80% full bloom until the 3 to 5 mm fruit size range in order to affect fruit shape (Williams and Fallahi, 1999). Cytokinins applied to apple trees in the dormant season stimulated branching more than applications during the growing season (Quinlan, 1978). Cytokinin application timing will also affect whether or not the chemical induces branching, or flower bud production in day-length sensitive plants.

#### **1.4.20.4 Application Methods**

Cytokinins are absorbed through the plant epidermis and are not adsorbed tightly to soil particles. Thus, they can be applied via foliar applications or root applications. Several methods may be employed and are described in the following sections.

#### **1.4.20.4.1 Applications Made in Conjunction with Pinching**

Regardless of the application method, there are benefits to applying cytokinins in conjunction with pinching. In many plants, the combination of a cytokinin application plus a pinch induces branching better than a pinch or spray alone. The exact timing of the cytokinin + pinch depends on the species. It may be better to apply the cytokinin 4 to 7 days prior to a pinch, or on the same day as the pinch. This synergistic effect has been noted in carnations with PBA (Jeffcoat, 1977), mums (Carpenter and Carlson, 1972) and azaleas (Ryan, 1974), but not dianthus (Foley and Keever, 1991) or ornamental peppers (Khademi and Khosh-Khui, 1977).

#### **1.4.20.4.2 Foliar Sprays**

Foliar sprays should be made in such a way as to contact the plant leaves, stems, and meristems as cytokinins will not travel very far in the plant from the point of contact (Fox and Weis, 1965; Zhu and Matsumoto, 1987). In order for cytokinins to affect branching or flowering, they must be absorbed by the meristem or on the stem below it. Spray solutions should be pH adjusted to neutral pH levels to improve absorption. Foliar sprays may be made with hand sprayers, boom sprayers, and air blast sprayers.

Usually, the entire plant should be covered, but there are some applications where only certain parts of the plant should be targeted. In Easter lily, it is best to target only the lower leaves in order to prevent lower leaf yellowing (Whitman et al., 2001). In watermelon, sprays should be limited to the ovaries in order to stimulate parthenocarpy (Maroto et al., 2005). Lower stem sprays have been used to stimulate branching in *Monstera* and *Alocasia*

(Henny and Fooshee, 1990a, 1990b). Crown sprays have been used on *Hosta* (Keever and Warr, 2005).

At neutral pH levels BA is a non-polar substance and is quickly absorbed through the leaf epidermis (Shafer, 1990). In tissue culture experiments, up to 65% of the total BA absorbed occurred in the first 30 minutes after exposure (Canal et al., 2000). When BA is swabbed onto citrus leaves, BA absorption peaks after 8 hours and is absorbed by both the leaves and buds (Zhu and Matsumoto, 1987). Shafer reported a rapid initial absorption of approximately 30% of the amount applied in less than 24 hours. The remaining amount in the experiment was absorbed slowly and approached 100% absorption after 432 hours. However, this experiment was done under conditions where the epidermis remained wet the entire time. In a greenhouse environment, the amount absorbed will likely be much lower as the surface of the leaf dries fairly soon after spray applications. Benzyladenine is absorbed more slowly than NAA in similar experiments (Bukovac, 1990). Shafer also noted that there are species differences in the amount of BA absorbed through the epidermis. Citrus leaves may only absorb 8 to 20% of the amount applied whereas apple leaves have been shown to absorb as much as 63% of the BA that is applied to them. *In-vitro* studies of BA absorption report that there is an initial high rate of linear absorption for about one hour followed by a lower rate of linear absorption consistent with passive uptake. Absorption rates are proportional to the concentration used and saturate at about 30% of the level of BA in the medium (Vogelman et al., 1984).

Foliar applications are best absorbed when the spray solution is at pH of 5 to 7. At very low or very high pH levels (under 4 and above 8), BA is very poorly absorbed because

it becomes polarly charged and thus moves slowly through the epidermis. However, no work has been done to determine if BA foliar sprays mixed at low or high pH levels would improve its solubility in water to enough to improve spray results despite the reduction in epidermis absorption. Shafer also noted that different plant surfaces will absorb BA more readily than others. The abaxial surface of *Ficus* leaves absorbed BA at a slightly higher rate than the adaxial surface. Also, surfaces with thinner epidermis layers (i.e., younger tissues) absorb more BA than surfaces with thick layers.

The concentration of BA appears to affect absorption in a cubic fashion (Norton and Norton, 1985) in tissue cultures. Thus higher concentrations of BA result in much higher absorption. In general, temperature affects absorption levels due to free energy interactions between the solution and the membrane, but there is no specific data for BA (Bukovac, 1990). However, temperature did not affect BA absorption into citrus buds (Zhu and Matsumoto, 1987). Temperature may affect BA absorption because the solubility of chemicals in water changes with temperature.

#### **1.4.20.4.3 Substrate Drenches**

Drenches may also be an effective method of applying cytokinins to rooted plants as they can be absorbed through the roots and will be transported via the xylem to the most metabolically active tissues, such as the meristems. Drenches may reduce or prevent leaf phytotoxicity caused by surfactants and solvents. However, care must be taken as roots tend to be more sensitive to exogenous cytokinins and high concentrations can hinder root growth. Soil applied cytokinins move throughout the plant rapidly. Cytokinin-induced photosynthesis rates start changing 1 to 2 hours after exogenous applications (Dong and Arteca, 1982).

Drenches may also be applied to newly planted crowns (Keever and Warr, 2005) or be mixed into the storage substrate used for bulb scaling (Hanks and Rees, 1977a). This author has observed that drench applications tend not to be as effective as foliar applications (ref. Chapter 7).

#### **1.4.20.4.4 Pre-plant Bulb Soaks**

Pre-plant bulb (crown, corm, rhizome, tuber, bulblet etc.) soaks may also be an effective method of applying cytokinins. The cytokinins can induce dormant or adventitious bud growth directly on the bulb. This method has been used effectively on hosta crowns, daylily crowns (Keever and Warr, 2005; Warr and Keever, 2004), calla bulbs (Naor et al., 2005), peony rhizomes (ref. Chapter 4), lily (Zhang et al., 1990), iris (Yue et al., 1988), and *Liatrix* (Moe and Berland, 1986) but has failed on caladium corms (Whipker et al., 2005). The soak time does not have to be very long but will vary based on the woodiness of the bulb. Callas may only need a few seconds, but woody peony rhizomes may need an hour. Experimenters have trialed various times from 5 seconds to 48 hours and the short soak periods tend to work just as well as the long periods (Vlahos, 1985).

#### **1.4.20.4.5 Seed Soak / Priming**

Some researchers have experimented with soaking or priming seeds with cytokinin solutions to improve germination. Priming has been studied on *Petunia*, *Impatiens*, *Primula*, *Verbena* and *Salvia* (Finch-Savage et al., 1991a, 1991c, 1991b) with mixed results. Priming has successfully improved germination in lavender seeds (Persson, 1993).

#### **1.4.20.4.6 Dips**

Some researchers have experimented with dipping plant parts into cytokinin solutions. Some have taken whole plants and dipped the top of the plant (foliar dip) into cytokinin solutions (e.g., lily (Franco and Han, 1997), *Alpinia* (Criley, 1988), gerbera daisy (Kamínek et al., 1987)). Some have dipped only the roots or crowns into cytokinins (e.g., *Hosta* (Leclerc et al., 2003; Keever and Warr, 2005)). Some have dipped fruit into cytokinin solutions while it was still attached to the parent plant (e.g., kiwifruit (Patterson, 1993)). Others have dipped stem cuttings (the entire cutting or just the basal end) into cytokinins (e.g., *Pseuderanthemum*, *Sanchezia* (Sanderson et al., 1987), geranium (Steinitz et al., 1987), spiraea (Yang and Read, 1991), pothos (Wang, 1987), *Hylocereus* (Shimomura and Fujihara, 1980)).

#### **1.4.20.4.7 Paste**

Lanolin, KY Jelly, and Vaseline paste have been used successfully to deliver cytokinins to plants. These substances are generally not phytotoxic to plants and since they are lipid based the cytokinins dissolve well in them. However, they must be applied by hand which is time consuming and expensive on a commercial scale. There may be certain times in which this is economical. For example, applying a paste during grafting may be economical because the plants are already being handled extensively. Applying a paste to plants or bulbs at planting time may also be economical.

Regardless of the economy, pastes have been successfully tested on poinsettia buds (Milbocker, 1972; Semeniuk and Griesbach, 1985), *Muscari* bulbs (Puchalski et al., 1979) rose stems (Ohkawa, 1984), rose buds (Zieslin et al., 1985; Carpenter and Rodriguez, 1971),

tulip bulbs (Saniewski and Mynett, 1977), Japanese red pine buds and branches (Wakushima, 2004), Japanese black pine roots (Yamaji and Tomioka, 1980), buds and stems (Wakushima, 2004), melon flowers (Jones, 1965), quack grass rhizomes (Taylor et al., 1994), tomato buds (Tucker, 1977), and apricot and plum tree collars (Grochowska and Hodun, 1997).

When applying the paste to a bulb, researchers usually focus on putting it only on the basal end of the bulb as that is where the crown is most accessible. When applying a paste to the stem, the goal is to get cytokinin into the buds. Some cover the entire stem while others put the paste only on the plant collar or the buds. Researchers have tried applying pastes to one side of the plant in order to use a single plant as both the control (untreated side) and treatment group (treated side).

#### **1.4.20.4.8 Capillary String**

This method of application involves wounding the stem with a girdling cut or with a puncture wound and inserting a cotton string around or into the wound. The other end of the string is placed in a container of liquid cytokinin solution that is drawn into the plant via capillary action. As with pastes above, this may not be an economical method to apply cytokinins for commercial growers of small ornamental plants. This method has been successful on lily stems (Iizuka et al., 1978), *Sophora* (Carswell et al., 1996), and citrus (Zhu and Matsumoto, 1987).

#### **1.4.20.4.9 Floral Cube**

This method of application involves soaking a fiberglass or oasis block in liquid cytokinin solutions. This is similar to drench applications as the solution is taken up by the

roots. This method has been successfully tested on roses to increase branching (Carpenter and Rodriguez, 1971).

#### **1.4.20.4.10 Cotton Swab**

This method of application is very similar to the capillary string method. A girdling wound is made around the stem. A cotton pad is soaked in a liquid solution of cytokinins and is fastened around the stem in a fashion similar to air layering. The pad can be re-moistened at various intervals if needed. Some have applied cotton swabs without making a wound (Mynett, 1979; Pais and Neves, 1982) to promote flowering or alter flower color.

#### **1.4.20.4.11 Droplets**

This method involves using a syringe to place a small droplet of liquid cytokinin solution onto a specific plant part such as a bud to influence flower opening, seed set, fruit set, or branching. This has been done by researchers on petunia (Nishijima et al., 2006), *Anagallis* (Bismuth and Miginiac, 1984), *Bougainvillea* (Tse et al., 1974) ivy (Clark and Hackett, 1980, 1981) and mums (Pharis, 1972). This method has no practical uses for most commercial growers though as it is time consuming.

#### **1.4.20.4.12 Injection**

This method of application involves using a syringe to inject a liquid cytokinin solution into stems, buds, or bulbs for the purpose of stimulating flowering or branching. This method can be used to bypass the epidermis and place the cytokinin into the active bud or just below it. This method has been tested on rose stems (de Vries and Dubois, 1988), tulip bulbs (de Munk and Gijzenberg, 1977; Frannsen and Voskens, 1997; Moe, 1979; van Bragt and van Gelder, 1979), tulip buds (de Munk and Hoogeterp, 1975; Suh, 1997), tulip stems

(Hanks and Rees, 1977b), wheat flag leaf sheaths (Wang et al., 2001), orchid pseudobulbs (Goh and Yang, 1978), orchid bud scales (Chen et al., 1997), iris stems (Mae and Vonk, 1974), iris buds (Vonk and Ribot, 1982), and *Polianthes* corms (Chang et al., 1999).

This method would be very inefficient on commercial scales if done by hand. However, it could be well adapted for an automated system.

#### **1.4.20.4.13 Sub-Irrigation or Hydroponic Application**

Sub-irrigation is very similar to drenching. The difference lies in the number of times the chemical is applied. Drenches are typically applied only a few times. Sub-irrigation applications occur at almost every irrigation and may be applied to potted plants via drip or ebb-flood methods or to plants grown hydroponically. There is one published report of this being done with tomatoes. The sub-irrigation worked best at  $1 \text{ mg}\cdot\text{L}^{-1}$  kinetin for 2 days in a row (Dong and Arteca, 1982). Longer exposure times actually reduced growth rates. It has also been trialed successfully on ice plant to improve resistance to salt stress (Adams et al., 1991) and other ornamentals (Million et al., 1999). This author trialed sub-irrigation on *Zinnias*, dusty miller, and Madagascar periwinkle at concentrations of 1 to  $16 \text{ mg}\cdot\text{L}^{-1}$  applied daily for 3 weeks (ref. Chapter 7), but did not observe any beneficial effects.

#### **1.4.20.4.14 Pre-plant Substrate Spray**

This method involves spraying the potting substrate prior to potting the plant (Smith, 2007; Barrett et al., 2003). It is similar in effect to drenching and is amenable to automation. There are no published reports of cytokinins being applied in this manner.

#### **1.4.20.4.15 Liner Dips**

This method involves dipping the plug tray or the entire plug into a liquid solution of cytokinin. It is a relatively new application method (Latimer, 2004). There are no published reports of cytokinins being applied in this manner. This author trialed the cytokinin plug dip method on Madagascar periwinkle but the results were inconclusive (ref. Chapter 7).

#### **1.4.20.4.16 Sprenc**

This method involves spraying the plant with a high volume of liquid (at least 50% more than a typical foliar spray) so that the liquid can flow into the crevices of the plant and drip into the soil. For soil active PGRs like cytokinins, this can be a useful method. There are no published reports of cytokinins being applied in this manner.

#### **1.4.20.4.17 Impregnated Granules or Stakes**

There has been some research in other fields with impregnating granules or stakes with chemicals and mixing them into the growing substrate or inserting the granules into the plant stem. This latter method has been tried with orchids (Smeltz, 1995) and resulted in keiki formation. Research has also been done with slow release granules containing chlormequat on ornamental plants (Read et al., 1973).

#### **1.4.20.4.18 Paint**

There has been some research in sweet cherry production with mixing cytokinins into latex paint and painting it onto the bark of young trees (Jacyna and Puchala, 2004) or onto buds (Elfving and Visser, 2007) to improve branching. This method could be adapted for ornamental woody plant production.

#### **1.4.20.4.19 Sponge**

Some researchers use a moistened sponge or brush to rub a liquid solution of chemicals onto plant surfaces (e.g., coleus (Viswanath et al., 1971), lupine (Atkins and Pigeaire, 1993; Liu and Longnecker, 2001)). This method may be inefficient at commercial scales.

#### **1.4.20.4.20 Tubing**

This method involves sliding a rubber tube tightly over a cut stem and filling the tube with a cytokinin solution. This method has been used by researchers on *Plumeria* (Kwon and Criley, 1991) and ivy (Rogler and Hackett, 1975). This method may be inefficient at commercial scales.

#### **1.4.20.4.21 Vacuum Infusion**

Plant parts are enclosed in a vacuum chamber and chemicals are introduced via a tube. The pressure difference causes the chemicals to seep into the plants parts. Benzyladenine has been vacuum infused into *Freesia* corms (Gilbertson-Ferriss and Wilkins, 1981) in this manner.

#### **1.4.20.5 Combining Cytokinins with Other PGR Chemicals and Methods**

Cytokinins have been successfully mixed with anti-ethylene products (STS) and gibberellin with synergistic results. They could be tank mixed or co-applied with a large number of other products or practices for application to floriculture and nursery crops. Cytokinins may work well in conjunction with the following chemicals.

#### **1.4.20.5.1 Anti-Gibberellins**

Blocking GA biosynthesis causes an increase in endogenous cytokinins. This coupled with exogenous cytokinins could enhance the branching potential of exogenous cytokinin applications (Werbrouk et al., 1996). These could be tank mixed and applied at the same time or separately.

#### **1.4.20.5.2 Gibberellins**

This combination is already used (Fascination, Fresco) to reduce lower leaf yellowing and senescence in certain pot crops. This combination may also serve to induce flowering in some crops. However, gibberellins are also reported to be antagonistic to cytokinins and may actually reduce their ability to induce branching or reduce senescence. A combination BA+GA application may work better if BA and GA are applied separately (one to four weeks apart). This way, the grower gains the strongest effects of both. Benzyladenine would stimulate branching and the later GA could stimulate the growth of the new branches.

#### **1.4.20.5.3 Branching Agents**

Cytokinins could be co-applied with dikegulac sodium (Atrimmec), or ethephon (Florel) for synergistic effect on branching. Dikegulac sodium or ethephon would inhibit the apical meristems and thus reduce apical dominance. Cytokinins would stimulate adventitious bud / shoot formation and release dormant buds from quiescence. Cytokinins could also be used in conjunction with ethylene compounds to stimulate branching. The applications should not be made simultaneously as cytokinin reduces a plants' sensitivity to ethylene. Thus ethylene should be applied first followed by cytokinins a week later. Also, ethephon requires a low solution pH and cytokinins are absorbed best at neutral pHs so they should not

be mixed. Cytokinins may even reduce epinasty caused by ethylene applications. There is no published research in this area.

#### **1.4.20.5.4 Anti-Ethylene Agents**

Cytokinins act to reduce the plants' sensitivity to ethylene. Anti-ethylene agents act to reduce the plants ability to synthesize ethylene. The combination of the two could prove to be synergistic in delaying senescence. The combination of BA and STS has already been reported to reduce flower senescence in pot plants (roses (Tjosvold et al., 1995)) and cut flowers (Freesia (Systema, 1986), Goldenrod (Philosoph-Hadas et al., 1996)). Benzyladenine + 1-MCP has also shown some success in lily (Çelikel et al., 2002).

Exogenous applications of cytokinins have been reported to stimulate ethylene production in some plants (Rushing, 1990). At high doses the cytokinin induced ethylene may inhibit growth. It has also been reported that auxin-induced ethylene inhibits growth (Davies, 2004a). Thus anti-ethylene agents may be useful in preventing the increase in ethylene production and may allow for higher concentrations of cytokinins to be applied.

#### **1.4.20.5.5 Auxins**

Auxin is required to stimulate the growth of cytokinin induced branches and buds (Cline, 1997). Since cytokinins and auxins compete in the apical dominance process it may be best to apply them sequentially. Cytokinins could be applied first in order to stimulate branching and then auxins could be applied to stimulate growth or the new branches.

#### **1.4.20.5.6 Anti-Auxins**

Cytokinins and auxins compete in the apical dominance process. Simultaneously increasing cytokinins and reducing auxins may have synergistic results in inducing branching

and reducing senescence. There has been some research into this in calla lily with no synergistic effects reported (Ngamu, 2001).

#### **1.4.20.5.7 Abscisic Acid**

Cytokinins are antagonistic to many ABA mediated physiological responses such as stomatal closure, leaf senescence, leaf abscission, fruit abscission and seed germination inhibition (Cowan et al., 1999). Therefore, it is unlikely that cytokinins and ABA would work well in a tank mix. Purine cytokinins appear to up-regulate ABA metabolism and there is evidence that CPPU down-regulates ABA biosynthesis. ABA stimulates senescence and closes stomata. Cytokinins inhibit senescence and open stomata. However, to reduce senescence and improve retail holding, cytokinins could be applied pre-shipping to combat senescence and ABA could be applied post-shipping to reduce water consumption at retail.

#### **1.4.20.5.8 Water Level**

Cytokinins can help reduce the effects of flooding on plants (senescence) and could be used soon after a flooding event to reduce plant damage and speed recovery. Cytokinins may exacerbate drought reactions, but at the same time, they may reduce plant senescence during drought conditions. Cytokinins applied at the end of a drought may speed up the plants' recovery from drought by reducing senescence that was triggered by the drought.

#### **1.4.20.5.9 Nutrition Level**

Cytokinins could help reduce the effects of nutrient deficiency on plants (discolorations, leaf malformations) and could be used in conjunction with a reduction in nutrient applications in order to reduce growth of a plant without causing senescence (Kuiper et al., 1988).

#### **1.4.20.5.10 Temperature**

Cytokinins can help reduce the stress of very low and very high temperatures on plants. Cytokinins could be used in conjunction with a drop in temperature to hold a crop or ship it. Cytokinins could be applied when temperatures are low/high in order to inhibit the reduction in flowering or senescence that may occur. Cytokinins have already been reported to improve seed germination at very high temperatures and have reduced bud blast in tulips at high temperatures (de Munk and Hoogeterp, 1975). Cytokinins improve the appearance of turf at very low or very high temperatures (Morales-Payan, 2004). Cytokinins reduce lower leaf yellowing in Easter Lilies at low temperatures (Han, 2001).

#### **1.5 Conclusion**

In conclusion, cytokinins have many potential uses in ornamental crops. However, as reported in past research there is no one ideal application method, concentration, or time. Crops vary more widely in their reactions to cytokinins than to most other PGRs. Therefore growers who use cytokinins in commercial production must have a very good understanding of their crops' current physiological state in order to maximize the response. It is likely that cytokinins will not be as widely used as other PGRs due to these challenges. However, for specific applications, cytokinins are very effective and economical to use.

This authors' research focused on growing herbaceous bedding plants in a commercial setting (pot sizes, irrigation methods, nutrition, time of year) and applying cytokinins to them using common commercial techniques (foliar spray, drench, fertigation, plug dip, bulb soak). The goal was to test a large variety of species and observe the effects of cytokinins on branching, growth habit, flowering, and in one case, release from dormancy.

Phytotoxicity was monitored and reported. The effects of cytokinins on root growth, disease resistance, senescence delay, and subsequent landscape performance was not evaluated. In general, cytokinins provided a commercially useful result on only a few of the crops tested. The best results occurred on petunia (Chapter 2), hens and chicks (Chapter 3), peony (Chapter 4), salvia (Chapter 5), Lenten rose (Chapter 6), and black-eyed Susan (Chapter 7). There were positive results on pansies, *Zinnia*, New Guinea impatiens, dusty miller, Dragon Wings begonia, Madagascar periwinkle, *Iresine*, coleus, purslane and *Lantana*, but they were either too minor to be useful or were overridden by the occurrence of foliar phytotoxicity (Chapter 7). Many plants had no positive reaction at all, including *Acalypha*, tickseed, *Pseuderanthemum*, pincushion flower, skullcap, *Oenothera*, *Pentas*, poinsettia, columbine, gerbera daisy, gayfeather, *Verbena*, sweet potato, *Exacum*, *Heuchera*, and bacopa. These results highlight the difficulties in converting positive research results based on laboratory methods and precise application techniques into beneficial results on a commercial scale.

## 1.6 Bibliography

- Accati, E.G., L. Basoccu, and S. Sulis. 1979. Effect of 6-BA and other cytokinins on flower production of spray carnation. *Acta Horticulturae* 91:115-121.
- Adams, P., D.E. Nelson, S. Yamada, W. Chmara, R.G. Jensen, H.J. Bohnert, and H. Griffiths. 1991. Growth and development of *Mesembryanthemum crystallinum*. *New Phytol.* 138:171-190.
- Agranova. 1997. *Herbicide Synopsis - a chronological listing of all herbicide, safener and PGR compounds to 1995*. 2nd ed. Indianapolis, IN: Ag Chem Information Services.
- Agrios, G.N. 1997. *Plant Pathology*. 4th ed. Burlington, MA: Elsevier Academic Press.
- Aharoni, N., A. Back, S. Ben-Yehoshua, and A. E. Richmond. 1975. Exogenous gibberllic acid and the cytokinin isopentyladenine retardants of senescence of Romaine lettuce *J. Amer. Soc. Hort. Sci.* 100 (1):4-6.

- Ainley, W.M., K.J. McNeil, J.W. Hill, W.L. Lingle, R.B. Simpson, M.L. Brenner, R.T. Nagao, and J.L. Key. 1993. Regulatable endogenous production of cytokinins up to 'toxic' levels in transgenic plants and plant tissues. *Plant Molecular Biology* 22:13-23.
- Albrecht, M.L., and H.K. Tayama. 1992. *Tips on the use of chemical growth regulators on floriculture crops*. Columbus, Ohio: Ohio Florists' Association.
- Aldwinkle, H.S., and I.W. Selman. 1967. Some effects of supplying benzyladenine to leaves and plants inoculated with viruses. *Ann. appl. Biol.* 60 (1):49-58.
- Alexieva, V., I. Sergiev, E. Karanov, E. Golovinsky, E. Stanoeva, M. Haimova, and G. Petrov. 1994. Anticytokinin activity of 4-substituted triazolo[4,5-d]pyrimidines and 4-substituted pyrazolo[3,4-d]pyrimidines. *J. Plant Growth Regul.* 13:123-129.
- Aloni, R., S.F. Baum, and C.A. Peterson. 1990. The role of cytokinin in sieve tube regeneration and callose production in wounded *Coleus* internodes. *Plant Physiol.* 93:982-989.
- Alvarado-Raya, H., J. Rodriguez-Alcázar, G. Calderón-Zavala, and E. Cárdenas-Soriana. 2000. Thidiazuron, flower budbreak and ovary dimensions in Japanese Plum (*Prunus salicina* L.) 'Shiro'. *Agrociencia* 34:321-327.
- Amrutavalli, S.A. 1980. Interaction of gibberellic acid (GA<sub>3</sub>) and benzyladenine (BA) on flowering and sex expression in Bulgarian coriander (*Coriandrum sativum* L.). *Indian Journal of Plant Physiology* 23 (1):14-20.
- Andres, H., B. Fernandez, R. Rodriguez, and A. Rodriguez. 2002. Phytohormone contents in *Corylus avellana* and their relationship to age and other developmental processes. *Plant Cell, Tissue and Organ Culture* 70:173-180.
- Antognozzi, E., and P. Proietti. 1995. Effects of CPPU (cytokinin) on table olive trees (cv. *Ascolana tenera*) under nonirrigated and irrigated conditions. *Acta Horticulturae* 379:159-166.
- Antognozzi, E., P. Proietti, and M. Boco. 1993. Effect of CPPU (cytokinin) on table olive cultivars. *Acta Horticulturae* 329:153-155.
- Arima, Y., K. Oshima, and K. Shudo. 1995. Evolution of a novel urea-type cytokinin: Horticultural uses of forchlorfenuron. *Acta Horticulturae* 394:75-83.
- Armstrong, D.J. 2002. Folke K. Skoog: In memory and tribute. *J. Plant Growth Regul.* 21:3-16.
- Artamonov, V. I. 1975. Some aspects of practical use of kinetin. *Soviet Plant Physiology* 22 (6):1126-1132.
- Arteca, R.N. 1982. Effect of root applications of kinetin and gibberellic acid on transplanting shock in tomato plants. *HortScience* 17 (4):633-634.
- Arzee, T., H. Langenauer, and J. Gressel. 1977. Effects of dikegulac, a new growth regulator, on apical growth and development of three Compositae. *Botanical Gazette* 138 (1):18-28.

- Atkins, C.A., and A. Pigeaire. 1993. Application of cytokinins to flowers to increase pod set in *Lupinus angustifolius* L. *Aust. J. Agric. Res.* 44:1799-1819.
- Auer, C.A. 1996. Cytokinin inhibition of *Arabidopsis* root growth: An examination of genotype, cytokinin activity, and N<sup>6</sup>-benzyladenine metabolism. *J. Plant Growth Regul.* 15:201-206.
- Auer, C.A. 1997. Cytokinin conjugation: recent advances and patterns in plant evolution. *Plant Growth Regulation* 23:17-32.
- Auer, C.A., J.D. Cohen, M. Laloue, and T.J. Cooke. 1992. Comparison of benzyl adenine metabolism in two *Petunia hybrida* lines differing in shoot organogenesis. *Plant Physiol.* 96:1035-1041.
- Auer, C.A., V. Motyka, A. Brezinova, and M. Kaminek. 1999. Endogenous cytokinin accumulation and cytokinin oxidase activity during shoot organogenesis of *Petunia hybrida*. *Physiol. Plant.* 105:141-147.
- Badizadegan, M., E. Tafazoli, and M. Kheradnam. 1972. Effect of N<sup>6</sup>benzyladenine on vegetative growth and tuber production in potato. *Amer Potato J* 49 (3):109-116.
- Bailey, D., and B.E. Whipker. 1998. Best management practices for plant growth regulators used in floriculture. Horticulture Information Leaflet 529, 1-16: North Carolina Cooperative Extension.
- Bailey, D.A. 1992. Plant growth regulators labeled for floriculture use. *North Carolina Flower Growers' Bulletin* 37 (3):6-9.
- Baker, J.A. 2001. *Plant Growth Regulators*: College of Agriculture and Life Sciences. N. C. State University. Raleigh, N. Carolina 27695-7603.
- Bangerth, F. 1993. Polar auxin transport as a signal in the regulation of tree and fruit development. *Acta Horticulturae* 329:70-76.
- Bangerth, F., C.J. Li, and J. Gruber. 2000. Mutual interaction of auxin and cytokinins in regulating correlative dominance. *Plant Growth Regulation* 32:205-217.
- Barker, S.J., and D. Tagu. 2000. The roles of auxins and cytokinins in mycorrhizal symbioses. *J. Plant Growth Regul.* 19:144-154.
- Barrett, J. E., R.K. Schoellhorn, C.A. Bartuska, D.G. Clark, and T.A. Nell. 2003. Uniconazole application to container medium surface prior to planting bedding plants. *HortScience* 38 (2):169-172.
- Beach, S.E. 2005. Shipping and nitrogen toning effects on postharvest shelf life of vegetative annuals, Floriculture, Texas A&M University.
- Beck, E.H. 1996. Regulation of shoot/root ratio by cytokinins from roots in *Urtica dioica*: Opinion. *Plant and Soil* 185:3-12.

- Beeson, R.C., and W.M. Proebsting. 1989. Picea graft success: Effects of environment, rootstock disbudding, growth regulators, and antitranspirants. *HortScience* 24 (2):253-254.
- Bell, M., R.A. Larson, and D.A. Bailey. 1997. Vegetative growth responses of florist azaleas to Dikegulac, GA<sub>4+7</sub>, and 6-benzylamino purine. *HortScience* 32 (4):690-697.
- Beltrano, J., D.O. Caldiz, R. Barreyro, G.S. Vallduvi, and R. Bezus. 1994. Effects of foliar applied gibberellic acid and benzyladenine upon yield components in sunflower (*Helianthus annuus* L.). *Plant Growth Regulation* 15:101-106.
- Bernier, G., A. Havelange, C. Houssa, A. Petitjean, and P. Lejeune. 1993. Physiological signals that induce flowering. *The Plant Cell* 5:1147-1155.
- Bernier, G., and C. Perilleux. 2005. A physiological overview of the genetics of flowering time control. *Plant Biotechnology Journal* 3:3-16.
- Bessler, B. 1997. The use of 6-benzylaminopurine for rapid multiplication of *Tillandsias* *HortScience* 32 (2):256-258.
- Biddington, N. L., and T. H. Thomas. 1978. Thermodormancy in celery seeds and its removal by cytokinins and gibberellins. *Physiol. Plant.* 42:401-405.
- Biran, I., B. Leshem, I. Gur, and A.H. Halevy. 1974. Further studies on the relationship between growth regulators and tuberization of *Dahlia*s. *Physiol. Plant.* 31:23-28.
- Bishopp, A., A.P. Mahonen, and Y. Helariutta. 2006. Signs of change: hormone receptors that regulate plant development. *Development* 133:1857-1869.
- Bismuth, F., and E. Miginiac. 1984. Influence of zeatin on flowering in root forming cuttings of *Anagallis arvensis* L. *Plant & Cell Physiol.* 25 (6):1073-1076.
- Blackman, P. G., and W. J. Davies. 1984. Age-related changes in stomatal response to cytokinins and abscisic acid. *Annals of Botany* 54:121-125.
- Blackman, P. G., and W.J. Davies. 1985. Cytokinins, abscisic acid and the control of plant water balance. *Acta Horticulturae* 171:255-261.
- Blanchard, M.G., L.A. Newton, E.S. Runkle, D. Woolard, and C.A. Campbell. 2007. Exogenous applications of abscisic acid improved the postharvest drought tolerance of several annual bedding plants. *Acta Horticulturae* 755:127-133.
- Blankenship, S. 2001. Ethylene effects and the benefits of 1-MCP. *Perishables Handling Quarterly* (108):2-4.
- Boe, A.A., R.B. Stewart, and T.J. Banko. 1972. Effects of growth regulators on root and shoot development on sedum leaf cuttings. *HortScience* 7 (4):404-405.

- Borden, P., and R.W. Campbell. 1985. Use of chemical growth regulators to increase growth of 'Meyer' zoysiagrass. *Proceedings of the plant growth regulation society of America* 12th annual meeting:38-44.
- Boyle, T.H. 1992. Modification of plant architecture in 'Crimson Giant' Easter cactus with benzyladenine. *J. Amer. Soc. Hort. Sci.* 117 (4):584-589.
- Brault, M., R. Maldiney, and E. Miginiac. 1997. Cytokinin-binding proteins. *Physiol. Plant.* 100:520-527.
- Buban, T. 2000. The use of benzyladenine in orchard fruit growing: a mini review. *Plant Growth Regulation* 32:381-390.
- Bukovac, M.J. 1990. Sorption of organic compounds by plant cuticles. *Weed Science* 38:289-298.
- Camacho, Y., L. Martinez-Castilla, S. Fragoso, S. Vazquez, E. Martinez-Barajas, and P. Coello. 2008. Characterization of a type A response regulator in the common bean (*Phaseolus vulgaris*) in response to phosphate starvation. *Physiol. Plant.* 132:272-282.
- Canal, M.J., H. Fernandez, P. Fernandez, M.L. Centano, and B. Fernandez. 2000. Uptake and metabolism of 6-benzyladenine in ventilated cultures of kiwifruit plants. *Plant Growth Regulation* 30 (3):209-204.
- Carey, D.J., B.E. Whipker, I. McCall, and W. Buhler. 2007. Cytokinin based PGR affects growth of vegetative petunia. *SNA Research Conference Proceedings* 52 (8):102-104.
- Carey, D.J., B.E. Whipker, I. McCall, and W. Buhler. 2008. Benzyladenine foliar sprays increase offsets in *Sempervivum* and *Echeveria*. *SNA Research Conference Proceedings* 53:19-21.
- Carlson, R.D., and A.J. Crovetti. 1990. Commercial uses of gibberellins and cytokinins and new areas of applied research. In *Plant Growth Substances 1988*, eds. R. P. Pharis and S. B. Rood, 604-610. Berlin ; New York, NY: Springer-Verlag.
- Carow, B., and K. Bahnemann. 1980. Influence of silver nitrate, kinetin, and benzylaminopurine on yellowing of *Pelargonium zonale* cuttings. *Gartenbauwissenschaft* 45 (6):273-278.
- Carpenter, W. J., and G.R. Beck. 1972. Growth regulator induced branching of poinsettia stock plants. *HortScience* 7 (4):405-406.
- Carpenter, W. J., and R.C. Rodriguez. 1971. The effect of plant growth regulating chemicals on rose shoot development from basal and axillary buds. *J. Amer. Soc. Hort. Sci.* 96 (3):389-391.
- Carpenter, W. J., R.C. Rodriguez, and W. H. Carlson. 1971. Growth regulator induced branching of non-pinned poinsettias. *HortScience* 6 (5):457-458.
- Carpenter, W.J., and W.H. Carlson. 1972. The effect of growth regulators on *Chrysanthemum*. *J. Amer. Soc. Hort. Sci.* 97 (3):349-351.

- Carroll, M.J., P.H. Dernoeden, and J.M. Krouse. 1996. Zoysiagrass establishment from springs following application of herbicides, nitrogen, and a biostimulator. *HortScience* 31 (6):972-975.
- Carswell, F.E., J.S. Day, and K.S. Gould. 1996. Cytokinins and the regulation of plant form in three species of *Sophora*. *New Zealand Journal of Botany* 34:123-130.
- Çelikel, F.G., L.L. Dodge, and M.S. Reid. 2002. Efficacy of 1-MCP (1-methylcyclopropene) and Promalin for extending the post-harvest life of Oriental lilies (*Lilium* × 'Mona Lisa' and 'Stargazer'). *Scientia Horticulturae* 93:149-155.
- Chang, H.C., M.L. Jones, G.M. Banowitz, and D.G. Clark. 2003. Overproduction of cytokinins in petunia flowers transformed with PSAG12-IPT delays corolla senescence and decreases sensitivity to ethylene. *Plant Physiol.* 132:2174-2183.
- Chang, S.T., W.S. Chen, C.Y. Hsu, H.C. Yu, B.S. Du, and K.L. Huang. 1999. Changes in cytokinin activities before, during and after floral initiation in *Polianthes tuberosa*. *Plant Physiol. Biochem.* 37 (9):679-684.
- Chen, W.S., H.W. Chang, W.H. Chen, and Y.S. Lin. 1997. Gibberellic acid and cytokinin affect *Phalaenopsis* flower morphology at high temperature. *HortScience* 32 (6):1069-1073.
- Chernyad'ev, I. I. 2005. Effect of water stress on the photosynthetic apparatus of plants and the protective role of cytokinins: A review. *Applied biochemistry and microbiology* 41 (2):115-128.
- Clark, D.G., J.W. Kelly, and H.B. Pemberton. 1991. Postharvest quality characteristics of cultivars of potted rose in response to holding conditions and cytokinins. *HortScience* 26 (9):1195-1197.
- Clark, J.R., and W.P. Hackett. 1980. Assimilate translocation in juvenile-adult grafts of *Hedera helix*. *J. Amer. Soc. Hort. Sci.* 105 (5):727-729.
- Clark, J.R., and W.P. Hackett. 1981. Interaction of Ancymidol and benzyladenine in control of growth of juvenile *Hedera helix*. *Physiol. Plant.* 53:483-486.
- Cline, M. 1997. Concepts and terminology of apical dominance. *Amer. J. Bot.* 84 (9):1064-1069.
- Cline, M.G., and K. Dong-II. 2002. A preliminary investigation of the role of auxin and cytokinin in sylleptic branching of three hybrid poplar clones exhibiting contrasting degrees of sylleptic branching. *Ann. Bot.* 90:417-421.
- Cowan, A.K., A.L.P. Cairns, and B. Bartels-Rahm. 1999. Regulation of abscisic acid metabolism: Towards a metabolic basis for abscisic acid-cytokinin antagonism. *J. Exp. Bot.* 50 (334):595-603.
- Criley, R.A. 1980. Stimulating lateral bud break on *Dracaena*. *Plant Propagator* 26 (2):3-5.

- Criley, R.A. 1988. Propagation of tropical cut flowers: *Strelitzia*, *Alpinia*, and *Heliconia*. *Acta Horticulturae* 226:509-517.
- Crovetti, A.J., and W.E. Shafer. 1989. Considerations in the commercial development of plant growth regulators. *Acta Horticulturae* 239:465-476.
- Csepely, I. T. , and Z. Barabás. 1979. Acceleration of vernalization in wheat *Triticum aestivum* L. by cytokinins: Preliminary report. *Cereal Res. Comm.* 7 (1):55-59.
- Dai, T.J.W., and R.E. Paull. 1991. Postharvest handling of *Alstroemeria*. *HortScience* 26 (3):314.
- Daoudi, H., L. Ferguson, and C. J. Lovatt. 2002. Reducing alternate bearing in pistachio with foliar applied 6-benzyladenine and low-biuret urea. *Proceedings of the plant growth regulation society of America* 29:49.
- Das, P., T. Bose, and P. Roy. 1977. Effect of growth regulators on the photoperiodic response of short and long day plants. *Orissa Journal of Horticulture* 5 (1/2):1-6.
- Davies, L.J. , P.R. Hicklenton, and J.L. Catley. 1996. Vernalization and growth regulator effects of flowering of *Gypsophila paniculata* L. cvs Bristol Fairy and Bridal Veil. *Journal of Horticultural Science* 71 (1):1-9.
- Davies, P.J. 1994. The plant hormones: Their nature, occurrence, and functions. In *Plant Hormones: Physiology, Biochemistry and Molecular Biology*, ed. P. J. Davies, 833. Dordrecht; Boston, MA: Kluwer Academic Publishers.
- Davies, P.J. 2004a. The plant hormones : Their nature, occurrence and function. In *Plant hormones biosynthesis, signal transduction, action!*, ed. P. J. Davies, 750. Dordrecht ; Norwell, MA: Kluwer Academic Publishers.
- Davies, P.J. 2004b. Regulatory factors in hormone action : level, location and signal transduction. In *Regulatory factors in hormone action : level, location and signal transduction*, ed. P. J. Davies, 750. Dordrecht ; Norwell, MA: Kluwer Academic Publishers.
- Day, J.S., P.E. Jameson, and K.S. Gould. 1995. Cytokinins associated with metamorphic vegetative growth in *Elaeocarpus hookerianus*. *Aust. J. Plant Physiol.* 22:67-73.
- Day, J.S., and B.R. Loveys. 1998. Propagation from cuttings of two woody ornamental Australian shrubs, *Boronia megastigma* Nees (brown boronia) and *Hypocalymma angustifolium* Endl. (white myrtle). *Australian Journal of Experimental Agriculture* 38:201-206.
- Dayuan, W. 1981. Effect of BA and GA on fruit drop of citrus. *HortScience* 16 (5):657-659.
- de Groot, C. C., L. F. M. Marcelis, H. Lambers, and R. van den Boorgaard. 2004. Response of growth of tomato to phosphorus and nitrogen nutrition. *Acta Horticulturae* 633:357-364.

- de Meutter, J., T. Tytgat, E. Witters, G. Gheysen, H. van Onckelen, and G. Gheysen. 2003. Identification of cytokinins produced by the plant parasitic nematodes *Heterodera schachtii* and *Meloidogyne incognita*. *Molecular Plant Pathology* 4 (4):271-277.
- de Munk, W.J., and J. Gijzenberg. 1977. Flower bud blasting in tulip plants mediated by the hormonal status of the plant. *Scientia Horticulturae* 7:255-268.
- de Munk, W.J., and P. Hoogeterp. 1975. Flower bud blasting in tulips. *Acta Horticulturae* 47:149-154.
- de Vries, D.P., and Lidwein A.M. Dubois. 1988. The effect of BAP and IBA on sprouting and adventitious root formation of 'Amanda' rose single-node softwood cuttings. *Scientia Horticulturae* 34:115-121.
- Deruère, J., and J.J. Kieber. 2002. Molecular mechanisms of cytokinin signaling. *J. Plant Growth Regul.* 21:32-39.
- Deutch, B. 1973. Bulblet formation in *Achimenes longiflora*. *Physiol. Plant.* 30:113-118.
- Dodd, I.C. 2005. Root-to-shoot signalling: Assessing the roles of 'up' in the up and down world of long-distance signalling in planta. *Plant and Soil* 274:251-270.
- Dong, C.N., and R.N. Arteca. 1982. Changes in photosynthetic rates and growth following root treatments of tomato plants with phytohormones. *Photosynthesis Research* 3:45-52.
- Drozdov, S.N., and R.I. Volkova. 1975. Effect of kinetin on potato growth and productivity. *Soviet Plant Physiology* 22 (3):527-528.
- Drüge, U. 2000. Influence of pre-harvest nitrogen supply on post-harvest behaviour of ornamentals: Importance of carbohydrate status, photosynthesis and plant hormones. *Gartenbauwissenschaft* 65 (2):52-64.
- Duan, H., Y. Li, Y. Pei, W. Deng, M. Luo, Y. Xiao, Luo K., L. Lu, W. Smith, R. J. McAvoy, D. Zhao, X. Zheng, and C. Thammina. 2006. Auxin, cytokinin and abscisic acid: Biosynthetic and catabolic genes and their potential applications in ornamental crops. In *Plant Biotechnology in Ornamental Horticulture*, 347-364: The Haworth Press, Inc.
- Duck, M.W., B.M. Cregg, R.T. Fernandez, Royal D. Heins, and F.F Cardoso. 2004. Height control of *Picea* spp. and *Chamaecyparis lawsoniana* with uniconazole and 6-benzyladenine. *J. Environ. Hort.* 22 (3):165-169.
- Durmus, N., and A. Kadioglu. 2005. Reduction of paraquat toxicity in maize leaves by benzyladenine. *Acta Biologica Hungarica* 56 (1/2):97-107.
- Eason, J.R. 1992. *Corynebacterium fascians*: cytokinin production is positively correlated with virulence. *Current plant science and biotechnology in agriculture* 13:511-516.

- Eason, J.R., R.O. Morris, and P.E. Jameson. 1996. The relationship between virulence and cytokinin production by *Rhodococcus fascians* (Tilford 1936) Goodfellow 1984. *Plant Pathology* 45:323-331.
- Edenfield, M.W., B.J. Brecke, D.G. Shilling, M.E. Kane, J.A. Dusky, Colvin D.L., and G.E. MacDonald. 1999. Evaluation of plant growth regulators on the phenology and growth and development of purple nutsedge (*Cyperus rotundus*) *Proceedings, Southern WEed Science Society* 52:169.
- El-Keltawi, N.E., and R. Croteau. 1987. Salinity depression of growth and essential oil formation in spearmint and majoram and its reversal by foliar applied cytokinin. *Phytochemistry* 26 (5):1333-1334.
- Elad, Y. 1993. Regulators of ethylene biosynthesis or activity as a tool for reducing susceptibility of host plant tissues to infection by *Botrytis cinerea*. *Neth. J. Pl. Path.* 99:105-113.
- Elfving, D.C., and D.B. Visser. 2007. Improving the efficacy of cytokinin applications for stimulation of lateral branch development in young sweet cherry trees in the orchard. *HortScience* 42 (2):251-256.
- Emino, E.R., J.E. Barrett, and D.G. Clark. 2002. Mediation of ethylene damage during shipping of geranium cuttings: Application of anti-ethylene growth regulators and cytokinins. *Proceedings of the plant growth regulation society of America* 29:181-185.
- EPA. 1994. Reregistration eligibility decision N<sup>6</sup>-benzyladenine List B Case 2040, ed. E. P. Agency.
- EPA. 2008. *Cytokinin, kinetin, N<sup>6</sup>-benzyladenine 116801,116802,116901) products* 2007 [cited 18 October 2008]. Available from [http://www.epa.gov/pesticides/biopesticides/ingredients/product/prod\\_116801.htm](http://www.epa.gov/pesticides/biopesticides/ingredients/product/prod_116801.htm).
- Erdei, L., and H. Mastumoto. 1991. Mitigation of symptoms of Ca<sup>2+</sup> deficiency by benzyladenine in cucumber: ion levels, polyamines and Ca<sup>2+</sup>-Mg<sup>2+</sup>-ATPase. *Biochemie und Physiologie der Pflanzen* 187 (3):177-188.
- Ervin, E.H., X. Zhang, and G. Seaver. 2006. Impact of seaweed-based cytokinins and zeatin riboside on creeping bentgrass heat tolerance. *PGRSA quarterly* 34 (2):28.
- Evans, L.T. 1975. *Daylength and the flowering plants*: Menlo Park, Calif. : W. A. Benjamin.
- Even-Chen, Z., R.M. Sachs, and W.P. Hackett. 1979. Control of flowering in *Bougainvillea* 'San Diego Red'. *Plant Physiol.* 64:646-651.
- Fagan, A.E., M.A. Dirr, and F.A. Pokorny. 1981. Effects of depulping, stratification and growth regulators on seed germination of *Liriope muscari*. *HortScience* 16 (2):208-209.
- Faust, M., A. Erez, L.J. Rowland, and S.Y. Wang. 1997. Bud dormancy in perennial fruit trees: Physiological basis for dormancy induction, maintenance, and release. *HortScience* 32 (4):623-628.

- Ferriera, F.J., and J.J. Kieber. 2005. Cytokinin signaling. *Current Opinion in Plant Biology* 8:518-525.
- Finch-Savage, W.E., D. Gray, and G.M. Dickson. 1991a. The combined effects of osmotic priming with plant growth regulator and fungicide soaks on the seed quality of five bedding plant species. *Seed Sci. & Technol.* 19:495-503.
- Finch-Savage, W.E., D. Gray, and G.M. Dickson. 1991b. Development of bulk priming/plant growth regulator seed treatments and their effect on the seedling establishment of four bedding plant species. *Seed Sci. & Technol.* 19:477-485.
- Finch-Savage, W.E., D. Gray, and G.M. Dickson. 1991c. Germination responses of seven bedding species to environmental conditions and gibberellic acid. *Seed Sci. & Technol.* 19:487-494.
- Findley, D.A., G.J. Keever, and C.H. Gilliam. 1994. BA-induced offset formation in *Hosta*. *SNA Research Conference Proceedings* 39:33-34.
- Foley, J.T., and G.J. Keever. 1991. Growth regulators and pruning alter growth and axillary shoot development of *Dianthus*. *J. Environ. Hort.* 9 (4):191-195.
- Fonseca, J.M. 2004. Effect of cytokinins on yield of iceberg lettuce. *PGRSA quarterly* 32 (2):70.
- Fooshee, W.C., and R.J. Henny. 1985. Guidelines for preparing solutions of gibberellic acid (GA<sub>3</sub>) and N<sup>6</sup>benzyladenine (BA). *Foliage Digest* 8 (5):7.
- Fox, J.E., and J.S. Weis. 1965. Transport of the kinin, N<sup>6</sup>-benzyladenine: Non-polar or polar? *Nature* 206:678-679.
- Franco, R.E., and S.S. Han. 1997. Respiratory changes associated with growth-regulator-delayed leaf yellowing in Easter lily. *J. Amer. Soc. Hort. Sci.* 122 (1):117-121.
- Franssen, J.M., and P.G.J.M. Voskens. 1997. Competition between sprout and daughter bulbs for carbohydrates as affected by mother bulb size and cytokinins. *Acta Horticulturae* 430:63-71.
- Frugier, F., S. Kosuta, J. Murray, M. Crespi, and K. Szczyglowski. 2008. Cytokinin: secret agent of symbiosis. *Trends in plant science* 13 (3):1360-1385.
- Funnell, K.A., and R.D. Heins. 1998. Plant growth regulators reduce postproduction leaf yellowing of potted asiflorum lilies. *HortScience* 33 (6):1036-1037.
- Furuta, T., and T.H. Straiton. 1965. Synergism of kinetin and gibberellic acid in flowering of unchilled azalea cultivar 'Red Wing'. *American Society for Horticultural Science* 88:591-594.
- Galuzska, P., I. Frebort, M. Sebel, and P. Pec. 2000. Degradation of cytokinins by cytokinin oxidases in plants. *Plant Growth Regulation* 32:315-327.
- Gianfagna, T.J., and R.H. Merritt. 2000. Rate and time of GA<sub>4/7</sub> treatment affect vegetative growth and flowering in a genetic line of *Aquilegia x hybrida* Sims. *Scientia Horticulturae* 83 (3-4):275-281.

- Gilbertson-Ferriss, T.L., and H.F. Wilkins. 1981. Response of *Freesia hybrida* corms to exogenous growth regulator applications. *HortScience* 16 (4):568-570.
- Ginzburg, C. 1973. Hormonal regulation of cormel dormancy in *Gladiolus grandiflorus*. *Journal of Experimental Botany* 24 (80):558-566.
- Giulini, A., J. Wang, and D. Jackson. 2004. Control of phyllotaxy by the cytokinin-inducible response regulator homologue ABPHYL1. *Nature* 430:1031-1034.
- Goh, C.J. 1979. Hormonal regulation of flowering in a sympodial orchid hybrid *Dendrobium* Louisa. *New Phytol.* 82:375-380.
- Goh, C.J., and A.L. Yang. 1978. Effects of growth regulators and decapitation on flowering of *Dendrobium* orchid hybrids. *Plant Science Letters* 12:287-292.
- Goszczyńska, D.M., R.M. Rudnicki, and M.S. Reid. 1985. The role of plant hormones in the postharvest life of cut flowers. *Acta Horticulturae* 167:79-93.
- Grayling, A., and D.E. Hanke. 1992. Cytokinins in exudates from leaves and roots of red *Perilla*. *Phytochemistry* 31 (6):1863-1868.
- Grochowska, M.J., and M. Hodun. 1997. The dwarfing effect of a single application of growth inhibitors to the root-stem connection - "the collar tissue" - of five species of fruit trees. *J. Hort. Sci.* 72 (1):83-91.
- Guak, S., M. Beulah, D. Neilsen, H.A. Quamme, and N.E. Looney. 2005. Effects of urea and plant bioregulators (Ethepon and Promalin) on tissue nitrogen levels, cold hardiness, and cropping of sweet cherry trees. *Acta Horticulturae* 667:453-460.
- Gulzar, S., I. Tahir, I. Amin, S. Farogg, and S.M. Sultan. 2005. Effect of cytokinins on the senescence and longevity of isolated flowers of day lily (*Heimerocallis fulva*) cv. Royal Crown sprayed with cycloheximide. *Acta Horticulturae* 669:395-403.
- Guzman, V. L. 1963. Concentration of N<sup>6</sup> benzyladenine, temperature, and time effects on retardation of senescence in celery and endive. *Proc. Fla. State Hort. Soc.* 75:196-201.
- Hagon, M.W. 1976. Germination and dormancy of *Themeda australis*, *Danthonia* spp., *Stipa bigeniculata* and *Bothriochloa macra*. *Aust. J. Bot.* 24:319-327.
- Halevy, A.H., D.R. Dilley, and S. H. Wittwer. 1965. Chemical regulation of leaf senescence. *Quart. Bull. Mich. agric. Exp. Stat.* 48:30-35.
- Halmann, M. 1990. Synthetic plant growth regulators. *Advances in Agronomy* 43:47-105.
- Hamilton, D.F., and P.L. Carpenter. 1976. Factors influencing low-temperature after-ripening in seed of *Elaeagnus umbellata* Thunb. *J. Amer. Soc. Hort. Sci.* 10 (2):171-175.

- Han, S.S. 1995. Growth regulators delay foliar chlorosis of Easter lily leaves. *J. Amer. Soc. Hort. Sci.* 120 (2):254-258.
- Han, S.S. 2001. Benzyladenine and gibberellins improve postharvest quality of cut asiatic and oriental lilies. *HortScience* 36 (4):741-745.
- Hanks, G.R., and A.R. Rees. 1977a. Growth regulator treatments to improve the yield of twin-scaled *Narcissus*. *Scientia Horticulturae* 6:237-240.
- Hanks, G.R., and A.R. Rees. 1977b. Stem elongation in tulip and *Narcissus*: The influence of floral organs and growth regulators. *New Phytol.* 78:579-591.
- Hansen, C.E., C. Kopperud, and O.M. Heide. 1988. Identity of cytokinins in *Begonia* leaves and their variation in relation to photoperiod and temperature. *Physiol. Plant.* 73:387-391.
- Hare, P.D., W.A. Cress, and J. van Staden. 1997. The involvement of cytokinins in plant responses to environmental stress. *Plant Growth Regulation* 23:79-103.
- Harkema, H., M.W.C. Dekker, and M.L. Edsers. 1991. Distribution of amino-oxyacetic acid in cut carnation flowers after pretreatment. *Scientia Horticulturae* 47 (3-4):327-333.
- Harkess, R.L., and R.E. Lyons. 1994. Gibberellin- and cytokinin-induced growth and flowering responses in *Rudbeckia hirta* L. *HortScience* 29 (3):141-142.
- Hartmann, H.T., D.E. Kester, F.E. Davies, and R. Geneve. 2001. *Plant propagation: Principles and practices*. 7 ed: Prentice Hall.
- Haver, D., and U. Schuch. 2001. Influence of root restriction and ethylene exposure on apical dominance of petunia (*Petunia x hybrida* Hort. Vilm.-Andr.). *Plant Growth Regulation* 35:187-196.
- Hayata, Y., Y. Niimi, K. Innoue, and S. Kondo. 2000. CPPU and BA, with and without pollination, affect set, growth, and quality of muskmelon fruit. *HortScience* 35 (5):868-870.
- Hayata, Y., Y. Niimi, and N. Iwasaki. 1995. Synthetic cytokinin--1-(2-chloro-4-pyridyl)-3-phenylurea (CPPU)--promotes fruit set and induces parthenocarp in watermelon. *J. Amer. Soc. Hort. Sci.* 120 (6):997-1000.
- Heide, O.M., and J. Oydvin. 1969. Effects of 6-benzylamino-purine on the keeping quality and respiration of glasshouse carnations. *Hort. Res.* 9:26-36.
- Hemberg, T. 1972. The effect of kinetin on the occurrence of acid auxin in *Coleus blumei*. *Physiol. Plant.* 26:98-103.
- Henny, R.J. 1986. Increasing basal shoot production in a non-branching *Dieffenbachia* hybrid with BA. *HortScience* 21 (6):1386-1388.

- Henny, R.J., and W.C. Fooshee. 1990a. Thidiazuron stimulates basal bud and shoot formation in *Alocasia X Chantrieri* Andre. *HortScience* 25 (1):124.
- Henny, R.J., and W.C. Fooshee. 1990b. Use of Thidiazuron in attempt to stimulate basal branching of *Monstera siltepecana*. In *CFREC-Apopka Research Report RH-90-24*.
- Herrera, E., M. Cardenas, and K. Gustafson. 1987. Promotion of lateral growth of pecans (*Carya illinoensis* (Wangenh.) K. Koch) with plant regulator sprays. *Phyton* 47 (1/2):53-62.
- Hirose, N., K. Takei, T. Kuroha, T. Kamada-Nobusada, H. Hayashi, and H. Sakakibara. 2008. Regulation of cytokinin biosynthesis, compartmentalization and translocation. *Journal of Experimental Botany* 59 (1):75-83.
- Ho, Y.S., K.C. Sanderson, and J.C. Williams. 1985. Effect of chemicals and photoperiod on the growth and flowering of Thanksgiving cactus. *J. Amer. Soc. Hort. Sci.* 110 (5):658-662.
- Hodgson, R.H., and R.H. Snyder. 1988. Thidiazuron effects on Malvaceae, Corn, *Zea mays*; and Soybean, *Glycine max*. *Weed Technology* 1988 (2):342-349.
- Hopkins, R., R. Beach, and R. Menendez. 2005. Benefits of Prestige (CPPU, Forchlorfenuron) use in California table grapes. *Proceedings of the 32nd Annual Meeting of the Plant Growth Regulation Society of America, Newport Beach, California, USA, 24-27 July, 2005 Research Triangle Park*:35.
- Hrotkó, K., L. Magyar, and B. Öri. 1999. Improved feathering on one-year-old 'Germersdorfi FL 45' sweet cherry trees in the nursery. *Gartenbauwissenschaft* 64 (2):75-78.
- Huang, K.L., and W.S. Chen. 2002. BA and sucrose increase vase life of cut *Eustoma* flowers. *HortScience* 37 (3):547-549.
- Huitron, M.V., M. Diaz, F. Dianez, and F. Camacho. 2007. Effect of 2,4-D and CPPU on triploid watermelon production and quality. *HortScience* 42 (3):559-564.
- Iizuka, M., K. Takeuchi, J. Watanabe, and Sein-Hla Bo. 1978. Artificial induction of bubils in *Lilium* species. *HortScience* 13 (6):666-667.
- Imamura, J.S., and T. Higaki. 1988. Effect of GA<sub>3</sub> and BA on lateral shoot production on *Anthurium*. *HortScience* 23 (2):353-354.
- Itai, A., K. Tanabe, F. Tamura, S. Susaki, K. Yonemori, and A. Sugiura. 1995. Synthetic cytokinins control persimmon fruit shape, size and quality. *Journal of Horticultural Science* 70 (6):867-873.
- Itakura, T., Y. Shiraki, and S. Shiraki. 1957. Effects of gibberellin on the growth and flowering of several ornamental plants. *J. hort. Ass. Japan* 26:236.

- Jackson, M.B., and D.J. Campbell. 1979. Effects of benzyladenine and gibberellic acid on the responses of tomato plants to anaerobic root environments and to ethylene. *New Phytol.* 82:331-340.
- Jacyna, T., and A. Puchala. 2004. Application of environment friendly branch promoting substances to advance sweet cherry tree canopy development in the orchard. *Journal of Fruit and Ornamental Plant Research* 12:177-181.
- Jaiswal, S., and S. Sawhney. 2006. Correlation of epiphyllous bud differentiation with foliar senescence in crassulacean succulent *Kalanchoe pinnata* as revealed by thidiazuron and ethrel application. *Journal of Plant Physiology* 163:717-722.
- Jameson, P.E. 1994. Cytokinin metabolism and compartmentation. In *Cytokinins: Chemistry, Activity and Function*, eds. D. W. S. Mok and M. C. Mok, 113-128. Boca Raton, FL: CRC Press.
- Jameson, P.E., and S.F. Clarke. 2002. Hormone-virus interactions in plants. *Critical Reviews in Plant Sciences* 21 (3):205-228.
- Jaroenkit, T., and R.E. Paull. 2003. Postharvest handling of *Heliconia*, red ginger, and bird-of-paradise. *HortTechnology* 13 (2):259-266.
- Jeffcoat, B. 1977. Influence of the cytokinin, 6-benzylamino-9-(tetrahydropyran-2-yl)-9H-purine, on the growth and development of some ornamental crops. *Journal of Horticultural Science* 52:143-153.
- Jones, C.M. 1965. Effects of benzyladenine on fruit set in muskmelon. *Proc. Amer. Soc. Hort. Sci.* 87:335-340.
- Jones, L.H., H. Martinkova, M. Strnad, and D.E. Hanke. 1996. Occurrence of aromatic cytokinins in oil palm (*Elaeis guineensis* Jacq.). *J. Plant Growth Regul.* 15:39-49.
- Jordi, W., A. Schapendonk, E. Davelaar, G.M. Stoop, C.S. Pot, R. de Visser, van Rhijn J.A., S. Gan, and R.M. Amasino. 2000. Increased cytokinin levels in transgenic PSAG12-IPT tobacco plants have large direct and indirect effects on leaf senescence, photosynthesis and N partitioning. *Plant, Cell and Environment* 23:279-289.
- Junttila, O. 1970. Effects of stratification, growth substances and temperature on the germination of some *Syringa* species. *Meld. Norg. LandbrHogsk.* 49 (35):1-58.
- Kamínek, M., T. Vanek, A. Kalendová-Kulasová, and J. Pilar. 1987. The effect of two cytokinins on production of stem cuttings by stock plants of *Euphorbia pulcherrima* Willd. and *Gerbera jamesonii* Hook. *Scientia Horticulturae* 33:281-289.
- Kapchina-Toteva, V., H. van Telgen, and E. Yakimova. 2000. Role of phenylurea cytokinin CPPU in apical dominance release in *in-vitro* cultured *Rosa hybrida* L. *J. Plant Growth Regul.* 19:232-237.

- Karanov, E., L. Iliev, G.T.S. Georgiev, M. Tsoleva, V. Alexieva, and I. Puneva. 1992. Physiology and application of phenylurea cytokinins. *Current plant science and biotechnology in agriculture* 13:842-851.
- Kaufman, J., and S.M. Ringel. 1961. Tests of growth regulators to retard yellowing and abscission of cauliflower. *Proc. Amer. Soc. Hort. Sci.* 78:349-352.
- Keever, G.J. 1994a. BA-induced offset formation in *Hosta*. *J. Environ. Hort.* 12 (1):36-39.
- Keever, G.J. 1994b. Plant growth regulators: Potential uses in the nursery industry. *Combined proceedings of the international plant propagator's society* 44:474-477.
- Keever, G.J., and W.J. Foster. 1990. Chemically induced branching of woody landscape plants. *J. Environ. Hort.* 8 (2):78-82.
- Keever, G.J., W.J. Foster, J.W. Olive, and M.S. West. 1993. Increasing 'Bradford' pear crotch angles and lateral shoot counts with benzyladenine or Promalin sprays. *HortScience* 28 (6):678.
- Keever, G.J., and J.C. Warr. 2005. Response of *Hosta* to method and time of BA application. *PGRSA quarterly* 33 (1):4-11.
- Keever, Gary J., and Teresa J. Morrison. 2003. Multiple benzyladenine applications increase shoot formation in *Nandina*. *J. Environ. Hort.* 21 (3):144-147.
- Kessler, J.R., and B. Behe. 1998. Pansy production and marketing Alabama Cooperative Extension Publication ANR-0596.
- Khademi, M., and M. Khosh-Khui. 1977. Effect of growth regulators on branching, flowering, and fruit development of ornamental pepper (*Capsicum annuum* L.). *J. Amer. Soc. Hort. Sci.* 102 (6):796-798.
- Khaimov, A., and Y. Mizrahi. 2006. Effects of day-length, radiation, flower thinning and growth regulators on flowering of the vine cacti *Hylocereus undatus* and *Selenicereus megalanthus*. *Journal of Horticultural Science & Biotechnology* 81 (3):465-470.
- Khryanin, V.N. 2002. Role of phytohormones in sex differentiation in plants. *Russian Journal of Plant Physiology* 49 (4):545-551.
- King, J.W., J.B. Beard, and P.E. Rieke. 1982. Factors affecting survival of Kentucky bluegrass sod under simulated shipping conditions. *J. Amer. Soc. Hort. Sci.* 107 (4):634-637.
- Kuiper, D., J. Schuit, and P.J.C. Kuiper. 1988. Effects of internal and external cytokinin concentrations on root growth and shoot to root ratio of *Plantago major* ssp *pleiosperma* at different nutrient conditions. *Plant and Soil* 11:231-236.
- Kulaeva, O.N., J. Corse, and S.Y. Selivankina. 1995. Effects of trans- and cis-Zeatin and optical isomers of synthetic cytokinins on protein kinase activity *in vitro*. *J. Plant Growth Regul.* 14:41-47.

- Kumar, M.U., and K.S.K. Sastry. 1974. Effect of exogenous application of growth regulators on germinating ability of developing sunflowers. *Indian Journal of Experimental Biology* 12:543-545.
- Kurakawa, T., N. Ueda, M. Maekawa, K. Kobayashi, M. Kojima, Y. Nagato, H. Sakakibara, and J. Kyojuka. 2007. Direct control of shoot meristem activity by a cytokinin-activating enzyme. *Nature* 445:652-655.
- Kwon, E., and R.A. Criley. 1991. Cytokinin and ethephon induce greater branching of pruned *Plumeria*. *Horticultural Digest* 93:6-8.
- Lalouem, M., and J.E. Fox. 1989. Cytokinin oxidase from wheat. Partial purification and general properties. *Plant Physiol.* 90:899-906.
- Land, S.B., W.W. Elam, and M. Khan. 1995. Rejuvenated sycamore cuttings for energy plantations. *Biomass and Bioenergy* 8 (4):255-264.
- Latimer, J.G. 2004. Trends and uses of plant growth regulators on herbaceous perennials. *Proceedings of the plant growth regulation society of America* 31:1-4.
- Leclerc, M., C.D. Caldwell, L. Mapplebeck, R.R. Lada, and J. Norrie. 2003. Enhancement of propagule formation of *Hemerocallis* and *Hosta*. *Proceedings of the plant growth regulation society of America* Thirtieth Annual Meeting:74.
- Leonard, R.T., and T.A. Nell. 2004. Short-term pulsing improves postharvest leaf quality of cut oriental lilies. *HortTechnology* 14 (3):405-411.
- Letham, D.S. 1994. Cytokinins as phytohormones - Sites of biosynthesis, translocation, and function of translocated cytokinin. In *Cytokinins: Chemistry, Activity and Function*, eds. D. W. S. Mok and M. C. Mok, 338. Corvallis, OR: CRC Press.
- Lieth, H., and L.L. Dodge. 2004. Efficacy and phytotoxicity of Fascination (6-benzyladenine and GA<sub>4</sub>+GA<sub>7</sub>) on a variety of ornamental plants. *Proceedings of the 32nd Annual Meeting of the Plant Growth Regulation Society of America, Newport Beach, California, USA, 24-27 July, 2005 Research Triangle Park*:52.
- Lindstrom, R.S., and S.H. Wittwer. 1957. Gibberellin promotes earlier flowering on some flower plants. *Quart. Bull. Mich. Agric. Exp. Stat.* 1958 41:477-478.
- Lipton, W.J., and M.J. Ceponis. 1962. Retardation of senescence and stimulation of oxygen consumption in head lettuce treated with N<sup>6</sup> benzyladenine. *Proc. Amer. Soc. Hort. Sci.* 91:379-384.
- Little, C.H.A. 1984. Promoting bud development in balsam fir Christmas trees with 6-benzylaminopurine. *Can. J. For. Res.* 14:447-451.
- Little, C.H.A. 1985. Increasing lateral shoot production in Balsam fir Christmas trees with cytokinin application. *HortScience* 20 (4):713-714.

- Liu, F.H., and N. Longnecker. 2001. Interactive effect of cytokinin and potassium on sink-source relationships in *Lupinus angustifolius*. *Plant Growth Regulation* 00:1-6.
- Liu, X., B. Huang, and G. Banowitz. 2002. Cytokinin effects on creeping bentgrass responses to heat stress: I. Shoot and root growth. *Crop Sci.* 42:457-465.
- Liu, Z., and W.R. Bushnell. 1986. Effects of cytokinins on fungus development and host response in powdery mildew of barley. *Physiological and molecular plant pathology* 29 (1):41-52.
- Lucaszewska, A.J., P. Barthe, and M.T. Le Page-Devigry. 1995. The effect of exogenous cytokinins on longevity of cut roses. *Acta Horticulturae* 405:422-426.
- Mae, T., and C.R. Vonk. 1974. Effect of light and growth substances on flowering of *Iris x hollandica* cv. Wedgewood. *Acta Bot. Neerl.* 23 (3):321-331.
- Maene, L.J., and P.C. Deburgh. 1982. Stimulation of axillary shoot development of *Cordyline terminalis* 'Celestine Queen' by foliar sprays of 6-benzylamino purine. *HortScience* 17 (3):344-345.
- Magyar, L., and K. Hrotkó. 2005. Effect of BA (6-benzyladenine) and GA<sub>4+7</sub> on feathering of sweet cherry cultivars in the nursery. *Acta Horticulturae* 667:417-422.
- Marczynski, S., G. Klimczyk, and K. Majchrzak. 1979. Branching stimulation of budded roses with growth regulators. *Acta Horticulturae* 91:467-474.
- Maroto, J.V., A. Miguel, S. Lopez-Galarza, A.S. Bautista, B. Pascual, J. Alagarda, and J.L. Guardiola. 2005. Parthenocarpic fruit set in triploid watermelon induced by CPPU and 2,4-D applications. *Plant Growth Regulation* 45:209-213.
- Maruyama, T., A. Tanaka, M. Oda, T. Suzuki, and T. Oritana. 1993. Synthesis and biological activity of new water-soluble cytokinins. *Biosci. Biotech. Biochem.* 57 (5):803-807.
- McAvoy, R.J., and B.B. Bible. 1998. Poinsettia bract necrosis is affected by scion/rootstock combinations and arrested by a benzyladenine spray. *HortScience* 33 (2):242-246.
- McCarthy, D., and G. Bünemann. 1981. The use of growth regulators in the production of dwarf ornamental shrubs I. Dwarf conifers. *Gartenbauwissenschaft* 46 (5):193-199.
- McGaw, B.A. 1994. Cytokinin biosynthesis and metabolism. In *Plant growth and development : a molecular approach*, ed. D. E. Fosket, 580 San Diego: Academic Press.
- McGaw, B.A., and L.R. Burch. 1995. Cytokinin biosynthesis and metabolism. In *Plant Hormones: Physiology, Biochemistry and Molecular Biology*, ed. P. J. Davies, 98-117. Dordrecht: Kluwer Academic Publishers.
- Meilan, R. 1997. Floral induction in woody angiosperms. *New Forests* 14:179-202.

- Meins, F. 1988. Cell commitment and determination in plants. *Genetic engineering : Principles and methods* 10:141-153.
- Menendez, R. 2002. Commercial uses of plant growth regulators in fruit production - an update. *Proceedings of the plant growth regulation society of America* 29:57-62.
- Menendez, V., M.A. Revilla, and H. Fernandez. 2006. Growth and gender in the gametophyte of *Blechnum spicant* L. *Plant Cell Tissue and Organ Culture* 86 (1):47-53.
- Messinger, N.L., and E.J. Holcomb. 1986. The effect of chlormequat chloride, ancymidol, BAS 106, and SD8339 on selected dianthus cultivars. *HortScience* 21 (6):1397-1400.
- Metzger, J.D. 1995. Hormones and reproductive development. In *Plant Hormones: Physiology, Biochemistry, and Molecular Biology*, ed. P. J. Davies, 833. Dordrecht, Boston MA: Kluwer Academic Publishers.
- Midcap, J.T., J.H. Clay, B.S. Brewer, and E.H. Moody. 2008. *Camellia culture for home gardeners*. Georgia Cooperative Extension Service Bulletin B813 1999 [cited 18 October 2008]. Available from <http://pubs.caes.uga.edu/caespubs/pubcd/B813-w.htm#Gibbing>.
- Milbocker, D.C. 1967. Dioecy in the holly. *Proc. 42nd Mtg Holly Soc. Amer.* 1967:10-11.
- Milbocker, D.C. 1972. Axillary shoot stimulation in poinsettia with kinetin. *HortScience* 7 (5):483-484.
- Miller, C.O. 1956. Similarity of some kinetin and red light effects. *Plant Physiol.* 31:318-319.
- Million, J.B., J. E. Barrett, T.A. Nell, and D.G. Clark. 1999. Inhibiting growth of flowering crops with ancymidol and paclobutrazol in subirrigation water. *HortScience* 34 (6):1103-1105.
- Moe, R. 1979. Hormonal control of flower blasting in tulips. *Acta Horticulturae* 91:221-228.
- Moe, R., and M. Berland. 1986. Effect of various corm treatments on flowering of *Liatris spicata* Willd. *Acta Horticulturae* 177:197-201.
- Mok, M.C. 1994. Cytokinins and Plant Development - An overview. In *Cytokinins: Chemistry, Activity and Function*, eds. D. W. S. Mok and M. C. Mok, 338. Corvallis, OR: CRC Press.
- Mor, Y., and A.H. Halevy. 1984. Dual effect of light on flowering and sprouting of rose shoots. *Physiol. Plant.* 61:119-124.
- Morales-Payan, J.P. 2004. Bermuda turfgrass response to benzyladenine and phosphorus fertilization. *PGRSA quarterly* 34 (2):67.
- Morris, R.O. 1988. Molecular aspects of hormone synthesis and action. In *Plant Hormones: Physiology, Biochemistry and Molecular Biology*, ed. P. J. Davies, 833. Boston, MA: Kluwer Academic Publishers.

- Murch, S.J., S. KrishnaRaj, and P.K. Saxena. 1997. Thidiazuron-induced morphogenesis of Regal geranium (*Pelargonium domesticum*): A potential stress response. *Physiol. Plant.* 101:183-191.
- Musgrave, M.E. 1994. Cytokinins and oxidative processes. In *Cytokinins: Chemistry, Activity and Function*, eds. D. W. S. Mok and M. C. Mok, 338. Boca Raton, FL: CRC Press.
- Mynett, K. 1979. Growth regulators in the bud development of carnation. *Acta Horticulturae* 91:461-465.
- Mynett, K.J. 1977. La benzyladenine influence les plantes meres chez L oeillet en serre. *Acta Horticulturae* 71:19-21.
- Nagel, L., R. Brewster, W.E. Riedell, and R.N. Reese. 2001. Cytokinin regulation of flower and pod set in soybeans (*Glycine max* (L.) Merr.). *Ann. Bot.* 88 (1):27-31.
- Naor, V., J. Kigel, and M. Ziv. 2005. The effect of gibberellin and cytokinin on floral development in *Zantedeschia* spp. *in vivo* and *in vitro*. *Acta Horticulturae* 673:255-263.
- Nauer, E.M., and S.B. Boswell. 1981. Stimulating growth of quiescent citrus buds with 6-benzylamino purine. *HortScience* 16 (2):162-163.
- Nell, T.A., and R.A. Larson. 1974. The influence of foliar applications of GA<sub>3</sub>, GA<sub>4,7</sub> and PBA on breaking flower bud dormancy on azalea cvs Redwing and Dogwood. *J. Hort. Sci.* 49:323-328.
- Nelson, P.V., W. Kowalczyk, C.E. Niedziela, N.C. Mingis, and W.H. Swallow. 2003. Effects of relative humidity, calcium supply, and forcing season on tulip calcium status during hydroponic forcing. *Scientia Horticulturae* 98:409-422.
- Neri, D., M. Mazzoni, F. Zucconi, and G. Dradi. 2004. Feathering control in sweet cherry (*Prunus avium* L.) nursery, by deblading and cytokinin. *Acta Horticulturae* 636:119-127.
- Ngamu, K. 2001. Promoting side shoot development in *Zantedeschia aethiopica* 'Green Goddess'. *Gartenbauwissenschaft* 66 (2):85-92.
- Nishijima, T., M. Hideari, K. Sasaki, and T. Okazawa. 2006. Cultivar and anatomical analysis of corolla enlargement of petunia (*Petunia hybrida* Vilm.) by cytokinin application. *Scientia Horticulturae* 111:49-55.
- Norman, S.M., R.D. Bennett, V.P. Maier, and S.M. Poling. 1983. Cytokinins inhibit abscisic acid biosynthesis in *Cercospora rosicola*. *Plant Science Letters* 28 (3):255-263.
- Norton, E., and A.A. Boe. 1982. *In vitro* propagation of ornamental rosaceous plants. *HortScience* 17 (2):190-191.

- Norton, M.E., and C.R. Norton. 1985. *In vitro* propagation of Ericaceae: A comparison of the activity of the cytokinins N<sup>6</sup>-benzyladenine and N<sup>6</sup>-isopentenyladenine in shoot proliferation. *Scientia Horticulturae* 27:335-340.
- Nowak, T.J. 1980. Effect of gibberellin, auxin and kinetin treatments combined with foliar applied NPK on the yield of *Capsicum annuum* L. fruits and their capsaicin content. *Acta Agrobotanica* 33 (1):81-92.
- Oates, J.M., G.J. Keever, and J.R.J. Kessler. 2005a. BA application frequency and concentration effects on two Indian hawthorn cultivars. *J. Environ. Hort.* 23 (1):37-41.
- Oates, J.M., G.J. Keever, and J.R.J. Kessler. 2005b. Developmental stage influences plant response to benzyladenine. *J. Environ. Hort.* 23 (3):149-152.
- Ogawa, Y., and R.W. King. 1980. Flowering in seedlings of *Pharbitis nil* induced by benzyladenine applied under a non-inductive daylength. *Plant & Cell Physiol.* 21 (6):1109-1116.
- Ohkawa, K. 1984. Effects of benzyladenine on bud break of roses. *Scientia Horticulturae* 24 (379-383).
- Olsen, D.F., R.L. Barnes, and J.R. Barbour. 2002. *Cladrastis kentukea* (Dum.-Cours.) Rudd; yellowwood. In *Woody-Plant Seed Manual*, ed. U. F. Service: Blackburn Press.
- Pais, M.S., and H.C. Neves. 1982. Regreening of *Zantedeschia aethiopica* Spreng. spathe induced by reapplied cytokinins. *Plant Growth Regulation* 1:233-242.
- Palevitch, D., and T. H. Thomas. 1974. Thermodormancy release of celery seed by gibberellins, 6-benzylaminopurine, and ethephon applied in organic solvent to dry seeds. *Journal of Experimental Botany* 25 (88):981-986.
- Parkinson, M., and M.M. Yeoman. 1982. Graft formation in cultured explanted internodes. *New Phytol.* 91:711-719.
- Patterson, K.J. 1993. Effects of CPPU (N-(2-chloro-4-pyridyl)-N'-phenylurea) on fruit growth, maturity, and storage quality of kiwifruit. *New Zealand Journal of Crop and Horticultural Science* 21:253-261.
- Paulin, A., and K. Muloway. 1979. Perspective in the use of growth regulators to increase the cut flowers vase life. *Acta Horticulturae* 91:135-141.
- Paull, R.E., and T. Chantrachit. 2001. Benzyladenine and the vase life of tropical ornamentals. *Postharvest Biology and Technology* 21:303-310.
- Pech, J., A. Latche, and M. Bouzayen. 2004. Ethylene Biosynthesis. In *Plant hormones biosynthesis, signal transduction, action!*, ed. P. J. Davies, 750. Dordrecht ; Norwell, MA: Kluwer Academic Publishers.

- Pederson, M.K., J.D. Burton, and H.D. Coble. 2006. Effect of cyclanilide, ethephon, auxin transport inhibitors, and temperature on whole plant defoliation *Crop Sci.* 46:1666-1672.
- Persson, B. 1993. Enhancement of seed germination in ornamental plants by growth regulators infused via acetone. *Seed Sci. & Technol.* 21:281-290.
- Pharis, R.P. 1972. Flowering of *Chrysanthemum* under non-inductive long days by gibberellins and N<sup>6</sup>-benzyladenine. *Planta* 105:205-212.
- Philosoph-Hadas, S., R. Michaeli, Y. Reuveni, and S. Meir. 1996. Benzyladenine pulsing retards leaf yellowing and improves quality of goldenrod (*Solidago canadensis*) cut flowers. *Postharvest Biology and Technology* 9:65-73.
- Pierik, R.L.M., and H.H.M. Steegmans. 1975. Effect of auxins, cytokinins, gibberellins, abscisic acid and ethephon on regeneration and growth of bulbets on excised bulb scale segments of hyacinth. *Physiol. Plant.* 34:14-17.
- Pinto, A.C.R., T.J.D Rodrigues, and J.C. Barbosa. 2005. Benzyladenine sprays and senescent flowers removal on postproduction performance of potted *Zinnia* 'Profusion Cherry'. *Acta Horticulturae* 683:391-397.
- Pogna, N. E. 1979. Interaction of kinetin and day length on vernalization of winter wheat. *Cereal Res. Comm.* 7 (3):175-181.
- Pons, T.L., W. Jordi, and D. Kuiper. 2001. Acclimation of plants to light gradients in leaf canopies: Evidence for a possible role for cytokinins transported in the transpiration stream. *J. Exp. Bot.* 52 (360):1563-1574.
- Preece, J.E. 1987. Treatment of the stock plant with plant growth regulators to improve propagation success. *HortScience* 22 (5):754-759.
- Pritts, M.P., G.S. Posner, and K.A. Worden. 1986. Effects of 6-BA application on growth and development in 'Tristar', a strong day-neutral strawberry. *HortScience* 21 (6):1421-1423.
- Puchalski, J., M. Puchalska, and M. Saniewski. 1979. Glucose-6-phosphate dehydrogenase electrophoretic forms during differentiation of benzyladenine induced bulblets of *Muscari*. *Acta Horticulturae* 91:241-245.
- Puglisi, S. 2002. Use of plant growth regulators to enhance branching of *Clematis* spp. Master of Science, Department of Horticultural Science, Virginia Polytechnic Institute and State University, Blacksburg.
- Puglisi, S., H.L. Scoggins, and J.G. Latimer. 2002. Atrimmec and Fascination enhance branching of *Clematis* spp. *Proceedings of the plant growth regulation society of America* 29:186.
- Quinlan, J.D. 1978. The use of growth regulators for shaping young fruit trees. *Acta Horticulturae* 80:39-48.

- Rademacher, W. 2006. Biosynthesis of plant hormones by microorganisms. *Proceedings of the 33rd Annual Meeting of the Plant Growth Regulation Society of America*:22-23.
- Ranwala, A.P., and W.B. Miller. 2000. Ancymidol drenches, reversed greenhouse temperatures, postgreenhouse cold storage, and hormone sprays affect postharvest leaf chlorosis in Easter lily. *J. Amer. Soc. Hort. Sci.* 125 (2):248-253.
- Ranwala, A.P., and W.B. Miller. 2005. Effects of cold storage on postharvest leaf and flower quality of potted Oriental-, Asiatic-, and LA-hybrid lily cultivars *Scientia Horticulturae* 105:383-392.
- Ranwala, A.P., and W.B. Miller. 1998. Gibberellin<sub>4+7</sub>, benzyladenine, and supplemental light improve postharvest leaf and flower quality of cold-stored 'Stargazer' hybrid lilies. *J. Amer. Soc. Hort. Sci.* 123 (4):563-568.
- Rashotte, A.M., H.S. Chae, B.B. Maxwell, and J.J. Kieber. 2005. The interaction of cytokinin with other signals. *Physiol. Plant.* 123:184-194.
- Read, P.E., V.L. Herman, and P. Gavilertvatana. 1973. Controlled release growth regulators for plant growth control and rooting of cuttings. *Combined Proceedings of the International Plant Propagators' Society, 1973* 23:289.
- Reid, M.S. 1994. Ethylene in plant growth, development, and senescence. In *Plant Hormones: Physiology, Biochemistry and Molecular Biology*, ed. P. J. Davies, 486-508. Dordrecht; Boston, MA: Kluwer Academic Publishers.
- Retamales, J., F. Bangerth, T. Cooper, and R. Callejas. 1995. Effects of CPPU and GA<sub>3</sub> on fruit quality of Sultanina table grape. *Acta Horticulturae* 394:149-157.
- Rhizopon Researcher. 2008. *Transplanting rose bushes using Rhizopon AA water soluble tablets* 1992 [cited 18 October 2008]. Available from <http://www.rooting-hormones.com/transplan.htm>.
- Richards, D. 1985. Effect of cytokinin application and environment on growth and flowering of *Boronia heterophylla* F. Meull. *Scientia Horticulturae* 27:325-334.
- Richards, D., and R.I. Wilkinson. 1984. Effect of manual pinching, potting-on and cytokinins on branching and flowering of *Camellia*, *Rhododendron*, and *Rosa*. *Scientia Horticulturae* 23:75-83.
- Rogler, C.E., and W.P. Hackett. 1975. Phase change in *Hedera helix*: Induction of the mature to juvenile phase change by gibberellin A<sub>3</sub>. *Physiol. Plant.* 34:141-147.
- Roh, M.S., and Y.G. Sim. 1996. Seed germination of *Lilium x formolongi* as influenced by temperature and plant growth regulators. *Acta Horticulturae* 414:243-250.
- Rulcová, J., and J. Popišilová. 2001. Effect of benzylaminopurine on rehydration of bean plants after water stress. *Biologia Plantarum* 44 (1):75-81.

- Runkle, E. 2006. Recovering from a PGR overdose. In *Greenhouse Product News*, 78.
- Rushing, J.W. 1990. Cytokinins affect respiration, ethylene production, and chlorophyll retention of packaged broccoli florets. *HortScience* 25 (1):88-90.
- Ryan, G. F. 1974. Chemicals to increase branching of *Photinia* 'Faseri' and *Rhododendron* Exbury azaleas. *HortScience* 9 (4):534-535.
- Sachs, T., and K.V. Thimann. 1967. The role of auxins and cytokinins in the release of buds from dominance. *Amer. J. Bot.* 54 (1):136-144.
- Sakai, K., Y. Katano, and H. Higuchi. 1979. Promoting flowering in *Cyclamen persicum* by benzyladenine. *Research Bulletin of the Aichi-Ken Agricultural Research Center* 11:81-87.
- Sakakibara, H. 2004. Cytokinin biosynthesis and metabolism. In *Plant hormones biosynthesis, signal transduction, action!*, ed. P. J. Davies, 750. Dordrecht ; Norwell, MA: Kluwer Academic Publishers.
- Sakakibara, H., H. Kashara, N. Ueda, M. Kojima, K. Takei, S. Hishiyama, T. Asami, K. Okada, Y. Kamiya, T. TYamaya, and S. Yamaguchi. 2005. *Agrobacterium tumefaciens* increases cytokinin production in plastids by modifying the biosynthetic pathway in the host plant. *PNAS* 102 (28):9972-9977.
- Sammons, B., J.F. Rissler, and J.B. Shanks. 1981. Effects of growth regulators on diseases of begonia, chrysanthemum, poinsettia, and rose. *HortScience* 16 (5):673-674.
- Sanderson, K.C., W.C. Martin, and R.D. Patterson. 1987. Prepropagation dips of Acanthaceae cuttings in growth regulators to retard subsequent growth. *HortScience* 22 (2):243-244.
- Sanderson, K.C., and J.A. McGuire. 1988. Growth regulator sprays during propagation increase African violet crowns and leaves. *HortScience* 23 (6):1085.
- Saniewski, M., and K. Mynett. 1977. The formation of parrot-like flowers in benzyladenine treated bulbs of some tulip cultivars. *Acta Horticulturae* 68:151-153.
- Saunders, M.J. 1992. Cytokinin signal transduction through  $CA^{2+}$  in mosses. *Current plant science and biotechnology in agriculture* 13:65-72.
- Saxena, O.P., G. Singh, and T. Pakeeraiah. 1987. Yield of okra, tomato, and pea as affected by seed treatments and foliar sprays. *Acta Horticulturae* 215:145-151.
- Schmulling, T. 2002. New insights into the functions of cytokinins in plant development. *J. Plant Growth Regul.* 21:40-49.
- Schmulling, T., S. Schafer, and G. Romanov. 1997. Cytokinins as regulators of gene expression. *Physiol. Plant.* 100:505-519.

- Schoene, G., and T. Yeager. 2005. Effects of benzyladenine applied alone or in combination with gibberellic acid on sweet viburnum. *SNA Research Conference Proceedings* 50:119-121.
- Schrader, W.L. 2005. Effects of plant growth regulators on heat stress in annual artichoke production. *Acta Horticulturae* 681:207-208.
- Scorecard. 2008. *Chemical: Benzyladenine* 2008 [cited 18 October 2008]. Available from [http://www.scorecard.org/chemical-profiles/pesticides.tcl?edf\\_substance\\_id=1214-39-7](http://www.scorecard.org/chemical-profiles/pesticides.tcl?edf_substance_id=1214-39-7).
- Selman, I.W., and S. Sandanam. 1972. Growth responses of tomato plants in non-aerated water culture to foliar sprays of gibberellic acid and benzyladenine. *Ann. Bot.* 36:837-848.
- Semeniuk, P., and R.J. Griesbach. 1985. Bud applications of BA induces branching of a nonbranching poinsettia. *HortScience* 20 (1):120-121.
- Serek, M., and M.S. Reid. 1993. Anti-ethylene treatments for potted Christmas cactus-Efficacy of inhibitors of ethylene action and biosynthesis. *HortScience* 28 (12):1180-1181.
- Serek, M., E.J. Woltering, E.C. Sisler, S. Frello, and S. Sriskandarajah. 2006. Controlling ethylene responses in flowers at the receptor level. *Biotechnology Advances* 24 (4):368-381.
- Shafer, W.E. 1990. Sorption of the cytokinin N<sup>6</sup>-benzyladenine by leaf cuticles: prediction from n-octanol:water partition coefficients. *Physiol. Plant.* 78:43-50.
- Sharma, S.P., P. Kaur, and S.I.S. Rattan. 1995. Plant growth hormone kinetin delays ageing, prolongs the lifespan and slows down development of the fruit fly *Zaprionus parvittiger*. *Biochemical and Biophysical Research Communications* 216 (3):1067-1071.
- Shaw, G. 1994. Chemistry of adenine cytokinins. In *Cytokinins: Chemistry, Activity, and Function*, eds. D. W. S. Mok and M. C. Mok. Boca Raton, FL: CRC Press.
- Shibakusa, R. 1980. Effect of GA<sub>3</sub>, IAA, ethrel, and BA on seed germination of *Picea glehnii* Masters. *J. Jap. For. Soc.* 62:440-443.
- Shimomura, T., and K. Fujihara. 1980. Stimulation of axillary shoot formation of cuttings of *Hylocereus trigonus* (Cactaceae) by pre-soaking in benzyladenine solution. *Scientia Horticulturae* 13:289-296.
- Shudo, K. 1994. Chemistry of phenylurea cytokinins. In *Cytokinins: Chemistry, Activity and Function*, eds. D. W. S. Mok and M. C. Mok, 338. Corvallis, OR: CRC Press.
- Siemans, J., I. Keller, J. Sarx, S. Kunz, A. Schuller, W. Nagel, T. Schmulling, M. Parniske, and J. Ludwig-Miller. 2006. Transcriptome analysis of *Arabidopsis* clubroots indicate a key role for cytokinins in disease development. *Molecular Plant-Microbe Interactions* 19 (5):490-494.
- Simmonds, J.A., and B.G. Cumming. 1976. Propagation of *Lilium* hybrids I. Dependence of bulblet production on time of scale removal and growth substances. *Scientia Horticulturae* 5:77-83.

- Sindagi, S.S., and K. Puttarudrappa. 1972. Sex conversion in castor (*Ricinus communis* Lin.). *Science and Culture* 39 (9):408-410.
- Siraj-Ali, Y.S., H.K. Tayama, T.L. Prince, and S.A. Carver. 1990. The relationship between maturity level and splitting in poinsettia. *HortScience* 25 (12):1616-1618.
- Skoog, F. 1994. A personal history of cytokinin and plant hormone research. In *Cytokinins: Chemistry, Activity, and Function*, eds. D. W. S. Mok and M. C. Mok, 1-14. Boca Raton, FL: CRC Press.
- Skutnik, E., A. Lukaszewska, M. Serek, and J. Rabiza. 2001. Effect of growth regulators on postharvest characteristics of *Zantedeschia aethiopica*. *Postharvest Biology and Technology* 21:241-246.
- Smeltz, K. 1995. An alternative method of *Phalaenopsis* stem propagation. *American Orchid Society Bulletin* May 1995:496-500.
- Smigocki, A., S. Heu, and G. Buta. 1992. Cytokinins as bioregulators promote insect resistance in plants transformed with the IPT gene. *PGRSA quarterly* 29:2-7.
- Smith, D.J., and W.W. Schwab. 1980. Cytokinin activity in oak (*Quercus robur*) with particular reference to transplanting. *Physiol. Plant.* 48:27-32.
- Smith, T. 2007. *Growth Regulators for Bedding Plants*, 3/07 2007 [cited 3 November 2007]. Available from [http://www.umass.edu/umext/floriculture/fact\\_sheets/greenhouse\\_management/pgr.html](http://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/pgr.html).
- Sotomayor, C., and J. Castro. 1998. Improvement of fruit set in almonds using growth regulators. *Acta Horticulturae* 470:262-267.
- Spaulding, D.W., and G.L. Steffens. 1969. Elimination of light requirements for tobacco seed germination with gibberellic acid, indole-3-acetic acid and N<sup>6</sup> benzyladenine. *Tobacco New York* 169 (19):25-28.
- Spiro, M.D., B. Torabi, and C.N. Cornell. 2004. Cytokinins induce photomorphogenic development in dark-grown gametophytes of *Ceratopteris richardii*. *Plant Cell Physiol.* 45 (9):1252-1260.
- Sponsel, V.M., and P. Hedden. 2004. Gibberellin biosynthesis and inactivation. In *Plant hormones biosynthesis, signal transduction, action!*, ed. P. J. Davies. Dordrecht ; Norwell, MA Kluwer Academic Publishers.
- Sprecker, M.A., A.G. Morrice, G.A. Gruber, N.J. Leonard, R.Y. Schmitz, and F. Skoog. 1976. Fluorescent cytokinins: stretched-out analogs of N<sup>6</sup>-benzyladenine and N<sup>6</sup>-( $\Delta^2$ -isopentenyl) adenine. *Phytochemistry* 15:609-613.
- Srinivasan, C., and M.G. Mullins. 1981. Induction of precocious flowering in grapevine seedlings by growth regulators. *Agronomie* 1 (1):1-5.

- Stanley, A. G. 1976. The effect of 6-furfurylaminopurine (kinetin) in conjunction with Naphthaleneacetic acid on the healing of newly grafted *Camellias*. *The Camellia Review* 37 (6):34-37.
- Steinitz, B., A. Ackerman, and A. Hagiladi. 1987. Improved storability of *Pelargonium* cuttings having root primordia. *Gartenbauwissenschaft* 52 (6):266-270.
- Stern, R.A., and M.A. Flaishman. 2003. Benzyladenine effects on fruit size, fruit thinning and return yield of 'Spadona' and 'Corsica' pear. *Scientia Horticulturae* 98:499-504.
- Strong, F., F. Okamura, M. von Saltza, C. Miller, and F. Skoog. 1955. Kinetin and other substances affecting plant growth. *Plant Physiol. Supplement* 30:35.
- Styer, R.C. 2002. Using Florel effectively. *Greenhouse Product News*, October 2002, 12 (10).
- Suh, J.K. 1997. Stem elongation and flowering response of *Tulipa* cultivars as influenced by bulb cooling, growth regulators and light quality *Acta Horticulturae* 430:101-106.
- Systema, W. 1986. Post-harvest treatment of *Freesia* with silver thiosulphate and cytokinins. *Acta Horticulturae* 181:439-442.
- Tabuchi, T., A. Uesugi, A. Furukawa, M. Mariyama, and K. Toba. 2005. Anatomical studies of the leaf yellowing process on *Lilium* 'Pollyanna' following some plant growth regulators application *Acta Horticulturae* 673:717-720.
- Takahashi, H., H. Suge, and T. Saito. 1980. Sex expression as affected by N<sup>6</sup>-benzylaminopurine in staminate inflorescence of *Luffa cylindrica*. *Plant & Cell Physiol.* 21 (4):525-536.
- Tamas, I. A., W. H. R. Langridge, S. D. Abel, S. W. Crawford, J. D. Randall, J. Schell, and A. A. Szalay. 1992. Hormonal control of apical dominance. Studies in tobacco transformed with bacterial luciferase and *Agrobacterium rol* genes. In *Progress in plant growth regulation: Proceedings of the 14th international conference on plant growth substances, Amsterdam, 21-26 July, 1991 Romanov, eds. C. M. Karszen, L. C. van Loon and D. Vreugdenhil*, 418-430.
- Taniguchi, M., N. Sasaki, T. Tsuge, T. Aoyama, and A. Oka. 2007. ARR1 directly activates cytokinin response genes that encode proteins with diverse regulatory functions. *Plant Cell Physiol.* 48 (2):263-277.
- Taverner, E., D.S. Letham, J. Wang, E. Cornish, and D.A. Willcocks. 1999. Influence of ethylene on cytokinin metabolism in relation to *Petunia* corolla senescence. *Phytochemistry* 51:341-347.
- Taylor, J.S., J.M. Robertson, K.N. Harker, M.K. Bhalla, E.J. Daly, and D.W. Pearce. 1994. Apical dominance in rhizomes of quackgrass, *Elytrigia repens*: the effect of auxin, cytokinins, and abscisic acid. *Can. J. Bot.* 73:307-314.
- Teo, C.K.H., L.E. Benidixen, and R.K. Nishimoto. 1973. Bud sprouting and growth of purple nutsedge altered by benzyladenine. *Weed Science* 21 (1):19-23.

- Teo, C.K.H., and R.K. Nishimoto. 1973. Cytokinin-enhanced sprouting of purple nutsedge as a basis for control. *Weed Res.* 13:118-121.
- Thomas, J.C., A.C. Smigocki, and H.J. Bonhert. 1995. Light-induced expression of *ipt* from *Agrobacterium tumefascians* results in cytokinin accumulation and osmotic stress symptoms in transgenic tobacco. *Plant Molecular Biology* 27:225-235.
- Thomas, T.H. 1982. Historical aspects of the development. In *Plant Growth Regulator Potential and Practice*, ed. T. H. Thomas, 271. Croydon: BCPC Publications.
- Tjosvold, S.A., M.J. Wu, and M.S. Reid. 1995. Reduction of postproduction quality loss in potted miniature roses. *HortScience* 29 (4):293-294.
- Tsantili, E., K. Rekoumi, P.A. Roussos, and C. Pontikis. 2002. Effects of postharvest treatment with N<sup>6</sup>-benzyladenine on green olive fruit. *Journal of Horticultural Science & Biotechnology* 77 (3):294-299.
- Tse, A.T.Y., A. Ramina, W.P. Hackett, and R.M. Sachs. 1974. Enhanced inflorescence development in *Bougainvillea* "San Diego Red" by removal of young leaves and cytokinin treatments. *Plant Physiol.* 54:404-407.
- Tucker, D.J. 1977. Hormonal regulation of lateral bud outgrowth in the tomato. *Plant Science Letters* 8:105-111.
- Ullmann, J., J. Krekule, L. Pavlová, Z. Josefusová, J. Opatrná, F. Seidlová, and D. Soucková. 1985. Effect of two- or three-component PGR solution on the flowering of short-day plant *Chenopodium rubrum*. *Biologia Plantarum* 27 (4-5):398-401.
- Upfold, S. J., and J. Van Staden. 1992. Cytokinins in cut carnations. X. The effect of stem length and holding time on the transport and metabolism of [8-<sup>14</sup>C]6-(benzylamino)purine. *Physiol. Plant.* 86:639-647.
- Uppar, D.S., and G.N. Kulkarni. 1989. Effect of nitrogen and growth regulators on seed yield and quality in sunflower. *Seed Research* 17 (2):113-117.
- Utsunomiya, N., K. Sogawa, and K. Sasaki. 1995. Sex expression of cv. Irwin mango flowers affected by temperature, soil water stress and plant bioregulators. *Acta Horticulturae* 394:183-190.
- Van Bragh, J., H. Van Gelder, and R.L.M. Pierik. 1976. Rooting of shoot cuttings of ornamental shrubs after immersion in auxin containing solutions. *Scientia Horticulturae* 4:91-94.
- van Bragt, J., and H. van Gelder. 1979. Effects of gibberellic acid 6-benzylaminopurine, a-naphthaleneacetic acid and ethephon on growth and flowering of tulip bulbs cv. 'Apeldoorn' and their bulblets. *Acta Horticulturae* 91:161-165.
- van Doorn, W.G., J. Hibma, and J. de Wit. 1992. Effect of exogenous hormones on leaf yellowing in cut flowering branches of *Alstroemeria pelegrina* L. . *Plant Growth Regulation* 11:59-62.

- van Staden, J., and N.R. Crouch. 1996. Benzyladenine and derivatives - their significance and interconversion in plants. *Plant Growth Regulation* 19:153-175.
- van Staden, J., and J.I. Joughin. 1988. Cytokinins in cut carnation flowers . IV Effects of benzyladenine on flower longevity and the role of different longevity treatments on its transport following application to the petals. *Plant Growth Regulation* 7:117-128.
- Venkata-Rao, M., and B. Narasimham. 1977. Prolonging storage life of betel leaves. *Indian Journal of Horticulture* 34 (2):175-182.
- Verdonk, J.C., K. Shibuya, H.M. Loucas, T.A. Colquhoun, B.A. Underwood, and D.G. Clark. 2008. Flower-specific expression of the *Agrobacterium tumefaciens isopentyltransferase* gene results in radial expression of floral organs in *Petunia hybrida*. *Plant Biotechnology Journal* 6:694-701.
- Viswanath, D.P., K.M. Appaiah, S.R. Rao, and K.S.K. Sastry. 1971. Effect of pre-treatment of leaves of *Coleus blumei*, Benth. with cytokinins on amino-acid induced abscission of debladed petioles. *Current Science* 40:19-20.
- Vlahos, J.C. 1985. Effects of GA<sub>3</sub> and BA on two cultivars of *Achimenes longiflora* under two levels of irradiance. *Acta Horticulturae* 167:225-235.
- Vogelman, T.C., C.H. Bornmann, and P. Nissen. 1984. Uptake of benzyladenine in explants of *Picea abies* and *Pinus sylvestris*. *Physiol. Plant.* 61:513-517.
- Vonk, C. R., and S.A. Ribot. 1982. Assimilate distribution and the role of abscisic acid and zeatin in relation to flower-bud blasting, induced by lack of light, in *Iris* cv. Ideal. *Plant Growth Regulation* 1:93-105.
- Wakushima, S. 2004. Promotion of female strobili flowering and seed production in two Japanese pine species by 6-benzylaminopurine (BAP) paste application in a field seed orchard. *J. Plant Growth Regul.* 23 (2):135-145.
- Walker, M.A., D.R. Roberts, J.L. Waite, and E.B. Dumbroff. 1989. Relationships among cytokinins, ethylene and polyamines during the stratification-germination process in seeds of *Acer saccharum*. *Physiol. Plant.* 76:326-332.
- Wang, G., C. Li, and F. Zhang. 2003. Effects of different nitrogen forms and combination with foliar spraying with 6-benzylaminopurine on growth, transpiration, and water and potassium uptake and flow in tobacco. *Plant and Soil* 256:169-178.
- Wang, J., and V.R. Walter. 2006. Effect of vernalization and plant growth regulators on flowering of *Ornithogalum* 'Chesapeake Snowflake' *Agricultural Science & Technology - Hunan* 7 (1):23-28.
- Wang, Y.T. 1987. Effect of warm medium, light intensity, BA, and parent leaf on propagation of golden pothos. *HortScience* 22 (4):597-599.

- Wang, Y.T. 1988. Branching Agents. *Greenhouse Manager*, August 1988, 7:136-141.
- Wang, Z., W. Cao, T. Dai, and Q. Zhou. 2001. Effects of exogenous hormones on floret development and grain set in wheat. *Plant Growth Regulation* 35:225-231.
- Warr, J.C., and G.J. Keever. 2004. Response of *Hosta* to BA crown drenches applied at division and establishment. *J. Environ. Hort.* 22 (3):129-132.
- Wawrzyńczak, A., and D.M. Goszczynska. 2003. Effect of pulse treatment with exogenous cytokinins on longevity and ethylene production in cut carnations. *Journal of Fruit and Ornamental Plant Research* 11:77-88.
- Weiss, D., and N. Ori. 2007. Mechanisms of cross talk between gibberellin and other hormones. *Plant Physiol.* 144:1240-1246.
- Werbrouk, S.P.O., P. Redig, A. Van Onckelen, and P.C. Debergh. 1996. Gibberellins play a role in the interaction between imidazole fungicides and cytokinins in Araceae. *J. Plant Growth Regul.* 15:87-93.
- Werbrouk, S.P.O., B. van der Jeugt, W. Dewitte, E. Prinsen, H.A. Van Onckelen, and P.C. Debergh. 1995. The metabolism of benzyladenine in *Spathiphyllum floribundum* 'Schott Petite' in relation to acclimatisation problems. *Plant Cell Reports* 14:662-665.
- Wertheim, S. J. 2000. Developments in the chemical thinning of apple and pear. *Plant Growth Regulation* 31:85-100.
- Western Plant Growth Regulator Society. 2000. Plant growth regulators for tree crops. Paper read at 2000 Proceedings of the twelfth annual conference of the western plant growth regulator society at Sacramento, California.
- Whipker, B.E. 2007. Personal communication: Exilis Plus increases flowering of Christmas cactus if applied during floral initiation phase. Raleigh.
- Whipker, B.W. 2008. Personal communication: Configure to obtain an experimental use registration.
- Whipker, B.W., B.A. Krug, and I. McCall. 2005. Pre-plant tuber soaks of 6-benzyladenine ineffective for chemical de-eyeing of *Caladium*. *PGRSA quarterly* 33 (1):16-20.
- White, R.H., and R.E. Schmidt. 1989. Bermudagrass response to chilling temperatures as influenced by iron and benzyladenine. *Crop Sci.* 29:768-773.
- White, R.H., and R.E. Schmidt. 1990. Fall performance and post-dormancy growth of 'Midiron' bermudagrass in response to nitrogen, iron, and benzyladenine. *J. Amer. Soc. Hort. Sci.* 115 (1):57-61.
- Whitman, C.M., R.D. Heins, R. Moe, and K.A. Funnell. 2001. GA<sub>4+7</sub> plus benzyladenine reduce foliar chlorosis of *Lilium longiflorum*. *Scientia Horticulturae* 89:143-154.

- Wijeratnam, R.S.W, D. Sivakumar, and M. Abeyesekere. 1995. Post harvest treatments and refrigerated storage studies on *Dracaena marginata*. *Acta Horticulturae* 405:415-421.
- Williams, K.M., and E. Fallahi. 1999. The effects of exogenous bioregulators and environment on regular cropping of apples. *HortTechnology* 9 (3):323-327.
- Wilton, M.T., G.J. Keever, and D.J. Eakes. 1994. Offset stage of development affects *Hosta* propagation by division. *SNA Research Conference Proceedings* 39:269.
- Witaszek, W. 1989. Light and growth regulators in the cuttings production of poinsettia *Euphorbia pulcherrima* mother plants. *Acta Horticulturae* 251:315-317.
- Wittwer, S. H., and R. R. Dedolph. 1962. "Youth" hormone keeps vegetables fresh longer. *American Vegetable Grower*, 10 (3):15, 54-55.
- Wittwer, S. H., and R. R. Dedolph. 1963. Some effects of kinetin on the growth and flowering of intact green plants. *Amer. J. Bot.* 50 (4):330-336.
- Worley, R.E. 1989. Pecans show little response to low rates of GA and BA. *HortScience* 24 (1):151.
- Wright, R. D. 1975. Benzyladenine-induced growth of holly axillary buds. *SNA Research Conference Proceedings* 20:100-101.
- Xing, J., Y. Xu, J. Tian, T. Gianfagna, and B. Huang. 2007. Effects of CPPU (N-(2-chloro-4-pyridyl)-N'-phenylurea) on fruit growth, maturity, and storage quality of kiwifruit. *Proceedings of the sixteenth annual Rutgers turfgrass symposium*:18.
- Xu, Y., and B. Huang. 2007. Effects of an ethylene inhibitor and cytokinin on heat-induced leaf senescence in creeping bentgrass. *Proceedings of the sixteenth annual Rutgers turfgrass symposium*:53.
- Yamaji, K., and K. Tomioka. 1980. Effect of 9-benzyl adenine on the promotion of rooting in Kuromatsu, Japanese black pine. *J. Jap. For. Soc.* 62:425-428.
- Yamane, K., E. Kuchii, N. Fujishige, N. Minegishe, and R. Ogata. 1997. Effects of BA pretreatment on vase life, ethylene production, and soluble sugar contents in cut florets of four members of the *Cattleya* alliance. *Journal of the Japanese Society for Horticultural Science* 65 (4):801-807.
- Yang, G., and P.E. Read. 1991. Influence of plant growth regulators and season on growth responses of forced woody stems. *Acta Horticulturae* 300:173-176.
- Yates, I.E., and D. Sparks. 1992. Pecan cultivar conversion by grafting onto roots of 70 year old trees. *HortScience* 27 (7):803-807.
- Yu, J.Q. 1999. Parthenocarpy induced by N-(2-chloro-4-pyridyl)-N'-phenylurea (CPPU) prevents flower abortion in chinese white-flowered gourd (*Lagenaria leucantha*). *Environmental and Experimental Botany* 42:121-128.

- Yu, T., L. Wang, Y. Yin, F. Feng, and X. Zheng. 2008. Suppression of postharvest blue mould of apple fruit by *Cryptococcus laurentii* and N<sup>6</sup>-benzyladenine. *J. Sci. Food Agric.* 88:1266-1271.
- Yue, D., Y. Komi, and H. Imanishi. 1988. Effects of ethylene exposure on flowering of Dutch iris 'Blue Magic' grown in the open. *J. Japan. Soc. Hort. Sci.* 57 (3):481-486.
- Zabadal, T.J., and M.J. Bukovac. 2006. Effect of CPPU on fruit development of selected seedless and seeded grape cultivars. *HortScience* 41 (1):154-157.
- Zhang, H., K.J. Horgan, P.H.S. Reynolds, and P.E. Jameson. 2003. Cytokinins and bud morphology in *Pinus radiata*. *Physiol. Plant.* 117:264-269.
- Zhang, N., and H. Hasenstein. 1999. Initiation and elongation of lateral roots in *Lactuca sativa*. *Int. J. Plant Sci.* 160 (3):511-519.
- Zhang, X., J.W. White, and D.J. Beattie. 1990. The effects of photoperiod, PPF, Promalin, STS and water on flowering of asiatic lily hybrids. *Acta Horticulturae* 266:243-249.
- Zhang, X.D., D.S. Letham, R. Zhang, and T.J.V. Higgins. 1996. Expression of the isopentyl transferase gene is regulated by auxin in transgenic tobacco tissues. *Transgenic Research* 5 (57-65).
- Zheng, B., Y. Deng, J. Mu, J. Zhendong, T. Xiang, Q.W. Niu, N.H. Chua, and J. Zuo. 2006. Cytokinin affects circadian-clock oscillation in a phytochrome B- and *Arabidopsis* response regulator 4-dependent manner. *Physiol. Plant.* 127:277-292.
- Zhu, X.R., and K. Matsumoto. 1987. Absorption and translocation of 6-benzylamino purine in satsuma (*Citrus unshiu* Marc.) trees. *Journal of the Japanese Society for Horticultural Science* 56 (2):159-165.
- Zieslin, N., Y. Mor, E. Khayat, and M. Levy. 1985. The use of cytokinins for promotion of flower production in roses. *Acta Horticulturae* 167:433-434.

## **Chapter 2**

### **Benzyladenine Affects Growth of Petunia**

(In the format appropriate for submission to HortTechnology)

## **Benzyladenine Affects Growth of Petunia**

Dennis J. Carey, Brian E. Whipker<sup>1</sup>, Ingram McCall, and Wayne Buhler

Department of Horticulture Science, Box 7609, North Carolina State University, Raleigh,

NC

27695-7609

<sup>1</sup>Corresponding author.

Received for publication \_\_\_\_\_, 2008 and in revised form \_\_\_\_\_.

Use of trade names in this publication does not imply endorsement of products named nor criticism of similar ones not mentioned. Thanks to Berger Peat Moss and Fafard Co. for the root substrates, Scotts Co. for the fertilizer, Dillen Products for the pots, and Fine Americas for financial support.

Subject Category: Research Report

### **Benzyladenine Affects Growth of Petunia**

*Additional Index Words:* Benzyladenine, BA, 6-BA, BAP, 6-Benzylaminopurine, N6-Benzyladenine, Cytokinin, Ornamental Plants, Petunia, Plant growth regulators

*Abstract:* Benzyladenine (BA) was applied as a foliar spray to determine its efficacy as a growth regulator and branching agent on a non-free-branching cultivar, three free-branching cultivars, and one vigorous cultivar of petunia. Foliar spray concentrations from 10 to 160 mg•L<sup>-1</sup> were applied 14 days after planting (DAP) onto the non-free-branching cultivar. BA at 40 or 80 mg•L<sup>-1</sup> applied once increased the number of branches for the non-free branching cultivar 'Improved Charlie'. Foliar spray concentrations from 10 to 160 mg•L<sup>-1</sup> were applied 14 and 21 DAP onto the free-branching cultivars. BA at 80 or 160 mg•L<sup>-1</sup> applied twice restricted the plant width for the free branching cultivars 'Red Fox Surprise White' and 'Red Fox Surprise Blue Vein Improved'. The free-branching cultivar 'Red Fox Surprise Red' was less affected at all concentrations. On the vigorous cultivar 'Wave Purple', benzyladenine was applied as either a foliar spray, a drench, or via fertigation. Foliar sprays of BA at 80 to 120 mg•L<sup>-1</sup> were applied 1 to 4 weeks after potting (WAP) and were applied alone or in a tank mix with daminozide at 2500 or 5000 mg•L<sup>-1</sup> and paclobutrazol at 15 or 30 mg•L<sup>-1</sup>. Single drenches were made at concentrations of 1.21 to 4.84 mg ai per pot at 2 WAP. Continuous feed (Fertigation) applications were made via drip tubes at concentrations of 2 to 16 mg•L<sup>-1</sup> from 1 WAP to 4 WAP. BA treatments to 'Wave Purple' were generally ineffective for all the combinations trialed. Thus BA can be used as a PGR on some petunia cultivars at foliar spray concentrations from 80 to 160 mg•L<sup>-1</sup>, but the effective spray, drench, or

fertigation concentrations for vigorous cultivars have not been determined yet, nor have the tank mix concentrations with paclobutrazol or daminozide.

## **2.1 Introduction**

Producers want to grow petunias in high density groups which often requires that they use plant growth regulators (PGRs) to control height and width (Dole and Wilkins, 2005). From a commercial standpoint, a high quality plant is one that is not stretched, is well branched, has plentiful flowers, and is narrow enough to minimize entanglement with its neighbors when packed densely on delivery trucks. Current anti-gibberellin based PGRs can control the height of petunias, but may delay flowering and do not improve branching (Blanchard and Runkle, 2007). Plant growth regulators with other modes of action are being investigated to determine their efficacy on controlling the growth of petunias (Jeffcoat, 1977). One such PGR is benzyladenine (BA). BA is a cytokinin known to increase cell division (Hartmann et al., 2001) and favor shoot formation (Leclerc et al., 2006). BA is currently labeled for use on ornamental plants to increase branching as Configure (Fine Americas, Inc., Walnut Creek, CA). BA was used as a foliar spray and substrate drench to determine its effects on decreasing the diameter of and increasing the branching of petunia plants. The petunia cultivars that were trialed consisted of non-free-branching cultivars that formed a small number of long branches (runners) during production as well as free-branching cultivars that were well-branched. The cultivars used were either vegetatively propagated or seed propagated.

## 2.2 Materials and Methods

### 2.2.1 Experiment One

*Experiment one* examined the effect of BA on a non-free-branching vegetative petunia cultivar 'Improved Charlie'. Commercially available plugs (105 cell, with a cell size of 4 x 3 x 3.5 cm) were transplanted into 750-mL (12 cm diameter) round, plastic containers on 20 February 2003. The root substrate was Berger<sup>®</sup> BM6 (Berger Peat Moss, St. Modeste, Quebec, Canada), which contains 75 to 80% Canadian sphagnum peat and 20 to 25% perlite. Plants were fertigated with 150 mg·L<sup>-1</sup> N of Excel<sup>®</sup> 15-5-15 Cal-Mag (Scotts, Marysville, OH) (15N-2.1P-12.5K). Greenhouse temperature day/night set points were 24/18°C (75/65°F) and the plants were grown under natural day-length. BA was sprayed at concentrations of 10, 20, 40, 80, or 160 mg·L<sup>-1</sup> on 1 March using a volume of 0.5 gal / 100 ft<sup>2</sup>. Untreated controls were included. The experiment was a completely randomized design with five single-plant replications of the six treatments. Plant shoot number was recorded on 15 April.

### 2.2.2 Experiment Two

*Experiment two* examined the effect of BA on free branching vegetative petunia cultivars 'Red Fox Surprise White', 'Red Fox Surprise Red', and 'Red Fox Surprise Blue Vein Improved'. Commercially available plugs (102 hex cell, with a cell edge size of 3.2 cm and depth of 4.3 cm) of each cultivar were transplanted into 5" round plastic azalea pots on 23 February 2007. The root substrate, fertilizer, light and temperatures were the same as experiment one. BA was sprayed at concentrations of 10, 20, 40, 80, and 160 mg·L<sup>-1</sup> using a volume of 0.5 gal / 100 ft<sup>2</sup> on 9 March (2 WAP) to two complete sets of plants. On 27 March (4 WAP), one subset of plants was given a second application at the same concentrations.

Untreated controls were included. The experiment was a completely randomized design with five single-plant replications of the six treatments. Plant diameter (measured at the widest dimension, turned 90°, and averaged), and total plant height (measured from the top of the pot to the uppermost branch or flower) were recorded on 17 April (7 WAP).

### **2.2.3 Experiment Three**

*Experiment three* examined the effect of BA on a very vigorous non-free-branching petunia cultivar ‘Wave Purple’. Commercially available plugs (288 cell pack, with a square cell edge length of 1.9 cm and depth of 2.69 cm) of each cultivar were transplanted into 6” round plastic azalea pots on 4 March 2008. The root substrate was Fafard® 4P (Conrad Fafard Inc., Anderson, SC), which contains 45% peat moss and 10% perlite, 15% vermiculite, and 30% bark. Plants were fertigated with 150 mg•L<sup>-1</sup> N of Excel® 15-5-15 Cal-Mag (Scotts, Marysville, OH) (15N-2.1P-12.5K). Greenhouse temperature day/night set points were 24/18°C (75/65°F) and the plants were grown under natural day-length. The experiment was a completely randomized design with five single-plant replications for each treatment. The treatments consisted of drenches, foliar sprays with BA alone or in a tank mix with either daminozide (Dazide, Fine Americas, Inc.) or paclobutrazol (Piccolo, Fine Americas, Inc.). Both the drench and spray groups had a control group treated with water only and there were foliar spray treatment groups treated with daminozide only or paclobutrazol only. Drench applications were made on 21 March, (2 WAP) at 1.21, 2.42, 3.63 and 4.84 mg active ingredient (ai) per pot. The drench volume was 118 ml (4 fl. oz.) per pot. Foliar sprays were made with BA at 100 mg•L<sup>-1</sup> at 1 WAP, 2 WAP, 3 WAP, and 4 WAP (14 March, 21 March, 28 March, 4 April). BA foliar sprays were also made at 80, 100, or 120 mg•L<sup>-1</sup> at 2 WAP

alone or in a tank mix with 2500 or 5000 mg•L<sup>-1</sup> daminozide or with 15 or 30 mg•L<sup>-1</sup> paclobutrazol. All spray applications were applied at a volume of 0.5 gal / 100 ft<sup>2</sup>. Data were taken 6 WAP (18 April) and consisted of height, average diameter, growth index, flower size, number of runners, number of branches, and branches per runner. Any phytotoxic reactions were recorded.

#### **2.2.4 Experiment Four**

*Experiment four* examined the effect of BA applied with every irrigation through the drip tubes (fertigation) on a very vigorous non-free-branching petunia cultivar ‘Wave Purple’. Commercially available plugs (18 PowerStrip™ EZ Elle trays: 5.08 cm diameter by 5.71 cm deep) of each cultivar were transplanted into 6” round plastic azalea pots on 6 June 2008. The root substrate was Fafard® 4P. Plants were fertigated daily with 150 mg•L<sup>-1</sup> N of Excel® 15-5-15 Cal-Mag (Scotts, Marysville, OH) (15N-2.1P-12.5K). Greenhouse temperature day/night set points were 24/18°C (75/65°F) and the plants were grown under natural day-length. The experiment was a completely randomized design with four single-plant replications for each treatment. The treatments consisted of adding BA to the fertilizer tanks at concentrations of 2, 4, 8, 12, or 16 mg•L<sup>-1</sup> plus an untreated control. Treatments were started on 14 June (1 WAP). Data were recorded on 5 July (4 WAP) and consisted of height, average diameter, growth index, flower size, number of flowers, number of runners, number of branches, and branches per runner. Any phytotoxic reactions were recorded.

In experiment 1 and 2, data were tested by analysis of variance (ANOVA) using general linear model (SAS Institute, Cary, N.C.) and mean separations were done using least

significant differences (LSD) at  $P < 0.05$ . In experiments 3 and 4, mean separations were done using the Tukey algorithm at  $P < 0.05$ .

## **2.3 Results**

### **2.3.1 Experiment One**

*Experiment one:* The application of BA to ‘Improved Charlie’ resulted in darker green foliage and an increase in shoot number (Figure 2.1). With more shoots there were more flowers and the plants had an improved appearance. The  $160 \text{ mg}\cdot\text{L}^{-1}$  spray resulted in slight phytotoxicity in the form of tip chlorosis that was temporary (Figure 2.2). The number of branches produced was greatest with BA concentrations of 10 to  $80 \text{ mg}\cdot\text{L}^{-1}$  (Table 2.1). There appears to be a saturation point with ‘Improved Charlie’, because the number of shoots produced with  $160 \text{ mg}\cdot\text{L}^{-1}$  BA was similar to the untreated control.

### **2.3.2 Experiment Two**

*Experiment two:* The application of BA to ‘Red Fox Surprise White’, ‘Red Fox Surprise Red’, and ‘Red Fox Surprise Blue Vein Improved’, had cultivar specific results. The ‘Red Fox Surprise White’ and ‘Red Fox Surprise Blue Vein Improved’ cultivars had smaller average diameters (Figure 2.3). Plant height was not statistically taller (data not shown). All plants were tightly branched and well filled out. The treated plants were more cone-shaped and tighter (fewer gaps in the canopy) than the untreated controls, which were more rounded (Figure 2.4). The flowers on the treated plants were also more densely packed resulting in more attractive (tighter) plants. The use of BA on ‘Red Fox Surprise Red’ had no effect. Overall, the ‘Red Fox Surprise Red’ plants were less compact than the ‘Red Fox Surprise Blue Vein Improved’, and ‘Red Fox Surprise White’ plants. The ‘Red Fox Surprise Blue

Vein Improved' and 'Red Fox Surprise White' plants sprayed twice were narrower than plants sprayed only once. For the cultivar 'Red Fox Surprise White' the highest concentration of BA ( $160 \text{ mg}\cdot\text{L}^{-1}$ ) resulted in the narrowest diameters. For the cultivar 'Red Fox Surprise Blue Vein Improved' the most effective concentrations of BA were from 20 to  $160 \text{ mg}\cdot\text{L}^{-1}$ . The average diameters were from 6 to 28% narrower, depending on cultivar.

### **2.3.3. Experiment Three**

*Experiment three:* Most measured characteristics were not statistically significant (at  $P \leq 0.05$ ) for BA spray and drench applications on the vigorous 'Wave Purple' petunias (data not shown). There were indications ( $P$  values between 0.09 and 0.11) that increasing the concentrations and/or number of applications beyond what were tried in this experiment may control the average diameter or number of branches per runner. BA sprays at  $100 \text{ mg}\cdot\text{L}^{-1}$  applied 4 WAP were significant and inhibited the number of runners produced by 3.6 runners per plant (Table 2.2). Unfortunately, this is contrary to what is expected with a cytokinin application and does not represent an improvement in plant quality. Also, the flower size of plants sprayed at 2 WAP with  $100 \text{ mg}\cdot\text{L}^{-1}$  BA was increased from  $42.25 \text{ cm}^2$  to  $53.96 \text{ cm}^2$  (Table 2.2). The results were not significant for other spray concentrations or other spray timings. There were indications that later sprays (4 WAP) worked better than earlier sprays (1 to 3 WAP) in controlling diameter. For example, the average diameter of plants sprayed at 4 WAP was 9.5 cm less than the control and less than all of the other spray timings, but the results of the means comparisons were not statistically significant (Table 2.2). Only one drench application affected the measured characteristics. A drench application of  $4.85 \text{ mg ai}$  increased the average number of branches per plant from 17.5 to 29.2 (Table

2.3). The tank mixes of BA with daminozide or paclobutrazol were not synergistic at the concentrations trialed. There appeared to be no interaction between BA and paclobutrazol (data not shown). Benzyladenine and daminozide both affected flower size index but the interaction was not significant (data not shown). When examining the main effects of each, benzyladenine at  $80 \text{ mg}\cdot\text{L}^{-1}$  increased the flower size index by  $6.5 \text{ cm}^2$  and daminozide at  $2500 \text{ mg}\cdot\text{L}^{-1}$  inhibited the flower size index by  $6.4 \text{ cm}^2$  (Table 2.4). No phytotoxicity was noted at any concentration. These results suggest that in future experiments, higher concentrations and/or more applications may be effective at reducing width, increasing flower size, or increasing the number of runners. It also suggests that later sprays (applied during the period of rapid growth) work better than earlier sprays.

#### **2.3.4 Experiment Four**

*Experiment four:* Except for one measurement, BA fertigation applications on the vigorous ‘Wave Purple’ petunias did not control any of the measured characteristics (data not shown). The 8 and  $16 \text{ mg}\cdot\text{L}^{-1}$  treatments inhibited branch production by 10.0 and 10.5 branches per plant respectively. Unfortunately, this is contrary to what is expected with cytokinin sprays and does not represent an improvement in plant quality. No phytotoxicity was noted at any concentration so future experiments could use higher concentrations.

#### **2.4 Discussion**

BA foliar sprays were effective in controlling petunia size and increased branching, but cultivar response varied. The most effective dosages vary based on the branching nature of the petunia cultivar as well as its vigor. For ‘Cascadia Improved Charlie’, the most effective doses were at concentrations of 20 to  $80 \text{ mg}\cdot\text{L}^{-1}$ . For the free-branching cultivars the most

effective concentrations were from 80 to 160 mg•L<sup>-1</sup>. In general, BA results in narrower, tighter, more highly branched plants for cultivars ‘Cascadia Improved Charlie’, ‘Red Fox Surprise Blue Vein Improved’, and ‘Red Fox Surprise White’. These experiments provide support for the commercial use of BA as part of a size control program in commercial petunia production. Further work is required to determine suitable application concentrations and suitable PGR tank mixes. There are indications that BA sprays or drenches may affect vigorous petunia cultivars at higher concentrations or with more frequent applications. Our results show no benefits of BA fertigation applications on the growth of petunias at the concentrations trialed.

## 2.5 Literature Cited

- Blanchard, M.G., and E.S. Runkle. 2007. Dipping Bedding Plant Liners in Paclobutrazol or Uniconazole Inhibits Subsequent Stem Extension. *HortTechnology* 17 (2):178-182.
- Dole, J.M., and H.F. Wilkins. 2005. *Floriculture: Principles and Species*. 2nd ed. Upper Saddle River, NJ: Pearson, Prentice Hall.
- Hartmann, H.T., D.E. Kester, F.E. Davies, and R. Geneve. 2001. *Plant Propagation: Principles and Practices*. 7th ed: Prentice Hall.
- Jeffcoat, B. 1977. Influence of the cytokinin, 6-benzylamino-9-(tetrahydropyran-2-yl)-9H-purine, on the growth and development of some ornamental crops. *Journal of Horticultural Science* 52:143-153.
- Leclerc, M., C.D. Caldwell, and R.R. Lada. 2006. Effect of plant growth regulators on propagule formation in *Hemerocallis* spp. and *Hosta* spp. *HortScience* 41 (3):651-653.

Table 2.1 Effects of benzyladenine foliar sprays on the number of branches of non-free-branching vegetative petunia ‘Improved Charlie’.

| Concentration (mg•L <sup>-1</sup> ) | Number of branches |     |
|-------------------------------------|--------------------|-----|
| 0                                   | 10.8               | c   |
| 10                                  | 13.4               | abc |
| 20                                  | 14.0               | ab  |
| 40                                  | 16.4               | a   |
| 80                                  | 16.2               | a   |
| 160                                 | 11.8               | bc  |

Means separated using Fisher's LSD with  $\alpha=0.05$

Table 2.2 Effects of single foliar sprays of 100 mg•L<sup>-1</sup> benzyladenine on ‘Wave Purple’ petunia at four different times (Expt. 3).

| Timing              | Average Diameter (cm) | Number of runners | Flower size index (cm <sup>2</sup> ) |
|---------------------|-----------------------|-------------------|--------------------------------------|
| Control (untreated) | 68.99                 | 12.6              | 42.25                                |
| 1 WAP               | 75.65                 | 12.4              | 48.06                                |
| 2 WAP               | 63.36                 | 13.8              | 53.95*                               |
| 3 WAP               | 63.62                 | 11.8              | 39.06                                |
| 4 WAP               | 59.47                 | 9.0*              | 52.80                                |

Means followed by ‘\*’ are significantly different at the  $\alpha= 5\%$  level using Tukey pair-wise comparisons.

Table 2.3 Effects of a single drench application of benzyladenine on ‘Wave Purple’ petunia (Expt. 3).

| Concentration<br>(mg ai per pot) | Number of<br>branches |
|----------------------------------|-----------------------|
| 0                                | 17.5                  |
| 1.21                             | 18.0                  |
| 2.42                             | 18.0                  |
| 3.63                             | 18.4                  |
| 4.85                             | 29.2*                 |

Means followed by ‘\*’ are significantly different at the  $\alpha=5\%$  level using Tukey pair-wise comparisons.

Table 2.4 Main effects of a single foliar spray of a tank mix of benzyladenine (80, 120 mg•L<sup>-1</sup>) with daminozide (2500, 5000 mg•L<sup>-1</sup>) on ‘Wave Purple’ petunia (Expt. 3).

| Concentration | Flower size<br>index (cm <sup>2</sup> ) |
|---------------|---|
| BA            |   |
| 0             | 41.70                                   |
| 80            | 48.21*                                  |
| 120           | 41.50                                   |
| Dazide        |   |
| 0             | 47.21                                   |
| 80            | 40.78*                                  |
| 120           | 42.34                                   |

Means followed by ‘\*’ are significantly different at the  $\alpha=5\%$  level using Tukey pair-wise comparisons.

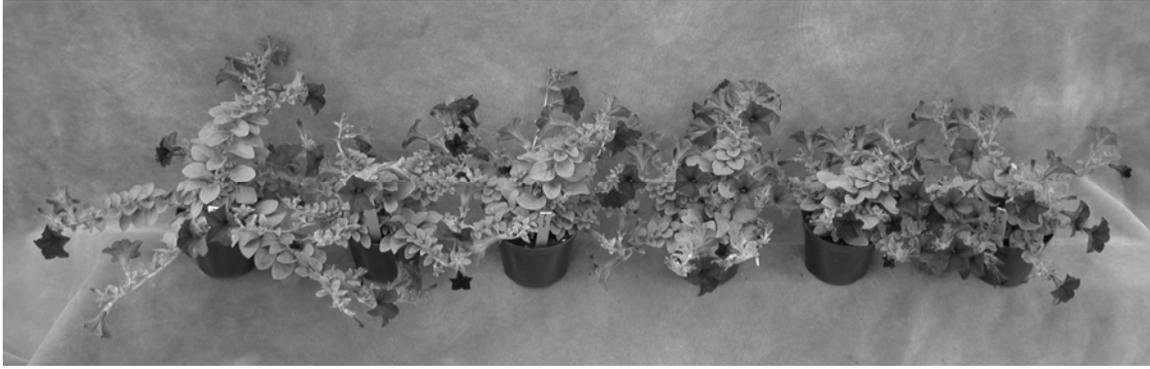


Figure 2.1 Top views of control, 10, 20, 40, 80, 160 mg·L<sup>-1</sup> benzyladenine on 'Improved Charlie' petunia.

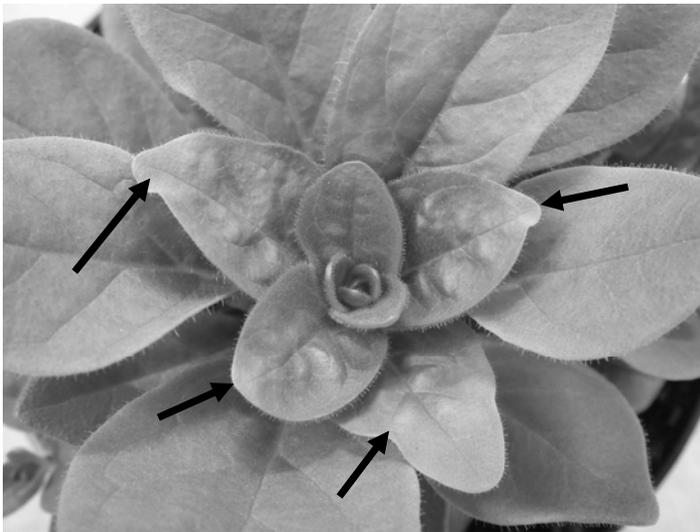


Figure 2.2 Slight phytotoxicity of 160 mg·L<sup>-1</sup> benzyladenine on 'Improved Charlie' petunia appears as yellowish spots near the leaf tips of new foliage.

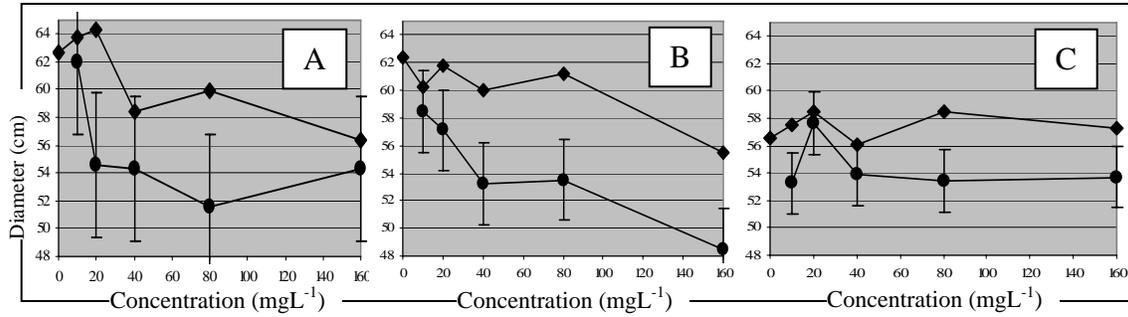


Figure 2.3 Effects of benzyladenine foliar sprays on the average diameter (cm) of vegetative petunias. One and two foliar sprays onto ‘Red Fox Surprise Blue Vein Improved’ (A), ‘Red Fox Surprise White’ (B), and ‘Red Fox Surprise Red’ (C). ♦ - Single foliar spray • - Two foliar sprays. Error bars shown for two foliar sprays only.

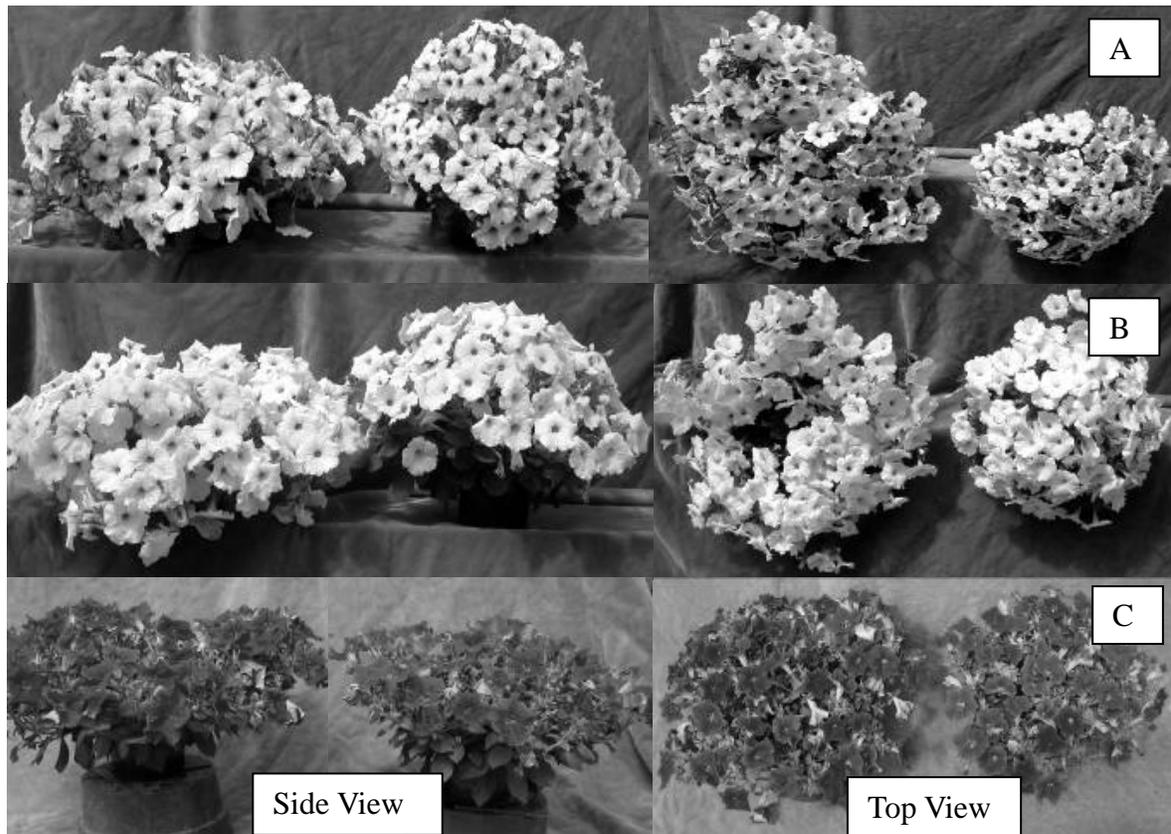


Figure 2.4. Side and top views of control plants and 2 spray applications of  $160 \text{ mg}\cdot\text{L}^{-1}$  benzyladenine on ‘Red Fox Surprise Blue Vein Improved’ (A), ‘Red Fox Surprise White’ (B), and ‘Red Fox Surprise Red’ (C) petunias.

## **Chapter 3**

### **The Effect of Benzyladenine Foliar Sprays on Offsetting of Succulents**

(In the format appropriate for submission to HortTechnology)

## **The Effect of Benzyladenine Foliar Sprays on Offsetting of Succulents**

Dennis J. Carey, Brian E. Whipker<sup>1</sup>, Ingram McCall, and Wayne Buhler

Department of Horticulture Science, Box 7609, North Carolina State University, Raleigh,

NC

27695-7609

<sup>1</sup>Corresponding author.

Received for publication \_\_\_\_\_, 2008 and in revised form \_\_\_\_\_.

Use of trade names in this publication does not imply endorsement of products named nor criticism of similar ones not mentioned. Thanks to Berger Peat Moss for the root substrates, Scotts Co. for the fertilizer, Dillen Products for the pots, and Fine Americas for financial support.

### **The Effect of Benzyladenine Foliar Sprays on Offsetting of Succulents**

*Additional Index Words:* BAP, 6-BA, 6-Benzylaminopurine, N6-Benzyladenine, Cytokinin, Hens and Chicks, Plant Growth Regulator, PGR

*Abstract:* Benzyladenine (BA) was applied as a foliar spray to three cultivars of *Aloe*, three cultivars of *Agave*, one cultivar each of *Aeonium*, *Jovibarba*, *Euphorbia suzannae*, *Echeveria setosa*, and seven cultivars of *Sempervivum* to determine if it increased offset number. A single foliar spray at concentrations from 50 to 1600 mg•L<sup>-1</sup> was applied 4 to 6 weeks after potting (WAP) onto the plants. The *Agaves* and *Aloes* received a second foliar spray at 10 WAP at the same concentrations. BA increased the number of offsets in *Sempervivum* cultivars ‘Green Wheel’, ‘Red Heart’, ‘Rubicon Improved’, ‘Dark Cloud’, and the species *S. cantabricum* × *montanum* var. *striatum*. BA also increased the number of offsets in *Jovibarba* cultivar ‘Emerald Spring’ and in *Echeveria setosa*. However, BA did not increase the number of offsets in *Aeonium* ‘Kiwi’, *Agave* cultivars ‘Lago Lindo’, ‘Blue Glow’, ‘Rasta Man’, *Aloe* cultivars ‘Pink Blush’, ‘Grassy Lassie’, ‘Midnight’, *Euphorbia suzannae*, or *Sempervivum* cultivars ‘Neptune’, and ‘Red Devils Food’. The ideal concentration for offset production varied for each cultivar. In addition, BA increased the inflorescence number on *Echeveria setosa* and *Aloe* ‘Grassy Lassie’. Thus, benzyladenine may be used to increase the number of offsets of *Sempervivum*, *Echeveria* and *Jovibarba* to increase the number of propagules or to improve the retail appearance of the plant. The increased number of offsets can be used as propagation material or can improve the retail quality of the plant.

### **3.1 Introduction**

Many succulents produce offsets that may be harvested and used for propagation (Winterwood, 2005). The offsets form at the end of short stolons or grow directly off of the crown of the parent plant. The offsets may or may not have roots on them at harvest. These offsets can be used as propagules in a manner similar to taking a stem cutting or dividing a perennial. Growers who propagate succulents this way are limited by the number of offsets produced by the parent plant. Cytokinins are known to induce branching in succulent plants such as *Sedum* (Boe et al., 1972), *Opuntia* (White et al., 1978; Nobel, 1996), *Hylocereus* (Shimomura and Fujihara, 1980) and holiday cactus (Boyle, 1992; Boyle et al., 1988; Yonemura and Higuchi, 1978; Yonemura, 1979; Ho et al., 1985). The primary objective of this experiment was to determine if benzyladenine (Configure, Fine Americas, Inc., Walnut Creek, CA), a cytokinin-based plant growth regulator (PGR), applied as a foliar spray, would increase the number of offsets produced. Other researchers have noted that cytokinin applications onto stock plants may hinder the ability of the propagules to form roots (Preece, 1987). Thus a second objective of this experiment was to determine if benzyladenine altered the rooting ability of *Sempervivum* offsets. Cytokinins have also been reported to alter the flowering habit of some succulents (Khaimov and Mizrahi, 2006) and so the plants were observed to determine if flowering was affected.

### **3.2 Materials and Methods**

#### **3.2.1 Experiment One**

*Sempervivum* plants were received as plugs in 102 count hex trays (3.2 cm hex x 4.4 cm deep). On 8 March, 2007, *Sempervivum* cultivars ‘Red Heart’ and ‘Green Wheel’ were placed in 11 cm round [575 ml volume (4 inch)] pots in a peat-based substrate (Berger BM6

- Berger Peat Moss, St. Modeste, Quebec, Canada), containing 75 to 80% Canadian sphagnum peat and 20 to 25% perlite. *Echeveria setosa* plants were received in 4" square pots. Plants were hand irrigated with clear water or with weekly fertilizations of 150 mg•L<sup>-1</sup> N of Excel<sup>®</sup> 15-5-15 Cal-Mag (Scotts, Marysville, OH) (15N-2.1P-12.5K). Greenhouse temperature day/night set points were 24/18°C (75/65°F) and the plants were grown under natural day length. On 30 March, 2007 (4 WAP), foliar sprays consisting of BA at concentrations of 50, 100, 200, or 400 mg•L<sup>-1</sup> were applied using a volume of 0.5 gal per 100 sq. ft using a hand pump sprayer. The experiment was a completely randomized design with six single plant replications. On 20 May (8 WAP), the offsets were counted. In addition, the number of flower stalks on the *Echeveria setosa* plants was counted on 5 July (14 WAP). Data were tested by analysis of variance using the generalized linear model (PROC GLM) of SAS (SAS Institute, Cary, NC). Means were separated by pair-wise testing using Fisher's least significant differences (LSD) at  $P < 0.05$ .

Next, *Sempervivum* 'Green Wheel' offsets were rooted to determine if treating the parent plant with BA affected rooting of the offset. On 12 July (15 WAP), mid-sized offsets were harvested off of parent plants from each BA treatment, and placed into 1203 cell packs [a 36 cell flat, (8 x 4 x 5.5 cm cells)] filled with Berger BM6 substrate. They were grown in similar conditions as the parent plants. The experiment was a completely randomized design with six single plant replications. On 27 September, 10 weeks after harvesting, the rooting success of the offsets was recorded. Plants were removed from the cell packs and the roots were washed. Due to the fragile nature of the roots, they could not be completely cleaned

and weighed. Instead, root quality was determined on a qualitative scale of 0-3 with 0 being dead, 1 having a root ball less than the height of the offset (minimal), 2 having a root ball 1 to 2 times the height of the offset (average), or 3 having a root ball more than 2 times the height of the offset (good). Data were tested by analysis of variance (ANOVA) as above.

### **3.2.2 Experiment Two**

Hybrid *Aeonium* 'Kiwi' plants were received as plugs in 50 count cell packs (round cells 3.49 cm in diameter and 4.44 cm deep). On 26 March, 2008 they were potted into 12.7 cm round [766 ml volume (5 inch)] pots in a peat-based substrate (Berger BM6). Plants were hand irrigated with clear water or with weekly fertilizations of 150 mg•L<sup>-1</sup> N of Excel<sup>®</sup> 15-5-15 Cal-Mag (15N-2.1P-12.5K). Greenhouse temperature day/night set points were 24/18°C (75/65°F) and the plants were grown under natural day length. Plants were sprayed on 9 April (2 WAP) with BA at concentrations of 100, 200, 400, 600, or 800 mg•L<sup>-1</sup>. An untreated control was also included. The experiment was a completely randomized design with six single plant replications. On 13 May (7 WAP) offsets were counted and plant height and width were measured. Data were tested by analysis of variance (ANOVA) as above.

### **3.2.3 Experiment Three**

*Agave* hybrid cultivars 'Blue Glow', 'Rasta Man' (with a low offsetting ability), and 'Lago Lindo' (with a high offsetting ability), were selected. *Aloe gastrolea* 'Midnight' and *Aloe* hybrid cultivars 'Pink Blush' and 'Grassy Lassie' were selected because they represent cultivars with low-, medium-, and high-offsetting ability, respectively. The plugs were received in 84 count trays (round cells 3.17 cm diameter and 4.44 cm deep) and were potted on 9 April 2008 into 15.24 cm round [1.29 liter volume (6 inch)] azalea pots in a peat-based

substrate (Berger BM6). Plants were hand irrigated with clear water or with weekly fertilizations of 150 mg•L<sup>-1</sup> N of Excel<sup>®</sup> 15-5-15 Cal-Mag (15N-2.1P-12.5K). Greenhouse temperature day/night set points were 24/18°C (75/65°F) and the plants were grown under natural day length. Plants were sprayed on 24 May (6 WAP) with BA at concentrations of 50, 100, 200, 400, 800, 1600 mg•L<sup>-1</sup>. The experiment was a completely randomized design with five single plant replications. The number of offsets was counted on 25 June (10 WAP) and the plants were sprayed a second time with the same concentrations. The offset number was counted again on 28 July (14 WAP) and 7 Sep (19 WAP). At 19 WAP, the number of flower stalks was counted on *Aloe* 'Grassy Lassie'. Data were tested by analysis of variance (ANOVA) as above.

#### **3.2.4 Experiment Four**

As a follow-up to experiment one, five additional *Sempervivum* cultivars, one cultivar of a closely related genus *Jovibarba*, and an unrelated plant *Euphorbia suzannae* were selected to determine if they produced offsets in response to BA sprays. The *Sempervivum* cultivars were 'Dark Cloud', 'Neptune', 'Red Devils Food', 'Rubicon Improved' and hybrid species *Sempervivum cantabricum* × *montanum* var. *striacum*. The *Jovibarba hirta* cultivar selected was 'Emerald Spring'. Newly harvested offsets of *Sempervivum* and *Jovibarba* were purchased bare-root. Offsets of *Euphorbia suzannae* plants were harvested in the fall of 2007 and rooted in 1203 cell packs during the winter. All of the plants were potted on 21 April 2008 into 1801 cell packs in a peat-based substrate (Berger BM6). Plants were hand irrigated with clear water or with weekly fertilizations of 150 mg•L<sup>-1</sup> N of Excel<sup>®</sup> 15-5-15 Cal-Mag (15N-2.1P-12.5K). Greenhouse temperature day/night set points were 24/18°C

(75/65°F) and the plants were grown under natural day length. Plants were sprayed on 23 May (4 WAP) with BA at concentrations of 50, 100, 200, 300, 400, 600, 800, 1200, and 1600 mg•L<sup>-1</sup>. The experiment was a completely randomized design with five single plant replications. The number of offsets was counted on 23 June (8 WAP). Data were tested by analysis of variance (ANOVA) as above.

### 3.3 Results

#### 3.3.1 Experiment One

*Echeveria setosa*, *Sempervivum* ‘Green Wheel’, and *S.* ‘Red Heart’ all responded to increasing BA concentrations by producing more offsets (Table 3.1). The effective concentrations for *Sempervivum* ‘Red Heart’ was 50 to 400 mg•L<sup>-1</sup>. The effective concentrations for the other two cultivars was 200 to 400 mg•L<sup>-1</sup>. In general, as the number of offsets produced increased, the size of the offsets appeared to be smaller (data not measured)(Figure 3.1). *Sempervivum* ‘Red Heart’ produced 71% more offsets than the control at 400 mg•L<sup>-1</sup> BA. *Sempervivum* ‘Green Wheel’ produced an average of 324% more offsets than the control with 400 mg•L<sup>-1</sup> BA. *Echeveria setosa* produced 222% more offsets than the control with 400 mg•L<sup>-1</sup> BA. Additionally, the *Echeveria setosa* plants produced more flower stalks than the control with BA concentrations of 200 and 400 mg•L<sup>-1</sup> (Table 3.2).

Applying BA to *Sempervivum* ‘Green Wheel’ parent plant did not affect the root quality of the offsets (Table 3.4). However, as the number of offsets increased the offset size was smaller (data not measured). Offsets that were below 1 cm in diameter did not root well

regardless if BA was applied to the parent plant (Table 3.3). Offsets greater than 1 cm in diameter from BA treated parent plants had similar root quality ratings as the control (Table 3.4).

### **3.3.2 Experiment Two**

*Aeonium* ‘Kiwi’ did not respond to BA sprays for any of the traits that were measured (data not shown). The p-value for the number of offsets was 0.0708 which was just outside of the cutoff value of 0.05. This is an indication that BA may affect the number of offsets if applied at higher concentrations than the  $800 \text{ mg}\cdot\text{L}^{-1}$  used, or with more applications, or with altered application timings. Further research should be done to confirm if BA can alter the number of offsets of *Aeonium*.

### **3.3.3 Experiment Three**

None of the *Agave* or *Aloe* hybrids produced more offsets in response to BA sprays (data not shown). It is possible that the concentrations trialed were too low, or that multiple applications were needed, or that the plants were not physiologically responsive to the BA treatments at the time of application. However, *Aloe* cultivar ‘Grassy Lassie’ did produce more flower stalks with increasing concentrations of BA. It appears that the ideal concentration to effect flowering is between  $200$  and  $400 \text{ mg}\cdot\text{L}^{-1}$  (Table 3.5).

### **3.3.4 Experiment Four**

Three of the five *Sempervivum* cultivars and the *Jovibarba* cultivar responded to BA by producing more offsets (Table 3.6). The *Sempervivum* cultivars ‘Neptune’ and ‘Red Devils Food’ did not produce a larger number of offsets per plant. The *Euphorbia suzannae* plants had an increase in the average number of offsets per plant with increasing BA concentration,

but the results were significant at a p-value of 0.0750. The p-value was low enough to suggest that further testing with different concentrations, repetitions or timings may provide significant results. The effective concentrations varied by cultivar. BA at 400 mg•L<sup>-1</sup> was optimal for *Sempervivum* cultivars ‘Dark Cloud’, ‘Rubicon Improved’, and the species *Sempervivum cantabricum* × *montanum* var. *striatum*. Using higher concentrations than 400 mg•L<sup>-1</sup> on these cultivars resulted in fewer offsets. *Jovibarba* produced the highest number of offsets at 1600 mg•L<sup>-1</sup>.

### 3.4 Discussion

Given the level of activity of BA in these experiments, it can be used to increase the productivity of stock plants of most *Sempervivum* cultivars, *Jovibarba* and *Echeveria setosa*. The cost of using BA is less than the value of the additional offsets, so there is an economic benefit. The offsets collected from the *Sempervivum* parent plants rooted normally and were not negatively affected by BA sprays to the parent plants. In general, 400 mg•L<sup>-1</sup> was an optimal concentration for increasing offsets in these plants, but there were cultivar differences. Growers who use this technique will want to strike a balance between increasing the number of offsets and producing too many small offsets. If growers wanted to harvest offsets over a period of time instead of all at once, they may want to maximize offset production by treating the stock plants with higher concentrations ( $\geq 400$  mg•L<sup>-1</sup>) of BA. Then they could harvest the largest offsets, wait a few weeks and harvest the remainder. If the grower wants to harvest offsets all at once, then lower concentrations are recommended ( $\leq 400$  mg•L<sup>-1</sup>). BA was ineffective at increasing the offsets of *Aeonium*, *Aloe* cultivars, *Agave* cultivars, *Euphorbia suzannae* as well as *Sempervivum* cultivars ‘Neptune’ and ‘Red

Devils Food'. Further research should be done to determine if higher concentrations, more applications or alternate spray timings are needed to affect these plants. BA ( $\geq 200 \text{ mg}\cdot\text{L}^{-1}$ ) increased the number of flower stalks in *Echeveria setosa* and *Aloe* 'Grassy Lassie', thus BA can be used as an enhancer of flowering.

### 3.5 Literature Cited

- Boe, A.A., R.B. Stewart, and T.J. Banko. 1972. Effects of growth regulators on root and shoot development on sedum leaf cuttings. *HortScience* 7 (4):404-405.
- Boyle, T.H. 1992. Modification of plant architecture in 'Crimson Giant' Easter cactus with benzyladenine. *J. Amer. Soc. Hort. Sci.* 117 (4):584-589.
- Boyle, T.H., D.J. Jacques, and D.P. Stimart. 1988. Influence of photoperiod and growth regulators on flowering of *Rhipsalidopsis gaertneri*. *J. Amer. Soc. Hort. Sci.* 113 (1):75-78.
- Ho, Y.S., K.C. Sanderson, and J.C. Williams. 1985. Effect of chemicals and photoperiod on the growth and flowering of Thanksgiving cactus. *J. Amer. Soc. Hort. Sci.* 110 (5):658-662.
- Khaimov, A., and Y. Mizrahi. 2006. Effects of day-length, radiation, flower thinning and growth regulators on flowering of the vine cacti *Hylocereus undatus* and *Selenicereus megalanthus*. *Journal of Horticultural Science & Biotechnology* 81 (3):465-470.
- Nobel, P.S. 1996. Shading, osmoticum, and hormone effects on organ development for detached cladodes of *Opuntia ficus-indica*. *Int. J. Plant Sci.* 157 (6):722-728.
- Preece, J.E. 1987. Treatment of the stock plant with plant growth regulators to improve propagation success. *HortScience* 22 (5):754-759.
- Shimomura, T., and K. Fujihara. 1980. Stimulation of axillary shoot formation of cuttings of *Hylocereus trigonus* (Cactaceae) by pre-soaking in benzyladenine solution. *Scientia Horticulturae* 13:289-296.
- White, J.W., C. Allen, M. Easley, and P. Strock. 1978. Effects of growth regulants on *Opuntia basilaris*. *HortScience* 13 (2):181-182.
- Winterwood, W. 2005. Raising Hens and Chickens. *Horticulture*, 102 (1):32-36.
- Yonemura, K. 1979. Studies on the control of flowering in Christmas cactus. *Aichi-ken Nogyo Sogo Shikenjo tokubetsu hokoku*:1-35.

Yonemura, K., and H. Higuchi. 1978. The control of flowering in Christmas cactus V. *Res. Bull. Aichi Agric. Res. Centr.* 10:30-35.

Table 3.1. The effects of benzyladenine spray concentration on the number of offsets produced by *Sempervivum* ‘Red Heart’, *Sempervivum* ‘Green Wheel’ and *Echeveria setosa* (Expt. 1).

| Plant                      | BA (mg•L <sup>-1</sup> ) |         |         |         |         |
|----------------------------|--------------------------|---------|---------|---------|---------|
|                            | 0                        | 50      | 100     | 200     | 400     |
|                            | Number of offsets        |         |         |         |         |
| <i>Echeveria setosa</i>    | 1.50 a                   | 1.67 a  | 1.50 a  | 3.67 b  | 4.83 b  |
| <i>Semp.</i> ‘Green Wheel’ | 7.50 a                   | 7.17 a  | 9.50 a  | 21.00 b | 31.83 c |
| <i>Semp.</i> ‘Red Heart’   | 12.83 a                  | 14.60 b | 15.50 b | 16.00 b | 22.00 c |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD and are listed by row.

Table 3.2. The effects of benzyladenine spray concentration on the average number of flower stalks per plant on *Echeveria setosa* at 14 WAP (Expt. 1).

| Plant                   | BA (mg•L <sup>-1</sup> )          |        |        |        |        |
|-------------------------|-----------------------------------|--------|--------|--------|--------|
|                         | 0                                 | 50     | 100    | 200    | 400    |
|                         | Number of flower stalks per plant |        |        |        |        |
| <i>Echeveria setosa</i> | 0.17 a                            | 0.00 a | 0.33 a | 1.17 b | 1.33 b |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD.

Table 3.3. The rooting quality of *Sempervivum* ‘Green Wheel’ as a function of offset size at harvesting (Expt. 1).

| Size (diameter) | Root Quality |
|-----------------|--------------|
| < 0.5 cm        | 1.5 a        |
| 0.5 to 0.99 cm  | 1.3 a        |
| 1.0 to 1.49 cm  | 2.6 b        |
| 1.5 to 1.99 cm  | 2.5 b        |
| 2.0 to 2.49 cm  | 2.5 b        |
| > 2.5 cm        | 3.0 b        |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD.

Table 3.4. The rooting quality of *Sempervivum* ‘Green Wheel’ offsets, greater than 1 cm in diameter, whose parent plants were treated with benzyladenine (BA) (Expt. 1).

| BA Concentration                | Rooting Quality |
|---------------------------------|-----------------|
| Control (0 mg•L <sup>-1</sup> ) | 2.45 a          |
| 50 mg•L <sup>-1</sup>           | 2.67 a          |
| 100 mg•L <sup>-1</sup>          | 2.50 a          |
| 200 mg•L <sup>-1</sup>          | 2.67 a          |
| 400 mg•L <sup>-1</sup>          | 2.33 a          |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD.

Table 3.5. The effects of benzyladenine (BA) spray concentration on the average number of flower stalks per plant produced by *Aloe* cultivar ‘Grassy Lassie’ (Expt. 3).

| Plant                       | BA (mg•L <sup>-1</sup> )          |       |       |        |        |
|-----------------------------|-----------------------------------|-------|-------|--------|--------|
|                             | 0                                 | 200   | 400   | 800    | 1600   |
|                             | Number of flower stalks per plant |       |       |        |        |
| <i>Aloe</i> ‘Grassy Lassie’ | 0.6 a                             | 2.0 b | 2.2 b | 0.8 ca | 1.6 bc |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD.

Table 3.6. The effects of benzyladenine spray concentration on the number of offsets produced by *Sempervivum*, *Jovibarba* and *Euphorbia suzannae* (Expt. 4).

| Plant  | BA (mg•L <sup>-1</sup> )    |      |        |       |         |        |        |        |       |        |
|--|-----------------------------|------|--------|-------|---------|--------|--------|--------|-------|--------|
|  | 0                           | 50   | 100    | 200   | 300     | 400    | 600    | 800    | 1200  | 1600   |
|  | Number of offsets per plant |      |        |       |         |        |        |        |       |        |
| <i>Euphorbia suzannae</i>  | 4.2                         | 5.2  | 8      | 10.8  | 14.6    | 10.6   | --     | 14.2   | --    | --     |
| <i>Jov.</i> ‘Emerald Spring’   | 8.0                         | 11.0 | 10.8   | 10.4  | 9.8     | 13.4 * | 18.6 * | 11.0   | 12.0  | 19.6 * |
| <i>Semp. cantabricum</i><br><i>×montanum</i><br><i>var. striacum</i> | 2.0                         | 2.4  | 7.8 *  | 6.6   | 14.0 *  | 15.4 * | 8.4 *  | 12.2 * | --    | --     |
| <i>Semp.</i> ‘Dark Cloud’  | 2.6                         | 5.2  | 10.0 * | 9.4 * | 10.0 *  | 12.4 * | --     | 8.6 *  | --    | --     |
| <i>Semp.</i> ‘Neptune’   | 3.6                         | 2.4  | 3.4    | 2.8   | 6       | 6.2    | 6.8    | 5.8    | --    | --     |
| <i>Semp.</i><br>‘Red Devils Food’                                    | 4.0                         | 3.0  | 2.4    | 3.4   | 4.6     | 4.4    | --     | 4.2    | --    | --     |
| <i>Semp.</i><br>‘Rubicon Improved’                                   | 1.0                         | 0.6  | 6.7 *  | 7.8 * | 11.25 * | 12.4 * | 9.75 * | 8.6 *  | 6.8 * | 9.0 *  |

-- : The cultivar was not tested at this concentration.

Means followed by a ‘\*’ are significantly different from the control group of that cultivar at the  $\alpha=5\%$  level and are listed by row.

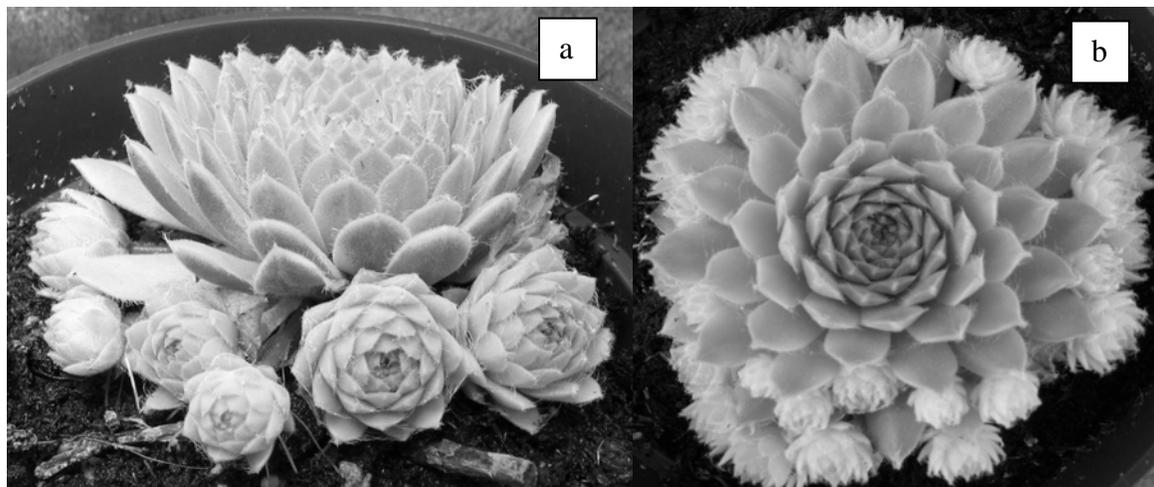


Figure 3.1. Comparison of *Sempervivum* 'Green Wheel' at benzyladenine concentrations of 0 (a) and 400 (b) ( $\text{mg}\cdot\text{L}^{-1}$ ) highlighting the difference in the size of the offsets (Expt. 1).

## **Chapter 4**

### **Peony Rhizome Soaks in Benzyladenine Reduce Dormancy**

(In the format appropriate for submission to HortTechnology)

## **Peony Rhizome Soaks in Benzyladenine Reduce Dormancy**

Dennis J. Carey, Brian E. Whipker<sup>1</sup>, Ingram McCall, and Wayne Buhler

Department of Horticulture Science, Box 7609, North Carolina State University, Raleigh,

NC

27695-7609

<sup>1</sup>Corresponding author.

Received for publication \_\_\_\_\_, 2008 and in revised form \_\_\_\_\_.

Use of trade names in this publication does not imply endorsement of products named nor criticism of similar ones not mentioned. Thanks to Fafard Co. for the root substrates, Scotts Co. for the fertilizer, Dillen Products for the pots, and Fine Americas for financial support.

## **Peony Rhizome Soaks in Benzyladenine Reduce Dormancy**

*Additional Index Words.* BA, BAP, 6-BA, 6-Benzylaminopurine, N6-Benzyladenine, Configure, Cytokinin, *Paeonia*, PGR

*Abstract:* Benzyladenine (BA) was applied as a 1 hour rhizome soak to Peony ‘Karl Rosenfield’ in autumn at concentrations of 0, 200, 400, 800, and 1600 mg•L<sup>-1</sup>. Rhizomes were potted and grown outdoors in Raleigh, North Carolina during the winter. In the spring, the date of emergence of the buds was analyzed to determine if BA reduced dormancy. BA did not increase the number of buds that emerged, nor did BA effect the date of emergence of the first buds on the plant. However, BA at 400 mg•L<sup>-1</sup> did reduce the number of days to the emergence of the last bud, accelerating bud emergence by 35 days over the untreated control.

### **4.1 Introduction**

Commercial peony growers use environmental techniques to manipulate the emergence, growth and flowering of the plants. These techniques include artificial chilling and warming of the rhizomes and chemical applications. Peonies require exposure to cold temperatures of around 1 to 3°C for 4 to 10 weeks in order to break dormancy in the spring (Evans et al. 1990; Halevy et al. 2004). The actual number of chill units required depends on the cultivar. Following the cold treatment, warm temperatures stimulate growth and flowering. Peonies will grow throughout the summer and go dormant again in late fall. The flower buds for the following year are produced in late summer and lie dormant until the following spring (Kamenetsky et al. 2007). Manipulating growth with temperature can be expensive to do on

a commercial scale, so various chemicals have been applied to peonies to determine if they affect emergence or flowering. Gibberellin (GA) advances flowering in pre-chilled peonies (Halevy et al. 2004) and breaks dormancy of un-chilled peonies (Evans et al. 1990).

Benzyladenine (BA) and BA+GA breaks epicotyl dormancy in tissue cultured peonies (Buchheim et al. 1994). For this experiment, BA was applied as a rhizome soak to Peony 'Karl Rosenfield' grown outdoors using commercial techniques to determine if it increased offset production or interrupted dormancy of peonies.

#### **4.2 Materials and Methods**

Peony cultivar 'Karl Rosenfield' was selected because it has a short cold requirement and is commonly grown in North Carolina. Rhizomes arrived on 15 November 2007 and were stored in a cooler at 5° C (41°F) until 19 November. The number of buds (eyes) varied between 2 to 16 per rhizome with an average of 6.6. One gallon solutions of BA (Configure, Fine Americas, Walnut Creek, CA) were made at concentrations of 200, 400, 800, and 1600 mg•L<sup>-1</sup>. An untreated control (tap water) was also included. Rhizomes were soaked for 1 hour in the solutions on and allowed to air dry over night. Rhizomes were planted into 25.24 cm round [7.57 liters ml volume (10 inch)] decorative containers with Fafard<sup>®</sup> 4P substrate (Conrad Fafard Inc., Anderson, SC), which contained 45% peat moss, 10% perlite, 15% vermiculite, and 30% bark. Rhizomes were placed so that the dormant buds (eyes) were 3.75 to 5 cm (1.5 to 2") below the substrate surface. Plants were hand irrigated with clear water as needed and were provided 28.3 g (1 ounce) of a controlled release fertilizer (Osmocote Standard 14-14-14, 3 to 4 month release – Scotts, Marysville, OH) on 28 February. The pots were placed outdoors on the ground in between hoop houses and were protected with plastic

sheeting whenever the night temperatures fell below  $-3^{\circ}\text{C}$  ( $26^{\circ}\text{F}$ ). Plants were grown under natural temperatures and day-length at the North Carolina State University Horticulture Field Laboratory in Raleigh, North Carolina ( $35^{\circ} 47'$  north latitude). Plants were monitored for shoot emergence and each shoot was marked as it emerged and the date of emergence was recorded. The experiment was a completely randomized design with six single plant replications for each treatment level. The experiment was terminated on 1 May 2008. The number of shoots per plant and the date of emergence of each shoot were analyzed to determine differences. Data were tested by analysis of variance using the generalized linear model (PROC GLM) of SAS (SAS Institute, Cary, NC). Means were separated by pair-wise testing using Fisher's least significant differences (LSD) at  $P < 0.05$ .

#### **4.3 Results**

A mean of 4.85 shoots emerged from each rhizome. BA treatments did not affect the mean (data not shown). Also, BA did not accelerate the emergence (break dormancy) of the first shoots on the plants. However, BA at  $400 \text{ mg}\cdot\text{L}^{-1}$  did hasten the time it took for the last shoots to emerge (Table 4.1). Thus the plants did not start emerging from dormancy any faster with BA at  $400 \text{ mg}\cdot\text{L}^{-1}$ , but they finished emerging more quickly. The concentration response was not linear and the highest concentrations of BA had emergence dates similar to the control. The optimal concentration of  $400 \text{ mg}\cdot\text{L}^{-1}$  advanced the emergence of the last bud on the plants by an average of 35 days over the untreated control.

#### **4.4 Discussion**

It is not particularly surprising that BA did not increase the number of buds to emerge from the rhizomes, because the spring buds had already formed by the time the rhizomes were

treated. Commercial peony growers often wait to sell potted plants until they have reached some minimum size. BA can be used to help peonies reach minimum sales size more quickly and in a more economical manner than by manipulating greenhouse temperatures (Figure 4.1). Further research into this area should look at the effect of BA on a wider range of cultivars as it has been for *Hosta* (Garner et al. 1997a, 1997b). It may be possible that BA could allow southern growers to produce northern high-chill cultivars in outdoor production by replacing some of the chilling hours. Also, different application timings and number of applications should be examined to determine if the results of this experiment can be improved (Garner et al. 1998; Schultz et al. 2000). BA+GA combinations should be examined to determine their effect on date of emergence. BA or BA+GA applications should be applied to peonies in late summer when they are producing next year's buds to see if the number of eyes can be increased. If successful, it would provide an inexpensive way for propagators to increase the value of their peony rhizomes as the price of a rhizome is tied to the number of eyes that it has. BA may work on peonies because it has proven successful on *Hosta* for increasing the number of offsets that are produced by parent plants.

#### **4.5 Literature Cited**

- Buchheim, J.A.T., L.F. Burkhart, and M.M. Meyer. 1994. Effect of exogenous gibberellic acid, abscisic acid, and benzylaminopurine on epicotyl dormancy of cultured herbaceous peony embryos. *Plant Cell, Tissue and Organ Culture* 36 (1):35-43.
- Evans, M.R., N.O. Anderson, and H.F. Wilkins. 1990. Temperature and GA<sub>3</sub> effects on emergence and flowering of potted *Paeonia lactiflora*. *HortScience* 25 (8):923-924.
- Garner, J.M., G.J. Keever, D.J. Eakes, and J.R.J. Kessler. 1997a. BA application promotes offset formation in *Hosta* cultivars. *J. Environ. Hort.* 15 (3):119-122.
- Garner, J.M., G.J. Keever, D.J. Eakes, and J.R.J. Kessler. 1997b. Benzyladenine-induced offset formation in *Hosta* dependent on cultivar. *HortScience* 32 (1):91-93.

- Garner, J.M., G.J. Keever, D.J. Eakes, and J.R.J. Kessler. 1998. Sequential BA applications enhance offset formation in *Hosta*. *HortScience* 33 (4):707-709.
- Halevy, A.H., A. Barzilay, and R. Kamenetsky. 2004. Flowering advancement in herbaceous peony. *Acta Horticulturae* 673:279-285.
- Kamenetsky, R., A. Barzilay, and M. Cohen. 2007. Herbaceous peony for cut flower production: Flowering physiologation techniques and cultivation techniques. *Acta Horticulturae* 755:121-125.
- Schultz, H.C., G.J. Keever, J.R.J. Kessler, and R.R. Dute. 2000. BA Application timing affects offset formation in *Hosta*. *J. Environ. Hort.* 18 (2):63-65.

Table 4.1 The effects of benzyladenine rhizome soaks on the number of days to emergence of the last bud on Peony ‘Karl Rosenfield’.

| Concentration (mg•L <sup>-1</sup> ) | Number of Days |
|-------------------------------------|----------------|
| Control (0)                         | 140.4          |
| 200                                 | 120.0          |
| 400                                 | 105.3 *        |
| 800                                 | 137.2          |
| 1600                                | 121.5          |

Means followed by \* are significantly different from the control at the  $\alpha=5\%$  level using Fisher’s LSD.



Figure 4.1 Benzyladenine rhizome soaks on Peony ‘Karl Rosenfield’ hasten the time for the later buds to emerge resulting in larger plants at the end of production. Shown here are plants on May 20 that had been treated the previous fall with benzyladenine at concentrations (from left to right) of 0, 200, 400, 800, and 1600 mg•L<sup>-1</sup>. The largest plant (circled) is the 400 mg•L<sup>-1</sup> plant. It is larger because its shoots emerged an average of 35 days earlier than the control.

## **Chapter 5**

### **Benzyladenine Foliar Sprays Increase the Number of Flower Stalks in *Salvia nemorosa* ‘Caradonna’**

(In the format appropriate for submission to HortTechnology)

**Benzyladenine Foliar Sprays Increase the Number of Flower Stalks in *Salvia nemorosa* ‘Caradonna’**

Dennis J. Carey, Brian E. Whipker<sup>1</sup>, Ingram McCall, and Wayne Buhler

Department of Horticulture Science, Box 7609, North Carolina State University, Raleigh,  
NC

27695-7609

<sup>1</sup>Corresponding author.

Received for publication \_\_\_\_\_, 2008 and in revised form \_\_\_\_\_.

Use of trade names in this publication does not imply endorsement of products named nor criticism of similar ones not mentioned. Thanks to Fafard Co. for the root substrates, Scotts Co. for the fertilizer, Dillen Products for the pots, and Fine Americas for financial support.

## **Benzyladenine Foliar Sprays Increase the Number of Flower Stalks in *Salvia nemorosa* ‘Caradonna’**

*Additional Index Words.* BA, BAP, 6-BA, 6-Benzylaminopurine, N6-Benzyladenine, Configure, Cytokinin, Meadow Sage, Plant Growth Regulator, PGR

*Abstract:* Benzyladenine (BA) was applied as a foliar spray to *Salvia nemorosa* ‘Caradonna’ to determine if it would increase branching or flowering. Single foliar sprays at concentrations of 100, 200, 400, 800 and 1600 mg•L<sup>-1</sup> were applied onto the plants 2 weeks after potting (WAP). Data on the size, branching and flowering were taken at 4 WAP. The number of days until the first flower opened was recorded. BA sprays controlled height, average diameter, growth index, and the number of flowers and buds at 4 WAP. The time until the first flower opened was delayed by 2 to 3 weeks. However, BA increased the number of flower stalks that ultimately formed. The most effective concentration was 800 mg•L<sup>-1</sup>. Phytotoxicity was observed at 1600 mg•L<sup>-1</sup> in the form of leaf edge necrosis.

### **5.1 Introduction**

*Salvia nemorosa* ‘Caradonna’ is a perennial sage that produces tall flower stalks with many small purple flowers. In production, the plants tend to form a single tall stalk instead of branching. Cytokinins are known to induce branching and influence flowering in many plants (Henny, 1986; Hoover et al., 1998; Carpenter and Beck, 1972; Boyle, 1992). The primary objective of this experiment was to determine if benzyladenine (Configure, Fine Americas, Inc., Walnut Creek, CA), a cytokinin based plant growth regulator (PGR), applied as a foliar spray, could influence the branching or flowering of *Salvia nemorosa* ‘Caradonna’.

## 5.2 Materials and Methods

The *Salvia* plants were received as plugs in 102 count hex trays (3.2 cm hex x 4.4 cm deep).

On 23 April 2008 they were placed into 15.24 cm [1.29 liter volume (6 inch)] azalea pots in a peat-based substrate Fafard<sup>®</sup> 4P (Conrad Fafard Inc., Anderson, SC), which contained 45% peat moss 10% perlite, 15% vermiculite, and 30% bark. Plants were fertigated with 150 mg•L<sup>-1</sup> N of Excel<sup>®</sup> 15-5-15 Cal-Mag (Scotts, Marysville, OH) (15N-2.1P-12.5K).

Greenhouse temperature day/night set points were 24/18°C (75/65°F) and the plants were grown under natural day length. On 7 May (2 WAP) foliar sprays consisting of BA at concentrations of 100, 200, 400, 800 or 1600 mg•L<sup>-1</sup> were applied at a volume of 0.5 gal / sq. ft. using a hand pump sprayer. An untreated control was included. The experiment was a completely randomized design with five single plant replications. On 22 May (4 WAP), data were collected on height (H) (as measured from the top of the pot to the top of the plant), width (at the widest point (W1) and at 90° from that point (W2)), average diameter [(W1+W2) / 2], growth index (W1\*W2\*H), number of flowers and buds, number of branches, and number of nodes per unit height. The plants were grown until they produced their first flowers. The number of days to first flower and the number of flower stalks present at first flower, height at first flower and number of buds present at first flower were recorded. Plants were observed for signs of phytotoxicity including, leaf chlorosis, necrosis, or cupping. Data was tested by analysis of variance using the generalized linear model (PROC GLM) of SAS (SAS Institute, Cary, NC). Means were separated by pair-wise testing using Fisher's least significant differences (LSD) at  $P < 0.05$ .

### 5.3 Results

The use of BA at 400 and 800 mg•L<sup>-1</sup> controlled plant height, average diameter, and growth index (Table 5.1) (Figure 5.1). A concentration of 1600 mg•L<sup>-1</sup> had the greatest amount of control, but was phytotoxic (Figure 5.2). Therefore this concentration will not be considered in the following presentation of results. The height control continued through flowering. The average height per plant at first flower was about 60% less in plants treated with 800 mg•L<sup>-1</sup> than with the control plants. BA appeared to control the average internode length as measured by the number of nodes per unit height. This measure nearly doubled from the control (0.30) to the 800 mg•L<sup>-1</sup> treated plants (0.57). BA did not affect the total number of branches present on each plant at 4 WAP (data not shown). BA delayed flowering, but once flowering began, the number of flowers produced was greater than the untreated control group (Table 5.2). Flower delay was measured by the number of flowering shoots present at 4 WAP (which were greatly reduced by BA), and the number of flowers and buds present at 4 WAP (nearly absent at all BA concentrations). BA delayed the onset of flowering, but increased the number of flower stalks that formed by the time the first flower opened. The greatest number of flower stalks occurred with 800 mg•L<sup>-1</sup> (7.8 per plant), but that concentration resulted in a delay of 21.2 days in the start of flowering. The average number of flower buds per plant that were present when the first flower opened was also greater with 400 to 1600 mg•L<sup>-1</sup> BA (5.0- 5.2) compared to the control group (1.0).

### 5.4 Discussion

BA can be used to improve *Salvia* 'Caradonna' plant quality by controlling height and average internode length, resulting in plants with a more compact appearance delaying the

onset of flowering, but ultimately increasing the flowering of the plant during the production cycle. If a grower is willing to wait 3 more weeks, he will be rewarded with shorter plants that produce 3.5 times more flower stalks. This response will greatly increase the retail quality of the plants. The ideal concentration for increasing flowering in this experiment was  $800 \text{ mg}\cdot\text{L}^{-1}$ . Further research should be conducted to determine the effect of multiple applications versus a single application, the effect of tank mixes of BA with other PGRs and to determine the effect of other concentrations in between 400 and 1600  $\text{mg}\cdot\text{L}^{-1}$ . It may be possible to increase the number of flower stalks without causing a delay by using BA with an auxin product or a gibberellin product as a tank mix or in sequential order.

### **5.5 Literature Cited**

- Boyle, T.H. 1992. Modification of plant architecture in 'Crimson Giant' Easter cactus with benzyladenine. *J. Amer. Soc. Hort. Sci.* 117 (4):584-589.
- Carpenter, W. J., and G.R. Beck. 1972. Growth regulator induced branching of poinsettia stock plants. *HortScience* 7 (4):405-406.
- Henny, R.J. 1986. Increasing basal shoot production in a non-branching *Dieffenbachia* hybrid with BA. *HortScience* 21 (6):1386-1388.
- Hoover, M.P., J.B. London, W.B. Miller, G. Legnani, and R.T. Fernandez. 1998. Benzyladenine induces branching in eleven new *Hosta* cultivars. *SNA Research Conference Proceedings* 43:303-304.

Table 5.1 The effects of benzyladenine (BA) on the growth characteristics of *Salvia nemorosa* 'Caradonna' at 4 WAP.

| BA Concentration                | Height (cm) | Average diameter (cm) | Growth index (cm <sup>3</sup> ) | Number of flowers and buds present | Number of nodes per unit height |
|---------------------------------|-------------|-----------------------|---------------------------------|------------------------------------|---------------------------------|
| Control (0 mg•L <sup>-1</sup> ) | 39.26 a     | 25.9 a                | 24244 a                         | 5.0 a                              | 0.31 a                          |
| 100 mg•L <sup>-1</sup>          | 23.08 bc    | 24.9 ab               | 14308 b                         | 0.4 b                              | 0.51 bc                         |
| 200 mg•L <sup>-1</sup>          | 29.02 ab    | 21.6 bc               | 12819 b                         | 0.8 b                              | 0.41 ab                         |
| 400 mg•L <sup>-1</sup>          | 15.82 cd    | 20.3 cd               | 6659 c                          | 0.2 b                              | 0.53 bcd                        |
| 800 mg•L <sup>-1</sup>          | 12.36 cd    | 19.1 cd               | 4528 c                          | 0.0 b                              | 0.57 cd                         |
| 1600 mg•L <sup>-1</sup>         | 11.80 d     | 17.5 d                | 3666 c                          | 0.0 b                              | 0.67 d                          |
| <i>p</i> -value                 | 0.0001      | 0.0005                | <0.0001                         | 0.0039                             | 0.0011                          |

Means followed by different letters are significantly different at the alpha = 5% level using Fisher's LSD.

Table 5.2 The effects of benzyladenine (BA) on the flowering characteristics of *Salvia nemorosa* 'Caradonna'.

| BA Concentration                | Number of days to first flower | Height in cm at first flower | Number of bolting shoots at first flower | Number of buds at first flower |
|---------------------------------|--------------------------------|------------------------------|--|--------------------------------|
| Control (0 mg•L <sup>-1</sup> ) | 24.4 a                         | 54.7 a                       | 2.0 a                                    | 1.0 a                          |
| 100 mg•L <sup>-1</sup>          | 37.8 bc                        | 43.4 b                       | 4.8 ab                                   | 1.6 a                          |
| 200 mg•L <sup>-1</sup>          | 33.4 ab                        | 40.8 bc                      | 3.6 a                                    | 2.8 ab                         |
| 400 mg•L <sup>-1</sup>          | 43.2 cd                        | 36.1 c                       | 7.0 bc                                   | 5.2 b                          |
| 800 mg•L <sup>-1</sup>          | 45.6 cd                        | 35.3 c                       | 7.8 cd                                   | 5.2 b                          |
| 1600 mg•L <sup>-1</sup>         | 49.4 d                         | 34.1 c                       | 10.2 d                                   | 5.0 b                          |
| <i>p</i> -value                 | 0.001                          | <0.001                       | <0.001                                   | 0.0396                         |

Means followed by different letters are significantly different at the alpha = 5% level using Fisher's LSD.



Figure 5.1 The effect of benzyladenine (BA) at concentrations of (from left to right) 0, 100, 200, 400, 800, or 1600  $\text{mg}\cdot\text{L}^{-1}$  on the height and flowering of *Salvia nemorosa* 'Caradonna'. Photo taken 4 WAP.



Figure 5.2 Benzyladenine (BA) at 1600  $\text{mg}\cdot\text{L}^{-1}$  causes slight phytotoxicity in the form of leaf edge necrosis indicated by the arrows.

## **Chapter 6**

### **Benzyladenine Foliar Sprays Increase Shoot Number in *Helleborus* *×hybridus***

(In the format appropriate for submission to HortTechnology)

**Benzyladenine Foliar Sprays Increase Shoot Number in *Helleborus*  
*×hybridus***

Dennis J. Carey, Adam Lowder, Helen Krauss, Brian E. Whipker, and Wayne Buhler

Department of Horticulture Science, Box 7609, North Carolina State University, Raleigh,  
NC

27695-7609

<sup>1</sup>Corresponding author.

Received for publication \_\_\_\_\_, 2008 and in revised form \_\_\_\_\_.

Use of trade names in this publication does not imply endorsement of products named nor criticism of similar ones not mentioned. Pine Knot Farms for the plants, and Fine Americas for financial support.

**Benzyladenine Foliar Sprays Increase Shoot Number in *Helleborus ×hybridus***

*Additional Index Words.* BA, BAP, 6-BA, 6-Benzylaminopurine, N6-Benzyladenine, Configure, Cytokinin, Lenten Rose, Plant Growth Regulator, PGR,

*Abstract:* Benzyladenine (BA) was applied as a foliar spray or a drench to *Helleborus ×hybridus* 1-gallon plants growing in a greenhouse to determine if it could cause an increase in the number of shoots. Foliar sprays at concentrations of 50, 100, 150, 200, 250, 300, 400, 600 and 800 mg•L<sup>-1</sup> were applied every 2 weeks starting 2 weeks after potting (WAP) and continuing until 12 WAP. Drenches at concentrations of 0.625, 1.25, 1.875, 2.5, 3.125, 3.75, 5, 7.5, and 10 mg active ingredient (ai) per pot were applied to a second set of plants on the same schedule. The shoots were counted every two weeks during this time. BA sprays increased shoots with the most effective concentration at 800 mg•L<sup>-1</sup>. BA drenches did not increase shoots. No phytotoxicity was noted, but leaf morphology was modified.

**6.1 Introduction**

*Helleborus ×hybridus* is a clump forming plant that is popular in the southeastern United States as a shade-loving perennial plant (Sibley and Wilson 2001). It blooms in the late winter or early spring at a time when few other plants are flowering. It produces nodding or outward facing flowers in a wide variety of pastel colors. It is unpalatable to deer, rabbits and slugs and is thus very popular with gardeners in rural areas. However, it is very slow to grow in commercial production and therefore is somewhat expensive (Lubell et al. 2005). Plants are sold at retail in 1 quart or 1 gallon pots. The plants must be grown at a nursery for 2 to 3 years before they reach a marketable size. Thus any methods that would increase

branching of the plants in production may be useful to growers. Cytokinins are known to induce branching in many herbaceous plants (Carpenter and Carlson 1972; Foley and Keever 1993; Henny and Fooshee 1985; Semeniuk and Griesbach 1985). The primary objective of this experiment was to determine if BA applied as a foliar spray or drench could increase the number of shoots on *Helleborus ×hybridus*.

## **6.2 Materials and Methods**

The *Helleborus ×hybridus* plants were donated by Pine Knot Farms (Clarksville, VA) and were received as 1-year-old seedlings in 606 cell packs (with a volume of 147 ml per cell). The plants were removed from the plug trays and the roots were visually inspected. Each plant was given a qualitative root rating of 1, 2 or 3 with 1 representing plants with large root systems, 2 representing plants with medium root systems and 3 representing plants with small root systems. On 16 May, 2008, they were potted into trade gallon pots with a 4:1 ratio composted pine bark : sand substrate (Kraus and Warren 2006). The plants were measured at potting and again at 18 weeks after potting (WAP). The height (H as measured from the top of the pot to the top of the plant), width (W1 at the widest point and W2 at 90° from that point), and average diameter  $[(W1+W2) / 2]$ , were measured, and the number of shoots were counted. The plants were grown on benches in a greenhouse on the North Carolina State University campus. Plants were irrigated as needed (typically twice per week). The plants were watered with spray stakes that provided 400 ml per plant at each application. Plants were fertigated with a 4 : 1 : 2 ratio of N : P : K formulated from ammonium nitrate, potassium phosphate and potassium sulfate at every irrigation at a concentration of 160 mg•L<sup>-1</sup> N. The plants were also provided with a micronutrient mix of boric acid at 0.5 mg•L<sup>-1</sup>.

<sup>1</sup>, copper sulfate at 0.02 mg•L<sup>-1</sup>, manganese chloride at 0.5 mg•L<sup>-1</sup>, ammonium molybdate at 0.1 mg•L<sup>-1</sup>, zinc sulfate at 0.05 mg•L<sup>-1</sup>, and chelated iron at 5 mg•L<sup>-1</sup> at every irrigation. The greenhouse temperature day/night set points were 24/18°C (75/65°F). The greenhouse had a pad and fan cooling system that kept the day time high temperatures at an average of 26.8°C (80.3°F) with a maximum of 32.6°C (90.7°F) that occurred on two very hot days. The plants were grown with natural day length under shade cloth providing 50% shade. The BA source was Configure (Fine Americas Inc., Walnut Creek, CA), which is a PGR labeled for use on ornamental crops. At 2 WAP the plants received their first chemical application. The plants were sprayed with a pump sprayer at BA concentrations of 50, 100, 150, 200, 250, 300, 400, 600 or 800 mg•L<sup>-1</sup> in tap water applied at a volume of 0.5 gal / 100 ft<sup>2</sup> or were drenched with concentrations of 0.625, 1.25, 1.875, 2.5, 3.125, 3.75, 5, 7.5, or 10 mg active ingredient (ai) per pot in 118 ml (4 fl. oz.) of tap water. The plants were irrigated prior to each spray or drench application. An untreated spray control and an untreated drench control were included. The spray control received tap water sprays at each chemical application and the drench control received tap water drenches at each application. The plants were treated again at 4, 6, 8, 10, and 12 WAP. The plants were then grown without treatments until 18 WAP. The experiment was a randomized complete block design with five single plant replications per treatment level. The design was blocked by the root quality of the seedlings as determined at potting. At 18 WAP, data were collected on height, width, average diameter, and number of shoots. Plants were observed for signs of phytotoxicity including, leaf chlorosis, necrosis, or cupping. Data was tested by analysis of variance using the generalized linear model (PROC GLM) of SAS (SAS Institute, Cary, NC). Means were separated by

pair-wise testing using Fisher's least significant differences (LSD) at  $P < 0.05$ .

### **6.3 Results**

BA sprays resulted in an increase in the number of shoots produced by the plant (Table 6.1) (Figure 6.1) but did not alter any other growth variable (data not shown). The increase was first detected at 6 WAP and the difference between the optimal concentration and the control increased until the last spray treatment was applied at 12 WAP. However, the only statistically significant treatment was  $800 \text{ mg}\cdot\text{L}^{-1}$  and these plants had a bushier appearance (Figure 6.2). None of the drench treatments produced significantly more shoots than the control group (data not shown).

Neither spray nor drench treatments were phytotoxic. However, both spray and drench treatments caused changes in leaf morphology (Figure 6.3). Some leaves were narrower, leaf edges were more feathered in appearance, and the number of segments per leaf increased on some leaves. Each sprayed plant had leaves with no morphological changes or one or more of the above changes. The leaves did not grow out of the morphology changes during the 6 week observation period after the treatments were halted, but it is possible that future growth would cover up these changes.

### **6.4 Discussion**

The level of activity of BA in these experiments suggests that there are possible uses for it in commercial production. The increase in shoot induction could reduce production time. This may allow growers to finish plants earlier which can lead to cost savings. The ideal concentration for increasing branching in this experiment was a foliar spray at  $800 \text{ mg}\cdot\text{L}^{-1}$ .

Future research should investigate treatment concentrations above 800 mg•L<sup>-1</sup>, the effects of BA applied weekly or monthly, the effect of starting treatments earlier or later in the production cycle, and the effect of longer application periods. Drench rates higher than 10 mg ai per pot should be studied. Research should also determine if flowering and landscape performance are affected in any way following treatment with BA. Finally, research should be conducted on plants grown in un-cooled greenhouses to see if BA can increase shoot numbers under more stressful temperatures. BA has been shown to cause morphology changes in other plants similar to what was observed in this experiment. For example, feathering of flower petals was reported in tulips with BA (Saniewski and Mynett 1977).

### **6.5 Literature Cited**

- Carpenter, W. J., and W. H. Carlson. 1972. Improved geranium branching with growth regulator sprays. *HortScience* 7 (3):291-292.
- Foley, J.T., and G.J. Keever. 1993. Chemically induced branching of *Vinca minor*. *J. Environ. Hort.* 11 (4):149-152.
- Henny, R.J., and W.C. Fooshee. 1985. Induction of basal shoots in *Spathiphyllum* 'Tasson' following treatment with BA. *HortScience* 20 (4):715-717.
- Kraus, H.T., and S.L. Warren. 2006. Nursery production of *Helleborus x hybridus*: Management of nitrogen and substrate pH. *J. Environ. Hort.* 24 (4):207-212.
- Lubell, J.D., D.M. Thompson, and M.H. Brand. 2005. Foliar sprays of benzyladenine increase bud and propagule production in *Epimedium x rubrum* Morren and *Helleborus x hybridus* L. *Propagation of Ornamental Plants* 5 (1):19-22.
- Saniewski, M., and K. Mynett. 1977. The formation of parrot-like flowers in benzyladenine treated bulbs of some tulip cultivars. *Acta Horticulturae* 68:151-153.
- Semeniuk, P., and R.J. Griesbach. 1985. Bud applications of BA induces branching of a nonbranching poinsettia. *HortScience* 20 (1):120-121.
- Sibley, J., and B. Wilson. 2001. *Helleborus x hybridus*. *American Nurseryman*, 194 (1):86.

Table 6.1. The effects of 6 foliar spray applications of benzyladenine on the number of shoots on *Helleborus ×hybridus* plants.

| BA<br>Concentration<br>(mg•L <sup>-1</sup> ) | Number of weeks after potting |     |     |       |       |       |       |      |       |      |
|--|-------------------------------|-----|-----|-------|-------|-------|-------|------|-------|------|
|  | 0                             | 2   | 4   | 6     | 8     | 10    | 12    | 14   | 16    | 18   |
| Control (0)                                  | 3.2                           | 3.2 | 5.1 | 7.0   | 8.2   | 11.2  | 12.3  | 15.5 | 18.2  | 20.2 |
| 50   | 3.6                           | 3.6 | 5.7 | 7.8   | 8.4   | 10.6  | 14.8  | 17.0 | 18.0  | 19.2 |
| 100  | 2.6                           | 2.6 | 4.6 | 6.6   | 7.0   | 8.8   | 10.2  | 11.8 | 14.4  | 17.0 |
| 150  | 3.4                           | 3.2 | 6.2 | 9.2   | 10.2  | 13.6  | 14.4  | 18.8 | 23.8  | 27.0 |
| 200  | 3.0                           | 3.0 | 5.3 | 7.6   | 9.4   | 13.8  | 16.2  | 19.2 | 24.2  | 26.8 |
| 250  | 3.2                           | 3.2 | 5.2 | 7.2   | 8.6   | 12.2  | 12.6  | 16.6 | 21.2  | 26.0 |
| 300  | 2.8                           | 2.8 | 4.2 | 5.5   | 7.0   | 8.7   | 9.7   | 11.5 | 12.3  | 14.3 |
| 400  | 3.2                           | 3.4 | 6.4 | 9.4   | 10.4  | 17.4  | 20.0  | 22.6 | 29.0  | 31.6 |
| 600  | 2.8                           | 3.0 | 4.7 | 6.3   | 6.5   | 10.8  | 11.2  | 13.5 | 15.2  | 16.7 |
| 800  | 4.2                           | 4.2 | 9.3 | 14.4* | 16.4* | 24.2* | 22.6* | 25.4 | 36.8* | 39.0 |

Means followed by \* are significantly different from the control group on that week at the alpha = 5% level using Fisher's LSD.

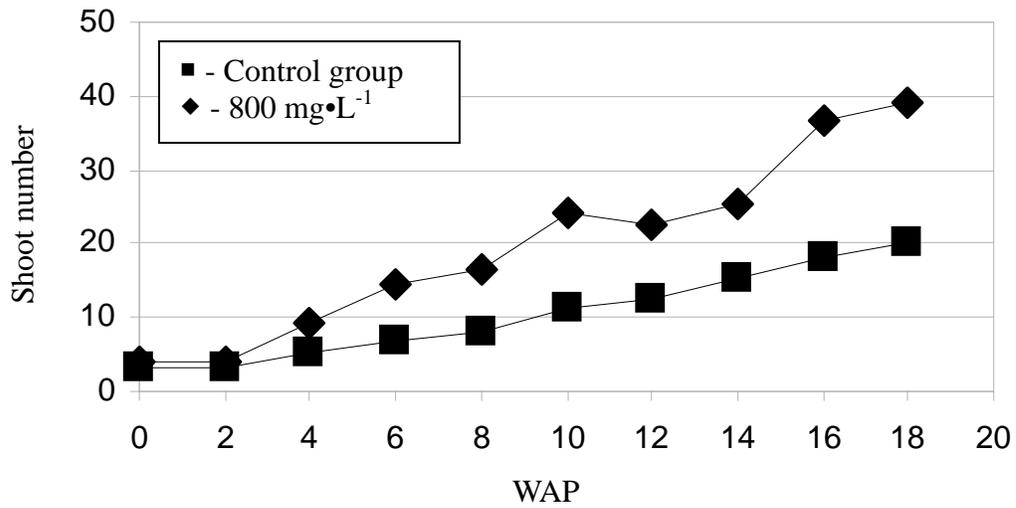


Figure 6.1 Number of shoots versus weeks after potting (WAP) of the control (■) and the 800 mg·L<sup>-1</sup> treatment (◆) for spray applications of benzyladenine on *Helleborus ×hybridus* plants. Shoot number significantly different after 6 weeks ( $P \leq 0.05$ ).



Figure 6.2. *Helleborus ×hybridus* control plant (left) and the 800 mg·L<sup>-1</sup> spray plant (right).

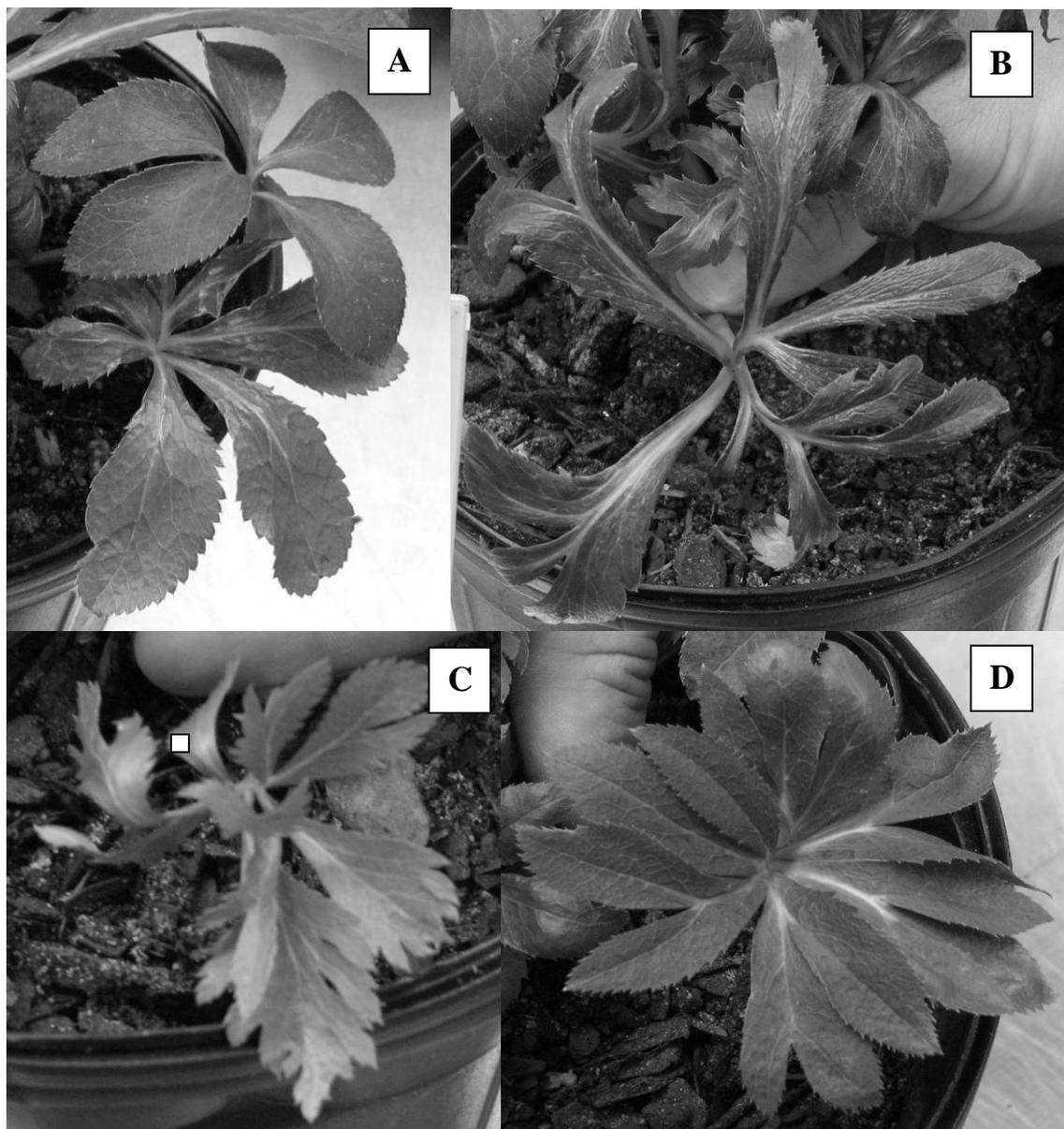


Figure 6.3. Leaf morphology changes on *Helleborus x hybridus* plants sprayed with benzyladenine. A) Untreated plant. B) Narrow leaf segments. C) Feathered leaf margin. D) Increased number of segments per leaf.

## **Chapter 7**

### **The Effect of Benzyladenine on Ornamental Plants**

(In the format appropriate for submission to HortTechnology)

## **The Effect of Benzyladenine on Ornamental Plants**

Dennis J. Carey, Brian E. Whipker<sup>1</sup>, Ingram McCall, and Wayne Buhler

Department of Horticulture Science, Box 7609, North Carolina State University, Raleigh,  
NC 27695-7609

<sup>1</sup>Corresponding author.

Received for publication \_\_\_\_\_, 2008 and in revised form \_\_\_\_\_.

Use of trade names in this publication does not imply endorsement of products named nor criticism of similar ones not mentioned. Thanks to Berger Peat Moss and Fafard Co. for the root substrate, Scotts Co. for fertilizer, Dillen Products for pots, and Fine Americas for financial support.

## **The Effect of Benzyladenine on Ornamental Plants**

*Additional Index Words:* BA, BAP, 6-BA, 6-Benzylaminopurine, N6-Benzyladenine, Configure, Cytokinin, Plant Growth Regulator, PGR

*Abstract:* Benzyladenine (BA) was applied to a wide variety of commercially available ornamental plants to determine if there was an effect on growth (plant size or branching) or flowering. Various application methods were used. BA was applied alone on most of the plants, but also in a tank mix with gibberellic acid (GA), or Flurprimidol. Number of applications (1-4) and timing of applications varied beginning 2 to 8 weeks after potting (WAP). Treatment concentrations used were in the range of 50 to 3200 mg•L<sup>-1</sup>. The plants tested were: *Acalypha microphylla*, *Aquilegia flabellate* (Columbine), *Begonia* × *hybrida* ‘Dragon Wings’ (Dragon Wing Begonia), *Catharanthus roseus* (Madagascar Periwinkle), *Coreopsis grandiflora* (Tickseed), *Euphorbia pulcherrima* (Poinsettia), *Exacum affine* (Persian Violet), *Gerbera jamesonii* (Gerber Daisy), *Heuchera micrantha* var. *diversifolia* (Coral Bells), *Impatiens hawkeri* (New Guinea Impatiens), *Ipomoea batatas* (Ornamental Sweet Potato Vine), *Iresine* hybrid, *Lantana camara*, *Liatris spicata* (Gayfeather), *Oenothera fruiticosa youngii* (Sundrops), *Pentas lanceolata*, *Portulaca oleracea* (Purslane), *Pseuderanthemum atropurpureum* (Varnish plant), *Rudbeckia hirta* (Black-eyed Susan), *Salvia splendens*, *Scabiosa caucasica* (Pincushion flower), *Scutellaria* hybrid (Skullcap), *Senecio cineraria* (Dusty Miller), *Solenostemon scutellarioides* (Coleus), *Sutera cordata* (Bacopa), *Verbena* hybrid, *Viola* × *wittrockiana* (Pansy), and *Zinnia elegans*. BA did not affect the growth or flowering characteristics of many of the plants. However, there were

some plants that did react to BA with smaller size or increased branching. These warrant further research. Phytotoxicity was observed on *Exacum* and *Viola* at low concentrations. No phytotoxicity was observed on *Solenostemon* at high concentrations. The specific materials and methods and results are summarized in tabular form.

## **7.1 Introduction**

Cytokinins induce branching and influence flowering in many plants (Boyle 1992; Khademi and Khosh-Khui 1977; Wilson and Nell 1983; Carpenter and Beck 1972). The primary objective of this experiment was to determine if BA, a cytokinin based plant growth regulator (PGR), applied via methods that are commonly used by commercial growers, could influence growth and flowering of a wide variety of popular annual and perennial bedding plants.

## **7.2 Materials and Methods**

All plants were grown in greenhouses at the North Carolina State University Horticultural Field Lab in Raleigh North Carolina (35° 47' north latitude) during the typical production season for the plant (Spring, Summer, Autumn, Winter). The plants were all grown using similar methods and any variations are noted in the results section. The plants were potted into azalea pots from Dillen products (Middlefield, OH) in a variety of sizes between 10 cm (4") and 20 cm (8") (Table 7.1). The substrate used was either Berger BM6 (Berger Peat Moss, St. Modeste, Quebec, Canada), containing 75 to 80% Canadian sphagnum peat and 20 to 25% perlite or Fafard<sup>®</sup> 4P (Conrad Fafard Inc., Anderson, SC), which contains 45% peat moss, 10% perlite, 15% vermiculite, and 30% bark. The fertilizer used was 150 mg•L<sup>-1</sup> N of Excel<sup>®</sup> 15-5-15 Cal-Mag (Scotts, Marysville, OH) (15N-2.1P-12.5K) and was applied at

every irrigation unless otherwise noted. Irrigation schedules were decided separately for each plant and were adjusted as needed. Young plants typically received irrigation every second or third day while mature plants usually received daily irrigations. Greenhouse temperature day/night set points were 24/18°C (75/65°F) and the plants were grown under natural day-length. The benzyladenine source was Configure (Fine Americas Inc., Walnut Creek, CA). All of the experiments were set up as a completely randomized design with 4, 5, 6, or 7 single plant replications per treatment and untreated controls.

Spray applications were made using a hand pump sprayer with 151.4 ml of solution applied to 8 square feet (equivalent to 0.5 gallons per 100 square feet) which is enough liquid to cover the leaves to runoff. The plants were spread out evenly within the 8 square foot area and the spray was applied evenly over the entire area, including any open area between the plants. Treatment concentrations varied for each species, but were in the range of 50 to 3200 mg•L<sup>-1</sup>. Drench applications were made at 59 ml (2 fluid ounces) per pot for 4 or 5” pots and 118 ml (4 fluid ounces) per pot for 6 or 8” pots. Drench amounts varied from 2.5 to 20 mg active ingredient (ai) per pot. The plants were always irrigated prior to drenching.

Fertigation applications were made via drip tube and were in the range of 2 to 16 mg•L<sup>-1</sup> BA. BA was mixed into the fertilizer tank at various concentrations and applied with each daily irrigation. The plants were all irrigated until water started running out of the bottom of the pots. The plug dip applications were made by soaking the entire plug in a container with BA liquid solution for 1 minute. The plugs had been watered prior to dipping and thus had moist root balls. The number of BA applications as well as the timing of the applications

will be noted for each plant. Applications generally began 2 to 8 weeks after potting (WAP) in order to give the plants time to root into the pot. In most cases only a single application was made, but some plants received 2 to 4 applications. Any exceptions to these materials and methods are noted.

The variables recorded were related to the size and flowering of the plant and usually included height (H, from the top of the pot to the top of the plant), average diameter (width at the widest point (W1), plus width at 90° from that point (W2) divided by 2), growth index ( $H*W1*W2$ ), number of branches, number of flowers and buds, and date of first flower. Any other traits that were recorded will be described below for that particular plant.

All plants were monitored for phytotoxicity, which usually appeared as leaf cupping, leaf edge necrosis or leaf chlorosis. The plants were all assigned a qualitative phytotoxicity rating by comparing each plant to the control group. Ratings of 0 meant no damage, 1 meant minimal damage, 2 meant diminished retail quality and 3 meant that the plants were too damaged to be sold at retail.

Data were tested by analysis of variance using the generalized linear model (PROC GLM) of SAS (SAS Institute, Cary, NC). Means were separated by pair-wise testing using Fisher's least significant differences (LSD) at  $P < 0.05$ .

## 7.3 Results

### 7.3.1 *Acalypha microphylla*

*Acalypha microphylla* was studied to determine if BA foliar sprays would increase branching or affect the growth habit. Plugs were received in 84 count cells (round cells 3.17 cm diameter and 4.44 cm deep, with a volume of 21.7 ml). Plants were potted on 23 April 2008 into 6" pots with Fafard 4P substrate. There were 4 single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 100, 200, and 400 mg•L<sup>-1</sup> was made 2 WAP. Data recorded at 4 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating and leaf size index. On each plant the largest leaf was selected from the second or third node from the top of the plant. Its length (L, at the longest point) and width (W, at the widest point) were measured. The leaf index was calculated as L\*W. The only characteristic that differed from the control group was the leaf size index (Table 7.2). However, the *p*-value for this trait was just outside of the prescribed limit (*p*-value = 0.0524). BA at 400 mg•L<sup>-1</sup> resulted in a smaller mean leaf size index (57% below the control mean) (Figure 7.1). BA at 400 mg•L<sup>-1</sup> also caused some phytotoxicity in the form of leaf cupping. These results do not indicate any potentially useful reactions at concentrations ≤ 400 mg•L<sup>-1</sup>.

### 7.3.2 *Aquilegia flabellate*

*Aquilegia flabellate* 'Cameo Mix' (Columbine) was studied to determine if BA foliar sprays would increase branching or affect the growth habit. Unvernalized plugs were received in 34 (17 by 2) cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plants were potted on 9 April 2008 into 6" pots with Fafard 4P substrate. There were 5

single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 50, 100, 200, 400, 800, and 1600 mg•L<sup>-1</sup> was made 4 WAP. Data recorded at 7 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating and the number of crowns per plant. BA at 800 and 1600 mg•L<sup>-1</sup> increased the average number of crowns per plant over the control from 1.0 per plant to 2.0 per plant. However, this did not impact the outward appearance of the plants as the various size indicators (height, average diameter, growth index) were not different from the control. At 1600 mg•L<sup>-1</sup> there was some minor phytotoxicity in the form of leaf edge necrosis (Figure 7.2). These results do not indicate any potentially useful reactions at concentrations of ≤ 1600 mg•L<sup>-1</sup>. However, it is possible that more applications may be required to elicit a growth response. The potential effect on flowering was not measured in this experiment.

### **7.3.3 *Begonia ×hybrida***

*Begonia ×hybrida* ‘Dragon Wing Red’ (Dragon Wing Begonia) was studied to determine if BA foliar sprays would increase branching or affect the growth habit or flowering. Plugs were purchased in 51 count plug flats (2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plants potted on 18 March into 6” pots with Fafard 4P substrate. There were 5 single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 40, 60, 80, 100, and 120 mg•L<sup>-1</sup> was made 2 WAP. Data recorded at 6 WAP included height, average diameter, growth index, number of branches and number of flowers. BA increased the number of branches over the control with the only effect at 80 mg•L<sup>-1</sup> (Table 7.3)(Figure 7.3). BA did not affect height ( $\bar{x}$  = 29.95 cm) or average diameter ( $\bar{x}$  = 34.16 cm), but it did control growth index at the 40 mg•L<sup>-1</sup> concentration. The other concentrations were similar

to the control so it is difficult to make a prediction about the growth index of the plant versus concentration. BA increased the number of flowers per plant at 6 WAP from 0.4 to a peak of 3.8 at 100 mg•L<sup>-1</sup>. The ideal concentration for this plant appears to be in the 80 to 100 mg•L<sup>-1</sup> range for control of branching and flowering. No phytotoxicity was noted. These results indicate that BA has potential use as a branching agent and a flower promoter on 'Dragon Wing Red' begonias.

#### **7.3.4 *Catharanthus roseus***

*Catharanthus roseus* 'Pacifica Lilac' (Madagascar Periwinkle) was studied to determine if BA foliar sprays, drenches or fertigation would increase branching or affect the growth habit or flowering. Plugs were purchased in 288 cell plug flats (square cells 1.9 cm wide and 2.84 cm deep, with a volume of 6.3 ml). Plants were potted on 7 June into 4.5" pots with Fafard 4P substrate. There were 5 single plant replications per treatment. Plants were treated with foliar sprays, root drenches, plug dips and fertigation. Single foliar sprays at concentrations of 0 (water), 50, 75, 100, 150, 200, 300, 400, and 800 mg•L<sup>-1</sup> were made at 2, 3 or 4 WAP. The 4 WAP plants received only the 50, 100, 200, and 400 mg•L<sup>-1</sup> concentrations. Single drench amounts of 0, 2.5, 5, 7.5, 10, 12.5, 15, and 20 mg ai per pot were made at 2 or 3 WAP. Fertigation concentrations of 0, 2, 4, 8, 12, and 16 mg•L<sup>-1</sup> were made with each irrigation starting at 2 WAP. Moistened plugs were soaked for 1 minute in BA at concentrations of 0 (water), 10, 20, 30, 40, 50, 60, 70, 80 and 90 mg•L<sup>-1</sup> prior to potting. Data were recorded at 5.5 WAP and included height, average diameter, growth index, number of branches, phytotoxicity rating, number of flowers, branches per unit height, and the flower to branch ratio. Each node on the plant produced two axillary buds and each bud

grew into either a branch or a flower. The flower to branch ratio was measured to determine if BA altered the morphogenesis of the bud in any way.

#### **7.3.4.1 Spray**

BA sprays were inconsistent at controlling height (data not shown). BA increased the number of branches produced by the plants. Sprays of 200, 300, and 800 mg•L<sup>-1</sup> at 2 WAP provided good results and 50 and 400 mg•L<sup>-1</sup> at 4 WAP provided optimal results (Table 7.4). This indicates that the plant may become less sensitive to BA with age and suggests that later sprays may be more beneficial than earlier sprays. Phytotoxicity was noted at 400 and 800 mg•L<sup>-1</sup>. BA had no other effects. Results indicate that foliar sprays of BA have potential commercial use as a branching agent on Madagascar periwinkle.

#### **7.3.4.2 Drench**

BA drenches resulted in smaller average diameters (Table 7.5). The 2 WAP applications were slightly more effective than the 3 WAP applications. The optimal concentration was 7.5 mg ai applied at 2 WAP. At this concentration, the average width of the plants was 22% less than the control. BA drenches also increased branching. The optimal amounts were 20 mg ai at 2 WAP and 15 mg ai at 3 WAP. Further research should be done at BA amounts above 20 mg ai to determine if these results can be improved. The 20 mg ai at 2 WAP and 15 mg ai at 3 WAP increased branching by 39% and 44% over the control respectively (Figure 7.4). BA drenches also altered the flower to branch ratio in favor of branches. *Catharanthus roseus* has an opposite branching structure. Every node produces 2 axillary meristems that become either a new branch or a flower. The flower to branch ratio measures the number of flowers that form versus the number of branches. In this experiment, BA drenches reduced the ratio

optimally at 20 mg ai at 2 WAP and 10 mg ai at 3 WAP, which indicates that more branches were forming from these buds than flowers. This implies that *Catharanthus roseus* plants drenched with BA may have more branches and fewer flowers than untreated plants. These results indicate that drenches of BA have potential commercial use as a branching agent on Madagascar periwinkle.

#### **7.3.4.3 Fertigation**

BA fertigation resulted in smaller-sized plants but did not impact branching or flowering. All three size variables (height, average diameter, growth index) decreased with increasing concentration (Table 7.6). The optimal results in this experiment occurred at 8 mg•L<sup>-1</sup> and higher. These results indicate that fertigation applications of BA have potential commercial use as a growth regulator on Madagascar periwinkle.

#### **7.3.4.4 Plug Dip**

BA plug dips provided inconsistent results (data not shown). All of the growth variables, plus branching and flowering were smaller at all concentrations in a statistically significant manner. However, the results were not logical as they were not linear, quadratic or cubic in nature. There is evidence to warrant further research using BA plug dips, but no specific recommendations can be made from this trial.

#### **7.3.5 *Coreopsis grandiflora***

*Coreopsis grandiflora* 'Sunray' (Tickseed) was studied to determine if BA foliar sprays would increase branching or affect the growth habit. Plugs were received in 34 (17 x 2) cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plants were potted on 9 April into 6" pots with Fafard 4P substrate. There were 5 single plant

replications per treatment. A single foliar spray at concentrations of 0 (water), 50, 100, 200, 400, 800, and 1600 mg•L<sup>-1</sup> was made at 4 WAP. Data recorded at 7 WAP included height, average diameter, growth index, number of branches, and phytotoxicity rating. BA had no effect on any of these variables (data not shown). *Coreopsis grandiflora* is induced to flower by an exposure to cold temperatures followed by long days. Cytokinins have been shown to induce flowering in long day or short day plants (Metzger 1995; Hansen et al. 1988; Letham 1994), but have never been trialed on complex photoperiod types. Further research could be done in this area to determine if one or more applications of BA can substitute for part of or this plants' entire cold requirement. Other than that, these results do not indicate any potentially useful reactions for commercial growers.

### **7.3.6 *Euphorbia pulcherrima***

*Euphorbia pulcherrima* 'Prestige Maroon' and 'Gala White' (Poinsettia): Poinsettias occasionally suffer from stress induced epinasty and senescence during shipping. Cytokinins have been shown to inhibit senescence in many plants under the stress of shipping (Emino et al. 2002; King et al. 1982; Beach 2005; Jaroenkit and Paull 2003). The purpose of this study was to determine if BA could inhibit stress induced senescence in poinsettias during shipping. Full-sized, retail ready 6" potted plants (at anthesis) were trialed. There were 5 single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 5, 10, and 20 mg•L<sup>-1</sup> was made. The plants were allowed to air dry over-night and they were randomly sealed into 2' x 2' x 2' cardboard boxes (4 plants per box) for 1 week. The design was a randomized complete block design with each box being a block. The boxes were stored in a cooler set at 68°F (20°C). After one week the plants were un-boxed and checked

for signs of senescence including leaf and bract color, spotting, edge burn, epinasty, crinkling, and a qualitative overall plant quality rank was assigned. There were no statistically significant effects on senescence (data not shown). All of the plants had similar levels of leaf and bract color, epinasty, abscission, spotting, and edge burn and all were of good quality. Further research should be done with longer storage periods, additional sources of ethylene in the boxes, and higher concentrations of BA.

### ***7.3.7 Exacum affine***

*Exacum affine* (Persian Violet) was studied to determine if BA foliar sprays would increase branching or affect the growth habit or flowering. Plants were potted on 7 June into 5.5” pots with Fafard 4P substrate. There were 5 single plant replications per treatment. Two foliar sprays were made, 1 week apart starting at 1 WAP at concentrations of 0 (water), 50, 100, 150, 200, 250, 300, 350, and 400 mg•L<sup>-1</sup>. Data were recorded at 4 WAP and included height, average diameter, growth index, and phytotoxicity rating. BA caused significant phytotoxicity at all concentrations trialed. *Exacum affine* was the most sensitive plant of all the plants that were trialed. Phytotoxicity symptoms appeared as chlorotic leaves, death of the apical meristems, extremely shrunken new growth and significantly delayed flowering (Figure 7.5). The size variables (height, diameter, etc.) were not affected by the BA sprays (data not shown). These results indicate that sprays of BA have no potential commercial uses on Persian violet at these concentrations. However, it is possible that very low concentrations of BA or BA substrate drenches may have beneficial effects and should not be ruled out.

### **7.3.8 *Gerbera jamesonii***

*Gerbera jamesonii* 'Festival Yellow with Light Eye' (Gerbera Daisy) was studied to determine if BA or BA + GA would affect the number of days to flowering in *Gerbera*. *Gerbera* tends to flower sporadically which makes bench runs of this crop difficult to manage. Plugs were received in 84 count cells (round cells 3.17 cm diameter and 4.44 cm deep, with a volume of 21.7 ml). Plants were potted on 18 March into 6" pots with Fafard 4P substrate. There were 6 single plant replications per treatment. Plants were sprayed at 2 WAP with factorial combinations of BA at 25 or 50 mg•L<sup>-1</sup> and one of 3 different Gibberellins, GA<sub>3</sub> (ProGibb 4% - Valent Biosciences, Richardson TX), GA<sub>4</sub> (NovaGib 0.95% - Fine Americas, Inc.), or GA<sub>7</sub> (FAL 900 0.95% - Fine Americas, Inc.) at concentrations of 12.5 or 25 mg•L<sup>-1</sup>. There were also treatment groups of BA alone and each of the GA's alone. The number of days until the third flower on each plant was open was counted. Neither GA nor BA by themselves or in any combination affected the time to flower (data not shown). These results indicate that sprays of BA have no potential commercial use for altering flowering on Gerbera daisy at these concentrations. However, it is possible that higher concentrations of BA may have beneficial effects and should not be ruled out.

### **7.3.9 *Heuchera micrantha* var. *diversifolia***

*Heuchera micrantha* var. *diversifolia* 'Palace Purple' (Coral Bells) was studied to determine if BA foliar sprays would increase branching or affect the growth habit. Plugs were received in 34 (17 by 2) cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plants were potted on 9 April into 6" pots with Fafard 4P substrate. There were 5 single plant replications per treatment. A single foliar spray at concentrations of 0 (water),

50, 100, 200, 400, 800, and 1600 mg•L<sup>-1</sup> was made at 4 WAP. Data recorded at 7 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating, and leaf size index taken from the largest leaf on each plant (refer to the *Acalypha* section for details on leaf size index). BA had no effect on any of these variables (data not shown). At 800 and 1600 mg•L<sup>-1</sup> BA caused phytotoxicity in the form of leaf crinkling, necrotic spots in the middle of the leaves and necrotic edges (edge burn) (Figure 7.6). Further research should be done using multiple applications of BA in the 400 mg•L<sup>-1</sup> range to determine if it can increase branching.

### **7.3.10 *Impatiens hawkeri* 'Fox Red' and 'Fox Pink'**

*Impatiens hawkeri* 'Fox Red' and 'Fox Pink' (New Guinea *Impatiens*) were studied to determine if BA or BA + GA would affect the number of days to flowering on plants grown in the late winter to early spring. Plugs were received in 102 count cells (3.2 cm hex x 4.4 cm deep, with a volume of 16 ml). Plants were potted on 23 February into 6" pots with Fafard 4P substrate. There were 6 single plant replications per treatment. Plants were sprayed at 2 and 4 WAP with factorial combinations of BA at 25 or 50 mg•L<sup>-1</sup> with GA<sub>3</sub>, GA<sub>4</sub>, or GA<sub>7</sub> at concentrations of 12.5 or 25 mg•L<sup>-1</sup> (refer to the *Gerbera* section for details). BA and the GA's were also applied alone. The number of days until the first flower on each plant opened was recorded. Overall, the effects were slight and only a few of the treatments were statistically significant. On the cultivar 'Fox Pink', BA at 25 mg•L<sup>-1</sup> accelerated the time to flowering by 1.93 days from 68.33 days to 66.4 days compared with the control. On the cultivar 'Fox Red', BA at 50 mg•L<sup>-1</sup> plus GA<sub>3</sub> at 25 mg•L<sup>-1</sup> delayed flowering by 2.67 days from 70.5 days to 73.16 days. On the cultivar 'Fox Red', BA at 50

mg•L<sup>-1</sup> plus GA<sub>7</sub> at 12.5 mg•L<sup>-1</sup> accelerated flowering by 2.5 days from 70.5 days to 68.0 days. These results indicate that further research could be done to further accelerate the flowering time by increasing the concentration of BA or the number of applications.

#### **7.3.11 *Impatiens hawkeri* 'Red Fox Riviera Bright Red'**

*Impatiens hawkeri* 'Red Fox Riviera Bright Red' (New Guinea Impatiens) was studied to determine if BA would affect the number of days to flowering on plants when applied after the buds had formed. Plugs were received in 105 count hex plug trays (2.77 cm hex by 4.44 cm deep, with a volume of 17.9 ml) and were potted on 7 February. Full grown and budded plants in 5" pots were used. There were 6 single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 50, 100, 200, 400, 800, and 1600 mg•L<sup>-1</sup> was made on 25 March when the plants had flower buds in the 4 to 6 mm size range (Kehoe 2008). Data recorded at 4 weeks after spraying included height, average diameter, growth index, number of branches, phytotoxicity rating, number of flowers and the number of days until the first flower opened. The only variable that BA controlled was the number of branches (Table 7.7). The optimal concentrations were 100 to 800 mg•L<sup>-1</sup> which increased branching by 12 to 20% over the control group. Some very minor phytotoxicity symptoms appeared at 800 and 1600 mg•L<sup>-1</sup> in the form of marginal chlorosis (Figure 7.7) on a few leaves. These results are not commercially useful, but indicate that further research should be done with increased BA concentrations or number of applications.

#### **7.3.12 *Ipomoea batatas***

*Ipomoea batatas* 'Sweet Caroline Red' (Ornamental Sweet Potato Vine) was studied to determine if BA could be used to increase the number of cuttings that could be harvested off

of stock plants grown during the winter. Plugs were received in 105 count hex plug trays (2.77 cm hex by 4.44 cm deep, with a volume of 17.9 ml). Plants were potted on 4 November into 6" pots with Berger BM6 substrate. The plants were pinched at 5.5 WAP in order to even out their size. There were 5 single plant replications per treatment. Foliar sprays of BA at concentrations of 0 (water), 12.5, 25, 50, 75, 100, 200, 300, 400, 800, and 1600 mg•L<sup>-1</sup> were made at 8, 10, 12, and 14 WAP. The data recorded at 16 WAP included the number of branches and the number of 3-node cuttings that were collected per plant. BA did not affect branching or increase the number of cuttings that each stock plant produced. BA at 800 and 1600 mg•L<sup>-1</sup> caused significant phytotoxicity in the form of leaf edge necrosis, leaf death, and also resulted in fewer cuttings per plant. The control group produced an average of 43.0 cuttings per plant and both the 800 and 1600 mg•L<sup>-1</sup> groups produced an average of 24.4 cuttings per plant. These results indicate that sprays of BA have no potential commercial use for stock plant maintenance of ornamental sweet potatoes. However, it is possible that drenches of BA may have beneficial effects and should not be ruled out because drenches could increase the number of slips produced in the crown of the plant.

### **7.3.13 *Iresine* hybrid**

*Iresine* hybrid 'Blazin Rose' was studied to determine if BA foliar sprays would increase branching or affect the growth habit. Plugs were received in 17 cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plugs were potted on 28 March into 6" pots with Fafard 4P substrate. There were 5 single plant replications per treatment. Foliar sprays of BA at concentrations of 0 (water), 200, 400, 800, 1600, and 3200 mg•L<sup>-1</sup> were made at 2 WAP. The data recorded at 5 WAP included height, average diameter, growth

index, number of branches, and phytotoxicity rating. At 3200 mg•L<sup>-1</sup> there was some phytotoxicity in the form of leaf cupping (Figure 7.8). BA at all concentrations except for 200 mg•L<sup>-1</sup> increased the number of branches compared to the control group (Table 7.8). The optimal concentration that did not cause phytotoxicity was 1600 mg•L<sup>-1</sup>, which increased the number of branches by 40% over the control. BA appeared to accelerate the emergence of the axillary buds at each node, but did not induce quiescent buds to sprout. These results suggest that future research should be done using multiple applications of BA to try and improve on these results. However, these results are not commercially useful.

#### **7.3.14 *Lantana camara* 'Miss Huff'**

*Lantana camara* 'Miss Huff' was studied to determine if BA foliar sprays would increase branching, affect the growth habit, or affect flowering. Plugs were purchased in 51 count plug flats (2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plugs were potted on 18 March into 6" pots with Fafard 4P substrate. There were 5 single plant replications per treatment. Foliar sprays of BA at concentrations of 0 (water), 40, 60, 80, 100, and 120 mg•L<sup>-1</sup> were made at 2 WAP. Another treatment group was pinched at 2 WAP to compare the growth of pinched versus sprayed plants. The data recorded at 6 WAP included height, average diameter, growth index and number of flowers. In this experiment, BA did not control any of the variables measured (data not shown). These results indicate that single sprays of BA have no potential commercial uses on 'Miss Huff' lantana at these concentrations. However, it is possible that multiple applications of BA or combinations of BA plus a second pinch may have beneficial effects and should not be ruled out.

### **7.3.15 *Lantana camara* 'Lucky Red Hot Imp'**

*Lantana camara* 'Lucky Red Hot Imp' was studied to determine if BA foliar sprays would increase branching, affect the growth habit, or affect flowering. Plugs were potted on 28 March into 6" pots with Fafard 4P substrate. There were 5 single plant replications per treatment. Foliar sprays of BA at concentrations of 0 (water), 200, 400, 800, 1600, and 3200 mg•L<sup>-1</sup> were made at 2 WAP. The data recorded at 5 WAP included height, average diameter, growth index, number of branches, number of flowers, number of branches plus flowers, the ratio of branches to flowers, and phytotoxicity rating. BA did not control any of the variables, except for the number of branches. At 3200 mg•L<sup>-1</sup> BA the number of branches were 50% less than the control (data not shown). Also, at 3200 mg•L<sup>-1</sup> there was some phytotoxicity in the form of edge necrosis on older leaves. Although statistically significant, these results are not commercially useful as growers need to increase the branching of lantana. However, it is possible that multiple applications of BA or combinations of BA plus a second pinch may have beneficial effects and should not be ruled out.

### **7.3.16 *Lantana camara* 'New Gold'**

*Lantana camara* 'New Gold' was studied to determine if BA foliar sprays at particular times would increase branching or affect the growth habit or flowering. Plugs were received on 6 June in 51 strip EZ Elle trays and were potted into 5.5" pots with Fafard 4P substrate. There were 5 single plant replications per treatment group. The plugs were pinched at potting to even out their size and to remove flower buds. The plants were treated with BA at concentrations of 800, 1200 or 1600 mg•L<sup>-1</sup> at 2 WAP, 2 and 3 WAP, or 2 and 4 WAP. Data were collected at 5 WAP and included height, average diameter, growth index, number of

branches, phytotoxicity rating, number of flowers, the ratio of flowers to branches, the ratio of flowers to growth index, and the number of branches per unit height. BA at all concentrations and timings increased branching (Table 7.9), but no other variable was affected. BA at 800 mg•L<sup>-1</sup> applied at 2 and 4 WAP increased branching the most and more than doubled the number of branches over the control group. These results indicate that multiple foliar sprays of BA have potential commercial use as a branching agent on lantana. Further research should be done to determine the optimal spray timing and to test 3 or more spray applications.

### **7.3.17 *Liatris spicata***

*Liatris spicata* (Gayfeather) was studied to determine if pre-plant bulb soaks in BA solutions would result in a shorter plant height without affecting flowering. On 11 January, 8 to 10 cm wide bulbs were soaked for 5 minutes in BA 100 mg•L<sup>-1</sup> plus flurprimidol (Topflor, SePro, Indianapolis, IN) 0, 12.5, 25, 37.5, or 50 mg•L<sup>-1</sup>. The bulbs were allowed to dry overnight. The bulbs were planted into 6" pots with Berger BM6 substrate. There were 5 bulbs per pot. The data recorded was the number of days to plant emergence, number of days to flower, plant height at flowering, and inflorescence height at flowering (from the bottom flower on the inflorescence to the top flower). Data were analyzed via 2-way analysis of variance to compare the affects of BA and flurprimidol separately and together. The results showed that BA had no effect on any of the variables. Flurprimidol did not effect plant height or flower height but delayed flowering by up to 23 days at 50 mg•L<sup>-1</sup> compared to the control (data not shown). These results indicate that BA bulb soaks have no potential commercial uses on *Liatris* at these concentrations and that flurprimidol does not control plant height and

negatively affects flowering. However, it is possible that much lower or much higher concentrations of BA may have beneficial effects and should not be ruled out. It is also possible that BA drenches made at plant emergence or BA sprays made when plants have reached a certain height could have an effect on flowering.

#### **7.3.18 *Oenothera fruticosa youngii***

*Oenothera fruticosa youngii* (Sundrops) was studied to determine if BA foliar sprays would increase branching or affect the growth habit or flowering. Plugs were received in 34 (17 by 2) cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plants were potted on 9 April into 6” pots with Fafard 4P substrate. There were 5 single plant replications per treatment. A single foliar spray of BA at 0 (water), 50, 100, 200, 400, 800, and 1600 mg•L<sup>-1</sup> was made 4 WAP. Data recorded at 7 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating, and the number of days until the first flower opened. BA did not affect any of the measured variables in this experiment (data not shown). The 1600 mg•L<sup>-1</sup> spray concentration caused phytotoxicity in the form of leaf cupping (Figure 7.9). These results indicate that single sprays of BA have no potential commercial uses on sundrops. However, it is possible that multiple applications of BA may have beneficial effects and should not be ruled out.

#### **7.3.19 *Pentas lanceolata***

*Pentas lanceolata* ‘Rio Rose’ was studied to determine if BA foliar sprays would increase branching or affect the growth habit or flowering. Plugs were received in 84 count cells (round cells 3.17 cm diameter and 4.44 cm deep, with a volume of 21.7 ml). Plants were potted on 23 April into 6” pots with Fafard 4P substrate. There were 4 single plant

replications per treatment. A single foliar spray at concentrations of 0 (water), 100, 200, 400, and 800 mg•L<sup>-1</sup> was made 2 WAP. Data recorded at 4 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating, number of flowers and number of buds. BA did not affect any of the measured variables (data not shown). No phytotoxicity was noted. These results indicate that single sprays of BA have no potential commercial uses on pentas at these concentrations. However, it is possible that multiple applications of BA or much lower or higher concentrations may have beneficial effects and should not be ruled out.

#### **7.3.20 *Portulaca oleracea***

*Portulaca oleracea* 'Rio Yellow' and 'Rio Scarlet' (Purslane) were studied to determine if BA foliar sprays would increase branching, affect the growth habit, or affect flowering. Plugs were received in 17 cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plants were potted on 23 April into 6" pots with Fafard 4P substrate. There were 5 single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 100, 200, 400, 800 and 1600 mg•L<sup>-1</sup> was made 2 WAP. Data recorded at 6 WAP included height, average diameter, and number of branches. BA did not affect any of the measured variables in the cultivar 'Rio Scarlet' (data not shown). However, in the cultivar 'Rio Yellow', BA increased the number of branches when compared to the control group (Table 7.10). The optimal concentration was 800 mg•L<sup>-1</sup>, which had an average of 14 more branches per plant than the control. These results indicate that single sprays of BA have potential commercial use as a branching agent on purslane. Further research should investigate the effect of multiple applications of BA.

### **7.3.21 *Pseuderanthemum atropurpureum***

*Pseuderanthemum atropurpureum* 'Black Varnish' (Varnish plant) was studied to determine if BA foliar sprays would increase branching or affect the growth habit. Plugs were received in 84 count cells (round cells 3.17 cm diameter and 4.44 cm deep, with a volume of 21.7 ml). Plants were potted on 23 April into 6" pots with Fafard 4P substrate. There were 4 single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 100, 200, and 400 mg•L<sup>-1</sup> was made 2 WAP. Data recorded at 4 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating and the leaf size index (refer to the *Acalypha* section for details) of the largest leaf on the plant. BA did not affect any of these variables (data not shown). However, there were indications that branching could be affected as branch number increased from 2.5 to 5.2 for the 0 and 400 mg•L<sup>-1</sup> BA sprays ( $P \leq 0.0549$ ). Further research should be done with higher concentrations and more applications of BA to investigate this possibility. No phytotoxicity was noted.

### **7.3.22 *Rudbeckia hirta***

*Rudbeckia hirta* 'Becky Mix' (Black-eyed Susan) was studied to determine if BA foliar sprays would increase branching, affect the growth habit, or affect flowering. Plugs were received in 34 (17 by 2) cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plants were potted on 9 April into 6" pots with Fafard 4P substrate. There were 5 single plant replications per treatment. A single foliar spray at concentrations of BA at 0 (water), 50, 100, 200, 400, 800, and 1600 mg•L<sup>-1</sup> was made 4 WAP. Data recorded at 7 WAP included height, average diameter, growth index, phytotoxicity rating and the number of days until the first flower opened. BA at 50 mg•L<sup>-1</sup> increased the height of the plants. The

middle concentrations: 100, 200, and 400 mg•L<sup>-1</sup>, had no impact on plant height. The high concentrations 800 and 1600 mg•L<sup>-1</sup> resulted in a lower plant height (Table 7.11)(Figure 7.10) compared to control. BA at 400, 800, and 1600 mg•L<sup>-1</sup> resulted in a lower growth index as well. None of the other variables measured were affected. The average number of days until the first flower opened was 55.0 days (±11.2) and the timing was not affected by BA. Further studies should be done with BA sprays on *Rudbeckia hirta* to map out the growth increase at low concentrations (around 50 mg•L<sup>-1</sup>) and to determine the effects of multiple applications on growth. Phytotoxicity was observed on the leaves at 800 and 1600 mg•L<sup>-1</sup> in the form of interveinal and edge chlorosis. These results indicate that single sprays of BA have potential commercial use as a growth retardant on Black-eyed Susan. Further research should investigate the effect of multiple applications of BA.

### **7.3.23 *Salvia splendens***

*Salvia splendens* 'Dancing Flame' was studied to determine if BA foliar sprays would increase branching, affect the growth habit, or affect flowering. Plugs were received in 84 count cells (round cells 3.17 cm diameter and 4.44 cm deep, with a volume of 21.7 ml). Plants were potted on 23 April into 6” pots with Fafard 4P substrate. There were 5 single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 100, 200, 400, 800, and 1600 mg•L<sup>-1</sup> was made 2 WAP. Data recorded at 4 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating, the number of flowers and number of buds. BA increased the number of branches produced by the plant at 4 WAP (Table 7.12). The optimal results occurred at 100 mg•L<sup>-1</sup> with a 67% increase in the number of branches over the control group. Visually, the 100 mg•L<sup>-1</sup> plant canopies looked

slightly denser than the control plants at 4 WAP. None of the other variables were affected by BA. There was some phytotoxicity at 800, and 1600 mg•L<sup>-1</sup> in the form of leaf cupping, formation of very small leaves and some edge necrosis. These results indicate that single sprays of BA have potential commercial use as a branching agent on annual salvia. Further research should investigate the effect of multiple applications of BA.

#### **7.3.24 *Scabiosa caucasica***

*Scabiosa caucasica* 'Perfecta alba' (Pincushion flower) was studied to determine if BA foliar sprays would increase branching, affect the growth habit, or affect flowering. Plugs were received in 34 (17 by 2) cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a volume of 20 ml). Plants were potted on 9 April into 6" pots with Fafard 4P substrate. There were 5 single plant replications per treatment. A single foliar spray of BA at concentrations of 0 (water), 50, 100, 200, 400, 800, and 1600 mg•L<sup>-1</sup> was made 4 WAP. Data recorded at 7 WAP included height, average diameter, growth index, phytotoxicity rating, the number of leaves, the number of crowns, the number of days until the first flower opened, and the number of buds on the plant at the time the first flower opened. BA did not affect any of the variables measured (data not shown). There was some phytotoxicity at 1600 mg•L<sup>-1</sup> in the form of leaf crinkling, and some leaf tip chlorosis (Figure 7.11). These results indicate that single sprays of BA have no potential commercial uses on Pincushion flower at these concentrations. However, it is possible that multiple applications of BA or applications made when the plant is closer to flowering might have beneficial effects, and so BA should not be ruled out as a PGR on this plant.

### **7.3.25 *Scutellaria hybrid***

*Scutellaria hybrid* 'Red Flamingo' (Skullcap) was studied to determine if BA foliar sprays would increase branching or affect the growth habit or flowering. Plugs were received in 84 count cells (round cells 3.17 cm diameter and 4.44 cm deep, with a volume of 21.7 ml). Plants were potted on 23 April into 6” pots with Fafard 4P substrate. There were 5 single plant replications per treatment. A single foliar spray at concentrations of 0 (water), 100, 200, and 400, mg•L<sup>-1</sup> was made 2 WAP. Data recorded at 4 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating, the number of flowers and the number of buds. BA had no effect on any of the variables measured (data not shown). These results indicate that single sprays of BA have no potential commercial uses on skullcap at these concentrations. However, it is possible that multiple applications of BA or much lower or higher concentrations may have beneficial effects and should not be ruled out.

### **7.3.26 *Senecio cineraria***

*Senecio cineraria* (Dusty Miller) was studied to determine if BA foliar sprays, drenches or fertigation would increase branching or affect the growth habit. Plugs were received in 288 count plug flats (square cells 1.9 cm wide and 2.84 cm deep, with a volume of 6.3 ml). Plants were potted on 7 June into 4.5” pots with Fafard 4P substrate. There were 5 single plant replications per treatment. Plants were treated with sprays, drenches and fertigation treatments (similar to the *Catharanthus* section above). Single foliar spray at concentrations of 0 (water), 50, 75, 100, 150, 200, 300, 400, and 800 mg•L<sup>-1</sup> were made at 2, 3 or 4 WAP. A single drench of 0, 5, 7.5, 10, 15, and 20 mg ai per pot were made at 2 or 3 WAP. Fertigation

concentrations of 0, 2, 4, 8, 12, and 16 mg•L<sup>-1</sup> were also made. Data were recorded at 5.5 WAP and included height, average diameter, growth index, phytotoxicity rating and the number of leaves.

#### **7.3.26.1 Spray**

BA sprays did not control height (data not shown), but the results suggest that further research should be pursued in this area as the plant height ranged from 10.75 cm for 0 and 9.62 cm for 800 mg•L<sup>-1</sup> ( $P \leq 0.730$ ). BA did affect the average diameter (Table 7.13). The 2 and 3 WAP treatments were inconsistent but the 4 WAP treatments controlled average diameter at every concentration except 400 and 800 mg•L<sup>-1</sup>. BA applied 2 WAP at 50 mg•L<sup>-1</sup> increased the growth index compared to the control by 44% (data not shown). No other concentration affected growth index. BA applied 2 WAP at 300 mg•L<sup>-1</sup> increased the number of leaves per plant compared to the control by 52% (data not shown). No other concentration affected the number of leaves per plant. None of the other variables measured were affected by BA. There was some phytotoxicity in the 4 WAP spray treatments at 75 mg•L<sup>-1</sup> and higher in the form of minor leaf cupping. These results indicate that foliar sprays of BA have potential commercial use as a branching agent on dusty miller. Further research should be done to determine the effect of multiple applications and different application timings.

#### **7.3.26.2 Drench**

BA drenches resulted in a lower plant height at all amounts and application timings (Table 7.13). The most effective amount was the 2 WAP treatment of 10 mg ai, which resulted in heights more than 50% smaller than the control. BA drenches also controlled the average diameter of the Dusty Miller plants at all amounts and application timings (Table 7.14),

except for the 3 WAP treatment of 10 mg ai. The most effective amount was the 2 WAP treatment of 20 mg ai, which resulted in an average diameter only 60% the size of the control group. However, this amount diminished the retail quality of the plants and so was not beneficial. Similarly, BA drenches resulted in a lower growth index at all amounts and timings. The most effective treatment was the 20 mg ai at 2 WAP, which resulted in plants with a growth index of just 19% of the control. However, this amount diminished the retail quality of the plants and so was not beneficial. BA drenches did not affect any of the other variables measured. There was some phytotoxicity in the form of leaf cupping with BA drenches, but the effect was inconsistent from treatment to treatment. These results indicate that drenches of BA have potential commercial use as a growth inhibitor on dusty miller but the drench effects were not as good as foliar sprays. Further research should be done to determine the effect of multiple applications and different application timings.

### **7.3.26.3 Fertigation**

BA fertigation treatments on dusty miller plants increased the plant height at low concentrations (2 to 4 mg•L<sup>-1</sup>) and decreased the height at higher concentrations (Table 7.15). The largest height increase was measured at 4 mg•L<sup>-1</sup> and was 21% taller than the control. The largest height reduction was at 16 mg•L<sup>-1</sup> and the plants were only 75% the height of the control group. The average diameter of the plants was smaller at concentrations of 8, 12, and 16 mg•L<sup>-1</sup>. The most effective concentration was 16 mg•L<sup>-1</sup> and resulted in plants that had diameters that were 70% of the diameter of the control. The growth index was less for the 12, and 16 mg•L<sup>-1</sup> concentrations. The most effective decrease in growth index was at 16 mg•L<sup>-1</sup>. The plants had a growth index only 35% of the control group. None

of the other variables measured were affected by BA fertigations, but there were indications that low concentrations increased the number of leaves and higher concentrations decreased the number. Further research is warranted to explore this effect further. These results indicate that fertigations with low concentrations of BA have potential commercial use as a growth enhancer on dusty miller. There is some potential commercial use for BA fertigations to decrease height, but overall, foliar sprays are more effective.

#### **7.3.27 *Solenostemon scutellarioides* 'Red Coat'**

*Solenostemon scutellarioides* 'Red Coat' (Coleus) was studied to determine if BA foliar sprays would increase branching or affect the growth habit. Plugs were purchased in 51 count plug flats (2.7 cm hex by 4.29 cm deep, with a volume of 20 ml) and potted on 18 March into 6" pots with Fafard 4P substrate. The plants were all pinched 2 WAP. There were 5 single plant replications per treatment. Foliar sprays of BA at concentrations of 0 (water), 40, 60, 80, 100, and 120 mg•L<sup>-1</sup> were made at 3 WAP. An additional treatment consisted of plants pinched a second time at 4 WAP. The data recorded at 6 WAP included height, average diameter, and growth index. BA did not affect any of the variables measured (data not shown). These results indicate that single sprays of BA have no potential commercial uses on coleus at these concentrations. However, it is possible that multiple applications of BA or much higher concentrations may have beneficial effects and should not be ruled out.

#### **7.3.28 *Solenostemon scutellarioides* 'Mint Mocha' and 'Indian Summer'**

*Solenostemon scutellarioides* 'Mint Mocha' and 'Indian Summer' (Coleus) were studied to determine if BA foliar sprays would increase branching or affect the growth habit. Plugs were received in 17 cell plug tray strips (hex cell 2.7 cm hex by 4.29 cm deep, with a

volume of 20 ml). Plugs were potted on 28 March into 6” pots with Fafard 4P substrate. There were 5 single plant replications per treatment. Foliar sprays of BA at concentrations of 0 (water), 200, 400, 800, 1600, and 3200 mg•L<sup>-1</sup> were made at 2 WAP. The data recorded at 5 WAP included height, average diameter, growth index, number of branches, and phytotoxicity rating. BA did not affect any of the variables measured for the cultivar 'Mint Mocha'. BA spray concentrations resulted in plants with a lower growth index in cultivar 'Indian Summer'. The only statistically significant effect occurred at 1600 mg•L<sup>-1</sup> and the plants had growth indices only 68% the value of the control group (data not shown). These results indicate that single sprays of BA have no potential commercial uses on coleus at these concentrations.

#### **7.3.29 *Sutera cordata***

*Sutera cordata* (Bacopa) was studied to determine if BA foliar sprays would increase branching or affect the growth habit. Plugs were purchased in 50 count plug flats (2.7 cm hex by 4.29 cm deep, with a volume of 20 ml) and potted on 18 March into 6” pots with Fafard 4P substrate. The plants were all pinched at 2 WAP. There were 5 single plant replications per treatment. Foliar sprays of BA at concentrations of 0 (water), 40, 60, 80, 100, and 120 mg•L<sup>-1</sup> were made at 3 WAP. An additional treatment group consisted of plants pinched a second time at 4 WAP. The data recorded at 6 WAP included height, average diameter, and growth index. BA did not affect any of the variables measured (data not shown). These results indicate that single sprays of BA have no potential commercial uses on bacopa at these concentrations. However, it is possible that multiple applications of BA or much higher concentrations may have beneficial effects and should not be ruled out.

### **7.3.30 *Verbena* hybrid**

*Verbena* hybrid (unknown red cultivar) was studied to determine if BA foliar sprays would increase branching, affect the growth habit, or affect flowering. Plugs were purchased in 84 count hex cell flats (round cells 3.17 cm diameter and 4.44 cm deep, with a volume of 21.7 ml) and potted on 9 February into 6” pots with Fafard 4P substrate. There were 7 single plant replications per treatment. Foliar sprays of BA at concentrations of 0 (water), 20, 40, 80, 120, and 160 mg•L<sup>-1</sup> were made at 2 WAP. An additional treatment group consisted of plants pinched at 2 WAP. The data recorded at 8 WAP included height, average diameter, and growth index and the number of days to reach the 5<sup>th</sup> open flower on the plant. BA did not affect any of the variables measured (data not shown). These results indicate that single sprays of BA have no potential commercial uses on verbena at these concentrations. However, it is possible that multiple applications of BA or much higher concentrations may have beneficial effects and should not be ruled out.

### **7.3.31 *Viola* ×*wittrockiana***

*Viola* ×*wittrockiana* 'Alpine Sun', 'Delta Pure Rose', 'Gem Antique Lavender', 'Imperial Frosty Rose', 'Majestic Giant Patricia', 'Matrix Orange', and 'Supreme Orange', (Pansy & *Viola*) were studied to determine if BA foliar sprays would increase branching, affect the growth habit, or affect flowering. Plugs were received on 12 September, 2007 in 288 cell plug flats (square cells 1.9 cm wide and 2.84 cm deep, with a volume of 6.3 ml). The cultivars represented fast, medium, and slow growing cultivars of pansy's and violas. The plants were potted on 24 September into 1801 cell packs (an 18 cell flat with whole flat dimensions of 53.34 x 26.67 x 5.71 cm, with a volume of 5310 ml). At 1 WAP, the plants

were sprayed with BA at concentrations of 0 (water), 100, 200, 400 and 800 mg•L<sup>-1</sup>. The data recorded at 5 WAP included height, average diameter, growth index, number of flowers, number of branches and phytotoxicity rating. The slow growing cultivars (Viola 'Alpine Sun' and 'Gem Antique Lavender' (Table 7.16)) were well controlled with BA. All of the growth variables were controlled, except for the number of branches. In general, increasing concentrations of BA decreased the size and delayed flowering of the plants. Phytotoxicity occurred at 400 and 800 mg•L<sup>-1</sup> in the form of chlorotic new leaves and minor leaf cupping (Figure 7.12). The fast growing cultivar ('Majestic Giant Patricia' (Table 7.18)) had less growth and an increase in branching with increasing concentrations of BA. Flowering was not affected. However, phytotoxicity was evident at every treatment level in the form of chlorotic leaf edges and leaf cupping. Two of the medium growth rate (Table 7.17) cultivars ('Delta Pure Rose', 'Supreme Orange') were generally unresponsive to BA, except for an increase in branching. The other two medium growth rate cultivars ('Imperial Frosty Rose', 'Matrix Orange') had less growth, an increase in branching, and less flowering with BA. All of the medium growth rate cultivars exhibited phytotoxicity at every treatment level in the form of chlorotic leaf edges and leaf cupping. In all cases, the phytotoxicity disappeared over time. Although BA improves the growth characteristics of pansies, it cannot be used as a foliar spray during typical production times because of the phytotoxicity. Further research should be done to investigate drench or fertigation applications of BA to determine if plants show the growth responses without the phytotoxicity.

### **7.3.32 *Zinnia elegans***

*Zinnia elegans* 'Dreamland Scarlet' was studied to determine if BA foliar sprays, drenches or fertigation would increase branching or affect the growth habit or flowering. There were two parts to this experiment. In part one, *Zinnia* seeds were sown into 1206 cell packs (a 72 cell flat with whole flat dimensions of 53.34 x 26.67 x 5.71 cm, with a volume of 4224 ml) on 12 June. Seedlings were potted into 4.5" pots on 4 July with Fafard 4P substrate. There were 5 single plant replications per treatment. Plants were treated with sprays, drenches and fertigation. Single foliar spray at concentrations of 0 (water), 50, 100, 200, 400, and 800 mg•L<sup>-1</sup> were made at 1, 2 or 3 WAP. Single drench amounts of 0, 2.5, 5, 7.5, and 10 mg ai per pot were made at 2 or 3 WAP. Fertigation concentrations were 0, 2, 4, 8, 12, and 16 mg•L<sup>-1</sup>. Data recorded at 4 WAP included height, average diameter, growth index, number of branches, phytotoxicity rating, number of flowers, number of buds, number of nodes, branch to height ratio, branch to growth index ratio, node to height ratio, and node to branch ratio.

#### **7.3.32.1 Spray – Part 1**

BA sprays controlled some of the growth variables and flowering variables (Table 7.19). The branch to growth index ratio (a measure of the “branchiness” of the plants) was increased by 800 mg•L<sup>-1</sup> at 1 WAP indicating that BA provided some minor improvement to branching. The number of nodes per unit height (a measure of the average internode length) was increased by 800 mg•L<sup>-1</sup> at 1 WAP, 400 and 800 mg•L<sup>-1</sup> at 2 WAP, and 100 mg•L<sup>-1</sup> at 3 WAP. This indicated that BA decreased the average internode length and also that the effective concentrations decreased as the plant grew older. BA decreased the number of flowers and buds when applied at the 2 and 3 WAP times. However, BA at 100 mg•L<sup>-1</sup> applied 1 WAP

increased the number of flowers and buds. Phytotoxicity appeared as leaf yellowing and leaf crinkling and was worse at higher spray concentrations and later spray timings (e.g., 800 mg•L<sup>-1</sup> at 3 WAP) (Figure 7.13). Phytotoxicity was not apparent at lower spray concentrations and earlier timings.

#### **7.3.32.2 Drench**

BA drenches applied at 3 WAP (Table 7.20) resulted in less flowers and buds at all concentrations. BA drenches at 2 WAP decreased the flower and bud count only at 5 mg ai. Drench applications did not affect any other measured variable. Phytotoxicity was fairly minor and appeared at 10 mg ai applied 3 WAP as a slight yellowing of the entire plant. These results indicate that drenches of BA have no potential commercial uses on Zinnia at these concentrations.

#### **7.3.32.3 Fertigation**

BA applied in the fertigation solution (Table 7.21) resulted in a lower growth index and average diameter, but not height at all concentrations. The plants were narrower, but not shorter. Fertigation also decreased the number of branches, nodes, flowers and buds at all concentrations trialed. Phytotoxicity was fairly minor and appeared at 16 mg•L<sup>-1</sup> as a slight yellowing of the entire plant. These results indicate that fertigations of BA have no potential commercial uses on zinnia at these concentrations. However, lower concentrations may have some affect and should be investigated.

#### **7.3.32.4 Spray – Part 2**

The second part of the zinnia experiment consisted only of foliar spray applications and explored the effects of multiple applications. Seeds were sown into 1206 cell packs (a 72

cell flat with whole flat dimensions of 53.34 x 26.67 x 5.71 cm, with a volume of 4224 ml) on 11 July 2008. Seedlings were potted up into 4.5” pots on 1 August with Fafard 4P substrate. There were 5 single plant replications per treatment. Plants were treated with foliar sprays at concentrations of 0 (water), 20, 40, 60, 80, 100, 120, and 140 mg•L<sup>-1</sup> and applications were made at 1 WAP, 1 and 2 WAP, or 1, 2 and 3 WAP. Data were recorded at 4 WAP and included height, average diameter, growth index, number of branches, phytotoxicity rating, number of flowers, number of buds, number of nodes, branch to height ratio, branch to growth index ratio, node to height ratio, and node to branch ratio. Multiple BA sprays did affect some growth characteristics of the plants (Table 7.22). BA sprayed once or twice was inconsistent at controlling height. When it was sprayed 3 times, it consistently decreased plant height at concentrations above 20 mg•L<sup>-1</sup>. BA controlled the growth index at most of the concentrations and timings in the trial. BA sprayed 3 times increased the number of branches produced on each plant with the optimal results at 80 mg•L<sup>-1</sup> applied 3 times, which nearly doubled the number of branches compared to the control. BA also controlled the number of branches per unit height (Table 7.23) optimally when sprayed 3 times and almost tripled the value at 80 mg•L<sup>-1</sup> applied 3 times. BA increased the number of nodes per plant only when sprayed 3 times with the optimal value (55% higher than the control) at 80 mg•L<sup>-1</sup>. BA increased the number of nodes per unit height optimal when sprayed 3 times with the optimal concentration at 80 mg•L<sup>-1</sup>. Phytotoxicity generally appeared as leaf crinkling and interveinal chlorosis, and was worse with 3 applications than with 1 or 2. The worst phytotoxicity occurred at 140 mg•L<sup>-1</sup> applied 3 times. The results of this experiment show that there are potential commercial uses for

multiple spray applications of BA on zinnias. However, phytotoxicity is a concern as it gets worse as application number increases.

#### **7.4 Discussion**

There is evidence that BA may be used on many species as a branching agent and to decrease plant size. Table 7.24 summarizes the effects of BA on all of the plants in this experiment. Spray applications were generally better than drench applications or fertigation. Phytotoxicity was a problem on most of these plants at high concentrations although the sensitivity of each species varied widely. *Exacum* was the most sensitive species trialed and exhibited phytotoxicity at the lowest concentration used ( $50 \text{ mg}\cdot\text{L}^{-1}$  applied 2 times). Pansies too were very sensitive and some cultivars exhibited phytotoxicity at only  $100 \text{ mg}\cdot\text{L}^{-1}$  applied once. Coleus, however, was very tolerant of BA and did not show any phytotoxicity at concentrations up to  $3200 \text{ mg}\cdot\text{L}^{-1}$ . BA tended to delay or inhibit flowering in some of the plants trialed. However, BA increased the number of flowers present on 'Dragon Wing' *Begonia* at 6 WAP and on *Zinnia* when applied once at  $100 \text{ mg}\cdot\text{L}^{-1}$ . Multiple applications of BA tended to be more effective at stimulating branching and reducing plant size than a single application. Although BA tended to decrease growth related variables in the plants studied here, there is evidence that at very low concentrations (typically under  $50 \text{ mg}\cdot\text{L}^{-1}$ ) it may actually increase the growth of plants.

#### **7.5 Literature Cited**

- Beach, S.E. 2005. Shipping and nitrogen toning effects on postharvest shelf life of vegetative annuals, Floriculture, Texas A&M University.
- Boyle, T.H. 1992. Modification of plant architecture in 'Crimson Giant' Easter cactus with benzyladenine. *J. Amer. Soc. Hort. Sci.* 117 (4):584-589.

- Carpenter, W. J., and G.R. Beck. 1972. Growth regulator induced branching of poinsettia stock plants. *HortScience* 7 (4):405-406.
- Emino, E.R., J.E. Barrett, and D.G. Clark. 2002. Mediation of ethylene damage during shipping of geranium cuttings: Application of anti-ethylene growth regulators and cytokinins. *Proceedings of the plant growth regulation society of America* 29:181-185.
- Hansen, C.E., C. Kopperud, and O.M. Heide. 1988. Identity of cytokinins in *Begonia* leaves and their variation in relation to photoperiod and temperature. *Physiol. Plant.* 73:387-391.
- Jaroenkit, T., and R.E. Paull. 2003. Postharvest handling of *Heliconia*, red ginger, and bird-of-paradise. *HortTechnology* 13 (2):259-266.
- Kehoe, R. 2008. Timing with a bud meter. *GrowerTalks*, 71 (10):34.
- Khademi, M., and M. Khosh-Khui. 1977. Effect of growth regulators on branching, flowering, and fruit development of ornamental pepper (*Capsicum annum* L.). *J. Amer. Soc. Hort. Sci.* 102 (6):796-798.
- King, J.W., J.B. Beard, and P.E. Rieke. 1982. Factors affecting survival of Kentucky bluegrass sod under simulated shipping conditions. *J. Amer. Soc. Hort. Sci.* 107 (4):634-637.
- Letham, D.S. 1994. Cytokinins as phytohormones - Sites of biosynthesis, translocation, and function of translocated cytokinin. In *Cytokinins: Chemistry, Activity and Function*, eds. D. W. S. Mok and M. C. Mok, 338. Corvallis, OR: CRC Press.
- Metzger, J.D. 1995. Hormones and reproductive development. In *Plant Hormones: Physiology, Biochemistry, and Molecular Biology*, ed. P. J. Davies, 833. Dordrecht, Boston MA: Kluwer Academic Publishers.
- Wilson, M.R., and T.A. Nell. 1983. Foliar applications of BA increase branching of 'Welkeri' *Dieffenbachia*. *HortScience* 18 (4):447-448.

Table 7.1 Description of the round azalea pot sizes used for this experiment.

| Diameter (in) | Diameter (cm) | Height (cm) | Volume (mL) |
|---------------|---------------|-------------|-------------|
| 4"            | 10.16         | 8.26        | 575         |
| 4.5"          | 11.43         | 8.26        | 606         |
| 5"            | 12.3          | 9.21        | 766         |
| 5.5"          | 13.34         | 11.59       | 1290        |
| 6"            | 14.76         | 10.80       | 1290        |
| 8"            | 19.91         | 14.12       | 2920        |

Table 7.2 Benzyladenine effect on *Acalypha microphylla* leaf size index.

| Concentration (mg•L <sup>-1</sup> ) | 0       | 100    | 200    | 400    |
|-------------------------------------|---------|--------|--------|--------|
| Leaf size index (cm <sup>2</sup> )  | 111.0 a | 92.1 a | 87.7 a | 63.8 b |

Means followed by different letters are significantly different at the  $P < 0.0524$  level using Fisher's LSD.

Table 7.3 The effect of a single foliar spray of benzyladenine on *Begonia* × *hybrida* ‘Dragon Wing Red’.

| Concentration<br>(mg•L <sup>-1</sup> )      | 0       | 40     | 60      | 80     | 100      | 120     |
|---|---------|--------|---------|--------|----------|---------|
| Number of<br>branches                       | 5.4 c   | 5.4 c  | 6.8 bc  | 9.2 a  | 6.8 bc   | 7.2 c   |
| Growth<br>index (thousand cm <sup>3</sup> ) | 29.1 ab | 18.5 c | 21.7 bc | 35.5 a | 28.2 abc | 31.5 ab |
| Number of<br>flowers                        | 0.4 b   | 0.0 b  | 2.0 ab  | 2.4 ab | 3.8 a    | 3.0 a   |

Means followed by different letters within rows are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD.

Table 7.4 The effects of single foliar sprays of benzyladenine on *Catharanthus roseus* ‘Pacifica Lilac’ at 5.5 weeks after potting.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0                  | 50       | 75      | 100     | 150     | 200     | 300      | 400      | 800      |
|--|--------------------|----------|---------|---------|---------|---------|----------|----------|----------|
|  | Number of branches |          |         |         |         |         |          |          |          |
| 2 WAP                                  | 11.4 d             | 12.4 cd  | 14.0 bc | 13.0 cd | 13.0 cd | 16.4 ab | 14.6 abc | 14.0 bc  | 14.4 abc |
| 3 WAP                                  | --                 | 13.8 cd  | 13.0 cd | 13.0 cd | 13.4 cd | 13.8 cd | 13.8 cd  | 14.6 abc | 12.4 cd  |
| 4 WAP                                  | --                 | 14.4 abc | --      | 13.8 cd | --      | 14.2 bc | --       | 16.8 a   | --       |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD.  
 -- indicates that the plant was not tested at that level.

Table 7.5 Effects of a single drench application of benzyladenine on *Catharanthus roseus* 'Pacifica Lilac' at 5.5 weeks after potting.

| Amount<br>(mg ai)                   | 0       | 2.5      | 5.0      | 7.5      | 10.0      | 12.5      | 15.0     | 20.0      |
|-------------------------------------|---------|----------|----------|----------|-----------|-----------|----------|-----------|
| Average diameter (cm <sup>2</sup> ) |         |          |          |          |           |           |          |           |
| 2 WAP                               | 14.2 a  | 13.8 ab  | 11.8 de  | 10.9 e   | 11.6 ed   | 12.3 cd   | 12.4 cd  | 11.4 ed   |
| 3 WAP                               | --      | 13.4 abc | 12.7 bcd | 12.0 de  | 12.6 cd   | 11.6 de   | 12.2 cde | 13.9 ab   |
| Number of branches                  |         |          |          |          |           |           |          |           |
| 2 WAP                               | 11.2 de | 10.8 e   | 11.2 de  | 12.2 de  | 12.0 de   | 13.4 bcde | 15.0 abc | 15.6 ab   |
| 3 WAP                               | --      | 12.4 cde | 11.2 de  | 12.8 cde | 13.6 abcd | 13.0 bcde | 16.2 a   | 13.8 abcd |
| Flower to branch ratio              |         |          |          |          |           |           |          |           |
| 2 WAP                               | 0.55 ab | 0.54 abc | 0.56 abc | 0.32 bcd | 0.41 bcd  | 0.51 abc  | 0.29 cd  | 0.23 d    |
| 3 WAP                               | --      | 0.55 ab  | 0.72 a   | 0.38 bcd | 0.21 d    | 0.36 bcd  | 0.33 bcd | 0.38 bcd  |

Means followed by different letters within rows are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.

-- indicates that the plant was not tested at that level.

Table 7.6 Fertigation applications of benzyladenine effects on *Catharanthus roseus* 'Pacifica Lilac' at 5.5 WAP.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0     | 2     | 4     | 8      | 12     | 16     |
|--|-------|-------|-------|--------|--------|--------|
| Growth index (cm <sup>3</sup> )        | 6779  | 8077  | 6492  | 2400*  | 1444*  | 1794*  |
| Height (cm)                            | 17.44 | 18.82 | 16.36 | 12.40* | 10.72* | 10.85* |
| Average diameter<br>(cm)               | 19.63 | 20.74 | 19.65 | 14.01* | 11.56* | 12.86* |

Means followed by \* are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.

Table 7.7 The effect of a single foliar spray of benzyladenine on the number of branches of *Impatiens hawkeri* 'Red Fox Riviera Bright Red' recorded at 4 weeks after spraying.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0      | 50       | 100      | 200       | 400       | 800    | 1600   |
|--|--------|----------|----------|-----------|-----------|--------|--------|
| Number of branches                     | 8.17 d | 8.83 bcd | 9.83 abc | 10.33 abc | 10.16 abc | 10.5 a | 8.67 d |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.

Table 7.8 The effect of single foliar sprays of benzyladenine on the number of branches present at 5 WAP on *Iresine* hybrid 'Blazin Rose'.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0   | 200  | 400    | 800    | 1600   | 3200   |
|--|-----|------|--------|--------|--------|--------|
| Number of branches                     | 9.0 | 11.0 | 11.4 * | 12.6 * | 13.2 * | 15.6 * |

Means followed by \* are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.

Table 7.9 The effect of foliar sprays of benzyladenine on the number of branches present at 5 WAP on *Lantana camara* 'New Gold'.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0    | 800    | 1200   | 1600   |
|--|------|--------|--------|--------|
| Number of branches                     |      |        |        |        |
| 2 WAP                                  | 10.2 | 14.4 * | 18.4 * | 18.0 * |
| 3 WAP                                  | --   | 13.8 * | 17.0 * | 19.2 * |
| 4 WAP                                  | --   | 21.4 * | 17.6 * | 16.8 * |
| 2 & 3 WAP                              | --   | 21.8 * | 26.2 * | 21.2 * |
| 2 & 4 WAP                              | --   | 28.0 * | 20.0 * | 17.8 * |

Means followed by \* are significantly different at the  $\alpha= 5\%$  level using Fisher's LSD.

Table 7.10 The effect of a single foliar spray of benzyladenine on the branching of *Portulaca oleracea* 'Rio Yellow'.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0      | 100    | 200    | 400    | 800    | 1600    |
|--|--------|--------|--------|--------|--------|---------|
| Number of<br>Branches                  | 41.8 c | 49.2 b | 48.4 b | 40.8 c | 55.8 a | 51.4 ab |

Means followed by different letters are significantly different at the  $\alpha= 5\%$  level using Fisher's LSD.

Table 7.11 The effect of a single foliar spray of benzyladenine on the growth characteristics of *Rudbeckia hirta* 'Becky Mix'.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0     | 50      | 100   | 200   | 400    | 800     | 1600    |
|--|-------|---------|-------|-------|--------|---------|---------|
| Growth index (cm <sup>3</sup> )        | 13614 | 13814   | 13779 | 9781  | 8573 * | 8182 *  | 8419 *  |
| Height (cm)                            | 14.72 | 17.86 * | 15.42 | 12.18 | 12.50  | 11.44 * | 10.53 * |

Means followed by \* are significantly different at the  $\alpha= 5\%$  level using Fisher's LSD.

Table 7.12 The effect of a single foliar spray of benzyladenine on the number of branches of *Salvia splendens* 'Dancing Flame'.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0      | 100    | 200     | 400    | 800    | 1600   |
|--|--------|--------|---------|--------|--------|--------|
| Number of Branches                     | 23.4 b | 39.2 a | 33.4 ab | 35.2 a | 35.2 a | 24.0 b |

Means followed by different letters are significantly different at the  $\alpha= 5\%$  level using Fisher's LSD.

Table 7.13 The effect of a single foliar spray of benzyladenine on the growth characteristics of *Senecio cineraria*.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0    | 50    | 75    | 100   | 150   | 200   | 300   | 400  | 800   |
|--|------|-------|-------|-------|-------|-------|-------|------|-------|
| Average Diameter (cm <sup>2</sup> )    |      |       |       |       |       |       |       |      |       |
| 2 WAP                                  | 21.9 | 21.9  | 20.3  | 21.3  | 20.2  | 21.0  | 18.1* | 21.0 | 18.3* |
| 3 WAP                                  | --   | 21.4  | 20.6  | 21.8  | 20.7  | 18.8  | 19.7* | 20.8 | 18.7  |
| 4 WAP                                  | --   | 18.9* | 19.5* | 17.4* | 18.7* | 18.8* | 17.3* | 21.0 | 19.2  |

Means followed by \* are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.

-- Means that the plant was not tested at that level.

Table 7.14 The effect of drench applications of benzyladenine on the growth characteristics of *Senecio cineraria*.

| Amount<br>(mg ai per pot)           | 0       | 5         | 7.5       | 10       | 15        | 20        |
|-------------------------------------|---------|-----------|-----------|----------|-----------|-----------|
| Height (cm)                         |         |           |           |          |           |           |
| 2 WAP                               | 10.90 a | 6.62 bcd  | 7.30 bc   | 5.36 d   | 6.30 bcd  | 5.72 cd   |
| 3 WAP                               | --      | 7.64 b    | 7.60 b    | 6.84 bcd | 6.42 bcd  | 5.66 cd   |
| Average diameter (cm <sup>2</sup> ) |         |           |           |          |           |           |
| 2 WAP                               | 16.42 a | 11.32 def | 11.78cdef | 10.18 ef | 10.76 def | 9.84 f    |
| 3 WAP                               | --      | 13.42 bc  | 12.16 cde | 14.64 ab | 12.30 cd  | 10.64 def |
| Growth Index (cm <sup>3</sup> )     |         |           |           |          |           |           |
| 2 WAP                               | 2982 a  | 857 cd    | 1133 bcd  | 602 d    | 791 d     | 587 d     |
| 3 WAP                               | --      | 1397 bc   | 1132 bcd  | 1496 b   | 977 bcd   | 615 d     |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.

-- Means that the plant was not tested at that level.

Table 7.15 The effect of fertigation applications of benzyladenine on the growth characteristics of *Senecio cineraria*.

| Amount<br>(mg ai per pot)           | 0        | 2        | 4       | 8         | 12       | 16      |
|-------------------------------------|----------|----------|---------|-----------|----------|---------|
| Height (cm)                         | 13.08 bc | 14.32 ab | 17.36 a | 11.18 bcd | 10.14 cd | 9.60 d  |
| Average diameter (cm <sup>2</sup> ) | 20.46 a  | 19.66 ab | 20.52 a | 17.30 bc  | 14.76 cd | 14.24 d |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.  
 -- Means that the plant was not tested at that level.

Table 7.16 The effect of a single foliar spray application of benzyladenine on the growth characteristics of slow-growth-rate viola cultivars.

| Concentration<br>(mg•L <sup>-1</sup> )             | 0                | 100     | 200     | 400     | 800    |
|--|------------------|---------|---------|---------|--------|
| Alpine Sun & Gem Antique Lavender results combined |                  |         |         |         |        |
| Height (cm)  | 8.30 a           | 7.00 b  | 6.64 bc | 6.46 bc | 5.86 c |
| Average Diameter (cm)                              | 11.44 a          | 10.88 a | 9.04 b  | 7.80 b  | 7.76 b |
| Growth index (cm <sup>3</sup> )                    | 1088 a           | 879 ab  | 570 bc  | 402 c   | 356 c  |
| Number of flowers                                  | 4.8 a            | 2.0 b   | 2.0 b   | 1.4 b   | 1.4 b  |
| Number of branches                                 | – not controlled |         |         |         |        |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.  
 -- Means that the plant was not tested at that level.

Table 7.17 The effect of a single foliar spray application of benzyladenine on the growth characteristics of medium-growth-rate pansy cultivars.

| Concentration<br>(mg•L <sup>-1</sup> )            | 0       | 100     | 200     | 400      | 800    |
|---|---------|---------|---------|----------|--------|
| <b>Delta Pure Rose</b>                            |         |         |         |          |        |
| Height (cm) – not significant                     |         |         |         |          |        |
| Average Diameter (cm) – not significant           |         |         |         |          |        |
| Growth index (cm <sup>3</sup> ) – not significant |         |         |         |          |        |
| Number of flowers – not significant               |         |         |         |          |        |
| Number of branches                                | 3.8 b   | 6.6 a   | 6.8 a   | 7.0 a    | 6.8 a  |
| <b>Imperial Frosty Rose</b>                       |         |         |         |          |        |
| Height (cm)                                       | 11.30 a | 8.42 b  | 7.90 b  | 7.42 b   | 4.94 c |
| Average Diameter (cm)                             | 10.64 a | 9.12 ab | 8.34 bc | 8.66 abc | 6.54 c |
| Growth index (cm <sup>3</sup> )                   | 1380 a  | 699 b   | 547 b   | 536 b    | 246 b  |
| Number of flowers                                 | 1.8 a   | 0.4 bc  | 0.6 b   | 0.2 bc   | 0.0 c  |
| Number of branches                                | 2.2 c   | 5.4 ab  | 6.2 a   | 4.6 b    | 4.8 b  |
| <b>Matrix Orange</b>                              |         |         |         |          |        |
| Height (cm)                                       | 9.04 a  | 8.49 ab | 7.90 bc | 7.58 c   | 6.78 d |
| Average Diameter (cm)                             | 11.57 a | 10.23 b | 9.50 bc | 8.97 c   | 8.71 c |
| Growth index (cm <sup>3</sup> )                   | 1227 a  | 911 b   | 757 bc  | 624 cd   | 560 d  |
| Number of flowers                                 | 1.70 a  | 0.80 b  | 0.63 b  | 0.77 b   | 0.63 b |
| Number of branches                                | 4.93 b  | 6.03 a  | 6.17 a  | 6.13 a   | 6.5 a  |
| <b>Supreme Orange</b>                             |         |         |         |          |        |
| Height (cm) – not significant                     |         |         |         |          |        |
| Average Diameter (cm) – not significant           |         |         |         |          |        |
| Growth index (cm <sup>3</sup> ) – not significant |         |         |         |          |        |
| Number of flowers – not significant               |         |         |         |          |        |
| Number of branches – not significant              |         |         |         |          |        |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.

-- Means that the plant was not tested at that level.

Table 7.18 The effect of a single foliar spray application of benzyladenine on the growth characteristics of fast-growth-rate pansy cultivar.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0       | 100     | 200      | 400    | 800     |
|--|---------|---------|----------|--------|---------|
| <b>Majestic Giant Patricia</b>         |         |         |          |        |         |
| Height (cm) – not significant          |         |         |          |        |         |
| Average Diameter (cm)                  | 12.72 a | 10.74 b | 11.18 ab | 8.72 c | 9.86 bc |
| Growth index (cm <sup>3</sup> )        | 1437 a  | 1104 ab | 1214 a   | 624 c  | 785 bc  |
| Number of flowers – not significant    |         |         |          |        |         |
| Number of branches                     | 3.2 c   | 4.6 bc  | 4.8 b    | 5.6 ab | 6.4 a   |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.

-- Means that the plant was not tested at that level.

Table 7.19 The effect of a single foliar spray application of benzyladenine on the growth characteristics of *Zinnia elegans* ‘Dreamland Scarlet’.

| Concentration<br>(mg•L <sup>-1</sup> )                             | 0        | 50         | 100        | 200        | 400        | 800      |
|--|----------|------------|------------|------------|------------|----------|
| <b>Branch to Growth index ratio (multiplied by 10<sup>3</sup>)</b> |          |            |            |            |            |          |
| 1 WAP  | 0.76 bcd | 0.51 d     | 0.49 d     | 0.52 d     | 0.94 abcd  | 1.28 a   |
| 2 WAP  | --       | 0.58 d     | 0.78 bcd   | 0.93 abcd  | 1.04 abc   | 1.18 ab  |
| 3 WAP  | --       | 1.19 ab    | 1.10 abc   | 1.06 abc   | 0.90 abcd  | 0.76 bcd |
| <b>Number of nodes per unit height</b>                             |          |            |            |            |            |          |
| 1 WAP  | 0.79 ef  | 0.81 ef    | 0.83 def   | 0.71 f     | 0.98 abcde | 1.19 a   |
| 2 WAP  | --       | 0.86 cdef  | 0.91 bcdef | 0.96 abcde | 1.14 ab    | 1.08 abc |
| 3 WAP  | --       | 0.96 abcde | 1.06 abcd  | 0.94 bcdef | 0.78 ef    | 0.80 ef  |
| <b>Number of Flowers and Buds</b>                                  |          |            |            |            |            |          |
| 1 WAP  | 2.2 bc   | 1.6 cd     | 3.2 a      | 2.8 ab     | 2.2 bc     | 1.2 d    |
| 2 WAP  | --       | 1.0 d      | 1.6 cd     | 1.2 d      | 0.8 d      | 1.0 d    |
| 3 WAP  | --       | 0.8 d      | 1.2 d      | 1.4 cd     | 1.4 cd     | 1.2 d    |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher's LSD.  
 -- Means that the plant was not tested at that level

Table 7.20 The effect of a single drench application of benzyladenine on the growth characteristics of *Zinnia elegans* ‘Dreamland Scarlet’.

| Amount<br>(mg ai)       | 0     | 2.5   | 5.0    | 7.5    | 10     |
|-------------------------|-------|-------|--------|--------|--------|
| <b>Flowers and Buds</b> |       |       |        |        |        |
| 2 WAP                   | 2.0 a | 2.0 a | 1.4 bc | 1.6 ab | 1.6 ab |
| 3 WAP                   | --    | --    | 1.0 c  | 1.0 c  | 1.0 c  |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD.

-- Means that the plant was not tested at that level.

Table 7.21 The effect of fertigation applications of benzyladenine on the growth characteristics of *Zinnia elegans* ‘Dreamland Scarlet’.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0       | 2       | 4        | 8       | 12       | 16      |
|--|---------|---------|----------|---------|----------|---------|
| Average diameter (cm <sup>2</sup> )    | 38.12 a | 30.53 b | 28.24 bc | 23.07 d | 24.95 cd | 2.94 d  |
| Growth index (cm <sup>3</sup> )        | 59804 a | 33421 b | 30271 bc | 18909 c | 21848 bc | 18586 c |
| Number of branches                     | 22.0 a  | 14.8 b  | 12.8 bc  | 9.8 cd  | 9.6 d    | 9.8 cd  |
| Number of nodes                        | 56.8 a  | 46.6 b  | 41.6 b   | 26.8 c  | 31.8 c   | 32.0 c  |
| Number of flowers and buds             | 4.8 a   | 2.8 b   | 2.6 bc   | 1.4 c   | 2.4 bc   | 2.0 bc  |

Means followed by different letters are significantly different at the  $\alpha=5\%$  level using Fisher’s LSD.

-- Means that the plant was not tested at that level.

Table 7.22 The effect of multiple foliar spray applications of benzyladenine on the growth characteristics of *Zinnia elegans* 'Dreamland Scarlet'.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0     | 20     | 40     | 60     | 80     | 100    | 120    | 140    |
|--|-------|--------|--------|--------|--------|--------|--------|--------|
| Height (cm)                            |       |        |        |        |        |        |        |        |
| 1 WAP                                  | 28.16 | 26.18  | 20.50* | 22.72  | 20.18* | 24.14  | 24.36  | 17.18* |
| 1 & 2 WAP                              | --    | 21.25* | 23.96  | 18.96* | 15.48* | 13.88* | 23.82  | 17.76* |
| 1, 2 & 3 WAP                           | --    | 23.70  | 20.08* | 18.76* | 15.34* | 18.16* | 16.80* | 16.80* |
| Growth index (cm <sup>3</sup> )        |       |        |        |        |        |        |        |        |
| 1 WAP                                  | 10952 | 8289   | 4867*  | 5253*  | 4539*  | 5034*  | 7261*  | 3632*  |
| 1 & 2 WAP                              | --    | 6133*  | 5927*  | 6544*  | 4010*  | 3170*  | 7762   | 4036*  |
| 1, 2 & 3 WAP                           | --    | 7975   | 5871*  | 4261*  | 3606*  | 5126*  | 5371*  | 3984*  |
| Number of Branches                     |       |        |        |        |        |        |        |        |
| 1 WAP                                  | 6.4   | 6.2    | 8.2    | 6.6    | 5.4    | 6.6    | 6.4    | 4.8    |
| 1 & 2 WAP                              | --    | 7.8    | 7.6    | 9.2*   | 7.8    | 6.0    | 8.0    | 6.8    |
| 1, 2 & 3 WAP                           | --    | 8.6    | 9.2*   | 9.6*   | 11.8*  | 9.2*   | 9.8*   | 9.8*   |
| Number of nodes                        |       |        |        |        |        |        |        |        |
| 1 WAP                                  | 13.0  | 11.6   | 15.0   | 12.0   | 13.0   | 13.8   | 12.4   | 10.2   |
| 1 & 2 WAP                              | --    | 14.0   | 12.8   | 16.4   | 8.6    | 13.2   | 15.8   | 13.4   |
| 1, 2 & 3 WAP                           | --    | 18.2*  | 19.4*  | 18.8*  | 20.2*  | 14.2   | 18.2*  | 16.6   |

Means followed by \* are significantly different from the control at the  $\alpha=5\%$  level using Fisher's LSD.

-- Means that the plant was not tested at that level.

Table 7.23 The effect of multiple foliar spray applications of benzyladenine on the ratios of growth variables of *Zinnia elegans* 'Dreamland Scarlet' indicate that multiple sprays increase branching and decrease average node length.

| Concentration<br>(mg•L <sup>-1</sup> ) | 0    | 20   | 40    | 60    | 80    | 100   | 120   | 140   |
|--|------|------|-------|-------|-------|-------|-------|-------|
| Number of Branches per unit height     |      |      |       |       |       |       |       |       |
| 1 WAP                                  | 0.23 | 0.24 | 0.41  | 0.31  | 0.27  | 0.29  | 0.27  | 0.28  |
| 1 & 2 WAP                              | --   | 0.36 | 0.31  | 0.49* | 0.60* | 0.44  | 0.33  | 0.39  |
| 1, 2 & 3 WAP                           | --   | 0.37 | 0.46* | 0.56* | 0.82* | 0.54* | 0.62* | 0.74* |
| Number of nodes per unit height        |      |      |       |       |       |       |       |       |
| 1 WAP                                  | 0.47 | 0.45 | 0.75  | 0.55  | 0.64  | 0.59  | 0.51  | 0.59  |
| 1 & 2 WAP                              | --   | 0.65 | 0.54  | 0.87* | 0.49  | 0.98* | 0.67  | 0.76  |
| 1, 2 & 3 WAP                           | --   | 0.83 | 0.97* | 1.06* | 1.38* | 0.82  | 1.08* | 1.36* |

Means followed by \* are significantly different from the control at the  $\alpha=5\%$  level using Fisher's LSD.  
 -- Means that the plant was not tested at that level.

Table 7.24 Summary of the effects of benzyladenine on the plants tested in this experiment.

| Plant  | Method                                       | Effect  |
|--|--|---|
| <i>Acalypha microphylla</i>                        | Foliar spray                                 | No beneficial effect*                               |
| <i>Aquilegia flabellate</i>                        | Foliar spray                                 | No beneficial effect*                               |
| <i>Begonia</i> × <i>hybrida</i> ‘Dragon Wings’     | Foliar spray                                 | Increased branching and flowering                   |
| <i>Catharanthus roseus</i>                         | Foliar spray, drench, fertigation, plug dips | Increased branching*                                |
| <i>Coreopsis grandiflora</i>                       | Foliar spray                                 | No beneficial effect                                |
| <i>Euphorbia pulcherrima</i>                       | Foliar spray                                 | No beneficial effect                                |
| <i>Exacum affine</i>                               | Foliar spray                                 | Severe phytotoxicity at all concentrations**        |
| <i>Gerbera jamesonii</i>                           | Foliar spray                                 | No beneficial effect                                |
| <i>Heuchera micrantha</i> var. <i>diversifolia</i> | Foliar spray                                 | No beneficial effect*                               |
| <i>Impatiens hawkeri</i>                           | Foliar spray                                 | Very slight acceleration in flowering               |
|  |  | Increased branching*                                |
| <i>Ipomoea batatas</i>                             | Foliar spray                                 | No beneficial effect**                              |
| <i>Iresine</i>                                     | Foliar spray                                 | Increased branching**                               |
| <i>Lantana camara</i>                              | Foliar spray                                 | Increased branching in 1 of the 3 cultivars tested* |

Table 7.24 (continued).

| <u>Plant</u>                         | <u>Method</u>                        | <u>Effect</u>  |
|--------------------------------------|--------------------------------------|--|
| <i>Liatris spicata</i>               | Bulb soak                            | No beneficial effect   |
| <i>Oenothera fruiticosa youngii</i>  | Foliar spray                         | No beneficial effect*  |
| <i>Pentas lanceolata</i>             | Foliar spray                         | No beneficial effect   |
| <i>Portulaca oleracea</i>            | Foliar spray                         | Slight increase in<br>branching in 1 of the<br>2 cultivars tested      |
| <i>Pseuderanthemum atropurpureum</i> | Foliar spray                         | No beneficial effect   |
| <i>Rudbeckia hirta</i>               | Foliar spray                         | Decrease in size*  |
| <i>Salvia splendens</i>              | Foliar spray                         | Increased branching  |
| <i>Scabiosa caucasica</i>            | Foliar spray                         | No beneficial effect*  |
| <i>Scutellaria</i>                   | Foliar spray                         | No beneficial effect   |
| <i>Senecio cineraria</i>             | Foliar spray, Drench,<br>fertigation | Decrease in size. One<br>treatment increased the<br>number of leaves.* |
| <i>Solenostemon scutellarioides</i>  | Foliar spray                         | Decreased size in 1 of the<br>3 cultivars tested                       |
| <i>Sutera cordata</i>                | Foliar spray                         | No beneficial effect   |
| <i>Verbena</i>                       | Foliar spray                         | No beneficial effect   |

Table 7.24 (continued).

| Plant                      | Method                            | Effect   |
|----------------------------|-----------------------------------|--|
| <i>Viola ×wittrockiana</i> | Foliar spray                      | Increased branching but also caused phytotoxicity at all concentrations tested**   |
| <i>Zinnia elegans.</i>     | Foliar spray, Drench, fertigation | Increase in branching and reduction in internode length. Increased or decreased flowering based on concentration. Decreased height** |

\* Minor phytotoxicity was observed.

\*\* Major phytotoxicity was observed.



Figure 7.1 The effect of benzyladenine on *Acalypha microphylla* leaf size. Pictured here (left to right) are 0, 100, 200, and 400 mg•L<sup>-1</sup>. Note the reduction in leaf size with increasing concentrations of benzyladenine.

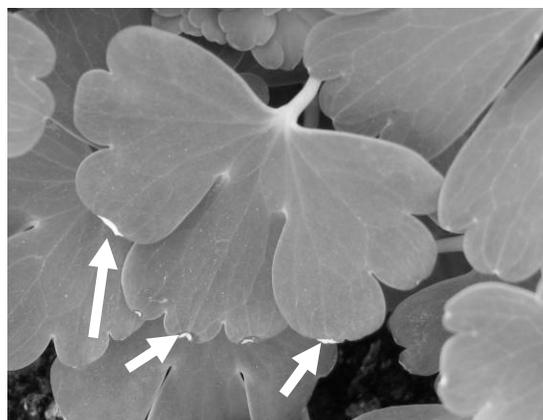


Figure 7.2 A single foliar spray of benzyladenine at a concentration of 1600 mg•L<sup>-1</sup> causes minor phytotoxicity on *Aquilegia flabellate* in the form of minor leaf edge necrosis.



Figure 7.3 The effect of single foliar sprays of benzyladenine on the branching of *Begonia* *×hybrida* 'Dragon Wing Red'. Photo taken at 6 WAP. From left to right is the control versus the 80 mg·L<sup>-1</sup> concentration.



Figure 7.4 Effects of a single drench application of benzyladenine on branching of *Catharanthus roseus* 'Pacifica Lilac'. Measurements taken at 5.5 WAP. From left to right – Control versus 15 mg ai at 3 WAP. Note the increased number of small branches at the base.



Figure 7.5 Phytotoxicity caused by 2 benzyladenine foliar sprays spaced one week apart on *Exacum affine* at  $400 \text{ mg} \cdot \text{L}^{-1}$ . The plant was chlorotic, the apical meristems were killed, the new growth was stunted, and flowering was inhibited during the entire length of the experiment.



Figure 7.6 Phytotoxicity caused by a single benzyladenine foliar spray at 4 WAP on *Heuchera micrantha* var. *diversifolia* 'Palace Purple' at  $1600 \text{ mg}\cdot\text{L}^{-1}$ . Note the crinkled leaves, necrotic spots and edge necrosis.



Figure 7.7 Phytotoxicity caused by a single benzyladenine foliar spray on *Impatiens hawkeri* 'Red Fox Riviera Bright Red' at 1600 mg•L<sup>-1</sup>. Note the edge chlorosis.



Figure 7.8 Phytotoxicity caused by a single benzyladenine foliar spray on *Iresine* hybrid 'Blazin Rose' at  $3200 \text{ mg}\cdot\text{L}^{-1}$ . Note the leaf cupping.



Figure 7.9 Phytotoxicity caused by a single benzyladenine foliar spray on *Oenothera fruticosa youngii* at  $1600 \text{ mg}\cdot\text{L}^{-1}$ . Note the leaf cupping.



Figure 7.10 A single foliar spray of benzyladenine affects growth index and height of *Rudbeckia hirta* 'Becky Mix'.



Figure 7.11 Phytotoxicity symptoms of a single foliar spray of benzyladenine at  $1600 \text{ mg}\cdot\text{L}^{-1}$  on *Scabiosa caucasica* 'Perfecta alba'. Note the leaf crinkling and the leaf edge chlorosis.



Figure 7.12 Phytotoxicity caused by a single foliar spray of benzyladenine at  $800 \text{ mg}\cdot\text{L}^{-1}$  on pansy cultivar 'Delta Pure Rose'. Note the severe yellowing on the new growth.



Figure 7.13 Phytotoxicity symptoms of a single foliar spray of benzyladenine at  $800 \text{ mg}\cdot\text{L}^{-1}$  applied at 3 WAP on *Zinnia elegans*. Note the leaf crinkling and the leaf edge chlorosis on the new leaves.

## APPENDIX

## **A1. Summary of Research on the Effects of Cytokinins on Horticultural Crops**

Cytokinins have been researched on numerous floriculture crops over the last 50 years. The majority of this work was with tissue culture. However, there is a large body of research that is useful to bedding plant or pot crop growers that deals with cytokinin applications to potted plants, bulbs, stock plants, and seeds. The following four tables summarize the research into the use of all types of cytokinins as PGRs on:

1. Herbaceous ornamental crops – Table A1
2. Cut flowers – Table A2
3. Woody ornamental crops – Table A3
4. Non-ornamental horticultural crops - Table A4

In the following tables, the following abbreviations for chemical names and for horticultural terms are used. AOA = Amino-oxyacetic acid, BA = Benzyladenine, CK = Cytokinin, CPPU = Forchlorfenuron, DAP = days after potting, DAS = Days after spraying, DAT = Days after transplant, DHZ = Dihydrozeatin, GA = Gibberellin, IAA = Indole acetic acid, IBA = Indole butyric acid, K = Kinetin, LD = Long Day, M = Molar, NAA = Napthalene acetic acid, PBA = Pyrylanyl-benzyladenine, SD = Short Day, STS = Silver thiosulfate, TDZ = Thidiazuron, WAP = Weeks after potting, WAS = Weeks after spraying, Z = Zeatin, ZR = Zeatin Riboside

## A1.1 Summary of Research on the Effects of Cytokinins on Herbaceous Ornamental Crops.

Table A1: Research efforts for exogenous cytokinins on herbaceous ornamental crops.

| Plant   | Notes   | Reference              |
|---|---|------------------------|
| <i>Acalypha microphylla</i>                                     | <u>Cytokinin</u> : BA 50 to 800 ppm (Configure) / Single Foliar spray applied 2WAP<br><u>Purpose</u> : Branching agent – Does BA affect growth or branching?<br><u>Effect</u> : Increasing rates of BA caused leaves to be smaller.   | [Ref. Chapter 7]       |
| <i>Achimenes longiflora</i> (Hot Water Plant)                   | <u>Cytokinin</u> : BA $10^{-8}$ M to $10^{-5}$ M or 6- $\gamma$ , $\gamma$ $10^{-8}$ M to $10^{-5}$ M or B-Nine + BA $2.5 \times 10^{-6}$ M or NAA + BA at various rates / Stem cuttings were rooted in a Petri dish containing liquid solutions of the PGRs<br><u>Purpose</u> : Propagation – Do cytokinins increase bulblet formation?<br><u>Effect</u> : BA greatly increased bulblet formation on stem cuttings except with NAA. BA $10^{-6}$ M and 6- $\gamma$ , $\gamma$ $10^{-7}$ M were best. BA even induced formation in non-inductive lighting conditions. | (Deutch 1973)          |
| <i>Achimenes longiflora</i> (Hot Water Plant)                   | <u>Cytokinin</u> : BA 25 to 100 ppm OR BA 25 ppm + GA 100 ppm / Foliar spray at potting and 2 weeks later<br><u>Purpose</u> : Branching agent – Can BA increase rhizome formation?<br><u>Effect</u> : BA caused leaf malformations and did not affect height. BA 50 to 100 ppm increased flower malformations (atrophic). BA 100 ppm increased fresh weight of rhizomes. BA + GA greatly increased height, number of leaf whorls, and atrophic flowers while reducing tuber weight.   | (Vlahos 1985a)         |
| <i>Achimenes longiflora</i> (Hot Water Plant)                   | <u>Cytokinin</u> : BA 1 to 100 ppm / Pre-plant bulb soak of dormant bulbs for 8 to 24hr followed by incubation in the dark.<br><u>Purpose</u> : Crop timing – Break Dormancy – Can BA break bulb dormancy for early flower production?<br><u>Effect</u> : Soak time made no difference. 50 ppm BA caused more sprouts to break but 100 ppm cause longer sprouts.  | (Vlahos 1985b)         |
| <i>Aeonium</i> hybrid   | <u>Cytokinin</u> : BA 50 to 400 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Branching agent – Does BA increase the number of offsets of affect growth characteristics?<br><u>Effect</u> : No effect   | [Ref. Chapter 3]       |
| <i>Aethusa cynapium</i> (Fool's Parsley)                        | <u>Cytokinin</u> : Kinetin $10^{-4}$ M (21.5 ppm) / Daily sprays for 10 days onto stems<br><u>Purpose</u> : Branching agent – Does Kinetin increase branching?<br><u>Effect</u> : Branching was increased. GA was antagonistic to this effect.  | (Lona and Bocchi 1957) |
| <i>Agave</i> hybrid, <i>A. guiengola</i> , <i>A. gemniflora</i> | <u>Cytokinin</u> : BA 100 to 800 ppm (Configure) / 2 Foliar sprays applied 1 month apart starting 6 weeks after potting up plugs.<br><u>Purpose</u> : Branching agent – Propagation - Does BA have any effect on offset formation?<br><u>Effect</u> : No effect   | [Ref. Chapter 3]       |

Table A1 Continued

| <b>Plant</b>                                     | <b>Notes</b>  | <b>Reference</b>            |
|--|---|-----------------------------|
| <i>Alchemilla mollis</i><br>(Lady's Mantle)      | <u>Cytokinin</u> : BA + GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)      |
| <i>Alocasia</i><br>(Elephant Ear)                | <u>Cytokinin</u> : Thidiazuron (Dropp 50) 1 to 100 ppm / Solution applied to base of plant at potting time.<br><u>Purpose</u> : Branching agent - Does BA increase the number of branches?<br><u>Effect</u> : 10 ppm produced the most lateral branches. Higher rates caused abnormal buds. Most of the lateral branches failed to grow out.              | (Henny and Fooshee 1990a)   |
| <i>Aloe</i> hybrids,<br><i>A. gastrolea</i>      | <u>Cytokinin</u> : BA 100 to 800 ppm (Configure) / 2 Foliar sprays applied 1 month apart starting 16 weeks after potting.<br><u>Purpose</u> : Branching agent – Propagation - Does BA have any effect on offset formation?<br><u>Effect</u> : No effect   | [Ref. Chapter 3]            |
| <i>Alpinia</i><br>(Red Ginger)                   | <u>Cytokinin</u> : BA or PBA 100 ppm / Foliar soak of rooted plants<br><u>Purpose</u> : Branching agent – Propagation – Can cytokinins improve the number of basal shoots available for cuttings?<br><u>Effect</u> : PBA enhances basal shoot development but not BA  | (Criley 1988)               |
| <i>Anagallis arvensis</i><br>(Scarlet pimpernel) | <u>Cytokinin</u> : Zeatin $10^{-5}$ M – $10^{-3}$ M / A single drop applied to young leaves of stem cuttings stuck in rooting media at various times after Long Day induction<br><u>Purpose</u> : Flower enhancer – How does zeatin affect flowering?<br><u>Effect</u> : Zeatin generally inhibited flowering   | (Bismuth and Miginiac 1984) |
| <i>Anthurium</i><br>(Flamingo flower)            | <u>Cytokinin</u> : BA 500 to 1500 ppm, BA + GA in a 2:1 ratio 500 to 1000 ppm BA / Two applications 15 days apart to 5 axillary buds.<br><u>Purpose</u> : Branching agent – Propagation – Can BA increase the number of shoots formed?<br><u>Effect</u> : BA 1500 ppm increased shoot formation the most (2.5x over control). BA + GA was less effective. | (Chandrappa et al. 2006)    |
| <i>Anthurium</i><br>(Flamingo flower)            | <u>Cytokinin</u> : BA 250 to 500 ppm / 10ml soil drench<br><u>Purpose</u> : Branching agent – Can BA increase basal branching?<br><u>Effect</u> : Yes. BA induced more basal branching.   | (Henny and Fooshee 1989)    |
| <i>Anthurium</i><br>(Flamingo flower)            | <u>Cytokinin</u> : BA or PBA 100 to 1500 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent – Can BA increase basal branching?<br><u>Effect</u> : 1000 ppm BA was the most effective rate at inducing branching.   | (Higaki and Rasmussen 1979) |

Table A1 Continued

| <b>Plant</b>                                     | <b>Notes</b>   | <b>Reference</b>             |
|--|--|------------------------------|
| <i>Anthurium andraeanum</i><br>(Flamingo flower) | <u>Cytokinin</u> : BA 500 to 1000 ppm / Single foliar spray after terminal portion pinched. GA<br><u>Purpose</u> : Branching agent - Can BA replace the need for topping and produce more shoots for propagation?<br><u>Effect</u> : BA 1000 ppm produced more lateral branches regardless of topping and could substitute for topping. 1000 ppm BA caused the greatest affect but also some phytotoxicity. However, topping + GA 500 ppm produced even more lateral branches than BA + no topping.  | (Imamura and Higaki 1988)    |
| <i>Antirrhinum</i><br>(Snapdragon)               | <u>Cytokinin</u> : PBA 250 to 750 ppm / Single Foliar spray application<br><u>Purpose</u> : Branching agent – Height control<br><u>Effect</u> : 500 ppm PBA increased lateral shoot formation of un-pinched plants prior to flower induction. No delay in flower development or size. No phytotoxicity noted   | (Jeffcoat 1977)              |
| <i>Aquilegia x hybrida</i><br>(Columbine)        | <u>Cytokinin</u> : BA 0.22 mM (50 ppm), BA+GA (Promalin) 0.22 mM BA (50 ppm) / Soil drench (50ml) at the 7 leaf stage<br><u>Purpose</u> : Growth enhancer – Does BA or Promalin alter growth or flowering of Columbine?<br><u>Effect</u> : Promalin reduced the days to flower by 6 to 19 days. BA & Promalin increased the number of flowers per plant (30% for BA and 80 to 300% for Promalin) but not by as much as GA alone. BA increased the number of spikes per plant but Promalin did not. Promalin increased plant height but BA did not. Promalin reduced the number of crowns per plant by BA had no effect. Promalin increased flower longevity by 280% which is about the same as GA alone. | (Gianfagna and Merritt 1998) |
| <i>Aquilegia</i><br>(Columbine)                  | <u>Cytokinin</u> : Kinetin + GA + Ethrel 0.5 mM + 1 mM + 1 mM / Pre-germination seed soak<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Promoted germination at, below, and above normal temperatures but not as well as 10 mM GA alone  | (Persson 1993)               |
| <i>Aquilegia flabellate</i><br>(Columbine)       | <u>Cytokinin</u> : BA 50 to 1600 ppm (Configure) / Single Foliar spray applied 2WAP<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : No effect  | [Ref. Chapter 7]             |
| <i>Aquilegia vulgaris plena</i><br>(Columbine)   | <u>Cytokinin</u> : BA + GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Significant phytotoxicity   | (Lieth and Dodge 2004)       |
| <i>Aranda</i><br>(Orchid)                        | <u>Cytokinin</u> : Kinetin $10^{-3}$ M to $10^{-4}$ M (2.15 to 21.5 ppm), BA 1 to $2 \times 10^{-3}$ M (225 to 450 ppm) OR BA+GA $10^{-4}$ M+ $10^{-4}$ M to $10^{-3}$ M+ $10^{-3}$ M each<br><u>Purpose</u> : Flower enhancer<br><u>Effect</u> : BA at any rate increased floral initials and number of flowers, but BA + GA at $10^{-3}$ M+ $10^{-3}$ M was better.  | (Goh 1977)                   |
| <i>Ardisia crispa</i><br>(Coral Ardisia)         | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – How does PBA affect growth?<br><u>Effect</u> : No effect.  | (Henley and Poole 1974)      |

Table A1 Continued

| <b>Plant</b>                                      | <b>Notes</b>  | <b>Reference</b>        |
|---|---|-------------------------|
| <i>Artemisia lactiflora</i><br>(White mugwort)    | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Increased branching. Caused no phytotoxicity   | (Lieth and Dodge 2004)  |
| <i>Aster novae angliae</i><br>(New England Aster) | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Significant phytotoxicity  | (Lieth and Dodge 2004)  |
| <i>Aster tartaricus</i><br>(Tatarian aster)       | <u>Cytokinin</u> : BA 50 to 1000 ppm alone or in combination with Maleic Hydrazide, CCC, GA, Ancymidol / Single foliar spray<br><u>Purpose</u> : Growth enhancer – Can BA alter growth of Aster?<br><u>Effect</u> : BA 50 ppm reduced plant height and increased branching but flowering was delayed by 9 days and there were 50% fewer flowers.  | (Ryu and Lee 1993)      |
| <i>Banksia ashbyi</i>                             | <u>Cytokinin</u> : BA 100 to 500 ppm sprays<br><u>Purpose</u> : Flower enhancer – Dormancy interruption - Branching agent – Can BA interrupt winter dormancy and affect growth?<br><u>Effect</u> : BA overcomes winter quiescence of buds and breaks apical dominance. The effects are long lasting. Plants have many more branches. 400 ppm BA sprayed on the overwintering inflorescences hastens spring flowering by 1 to 2 months   | (Wallerstein 1986)      |
| <i>Begonia</i><br>(Rex Begonia)                   | <u>Cytokinin</u> : BA 2 to 30 ppm / Dip leaf explants<br><u>Purpose</u> : Propagation – Stimulate shoot formation from leaf cuttings in tissue culture<br><u>Effect</u> : BA 30 ppm inhibits root formation for at least 69 days. BA reverses the polarity so that buds which normally form mainly on the proximal end of the leaf, form mainly on the distal end. Cultivars react differently.   | (Prevot 1967)           |
| <i>Begonia</i> hybrid<br>(Reiger begonia)         | <u>Cytokinin</u> : Kinetin, BA, PBA each at 1.5 to 150 $\mu$ M / 12hr Petiole soak OR PBA 0.03%-1.0% solutions in talc carrier / petiole dips OR PBA 30 to 1000 $\mu$ M single foliar sprays 4 to 26 days after planting OR foliar spray to stock plant prior to taking cuttings<br><u>Purpose</u> : Propagation – promote growth of leaf cuttings<br><u>Effect</u> : Kinetin had no effect. BA had a slightly less effect than PBA in stimulating shoot initiation. 0.01% PBA talc concentration worked better than petiole soak and was comparable to a foliar spray at 1000 $\mu$ M at 4 days after planting. A stock plant treatment of 1000 $\mu$ M PBA 1 day prior to cuttings was nearly as good at producing cuttings with lateral shoot formation. One cultivar was enhanced by these treatments and one cultivar was inhibited. Root development was inhibited at high rates of PBA | (Davies and Moser 1980) |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>  | <b>Reference</b>        |
|---|---|-------------------------|
| <i>Begonia x hiemalis</i> (Reiger Begonia)              | <p><u>Cytokinin</u>: Kinetin 0.63 to 40 *10<sup>-6</sup>M (0.013 to 0.84 ppm) / leaf cuttings grown on agar with cytokinins added</p> <p><u>Purpose</u>: Propagation - Can cytokinins be used to increase shoot formation from leaf cuttings?</p> <p><u>Effect</u>: Kinetin greatly increased the number of buds that formed per leaf cutting. The ratio of Kinetin to IAA was important. A 1:1 molar ratio worked best (40 *10<sup>-6</sup>M of both Kinetin and IAA). Kinetin reduced rooting of the plants unless IAA was supplied at a 1:4 Kinetin:IAA ratio.</p> | (Heide 1965)            |
| <i>Begonia x hiemalis</i> (Reiger Begonia)              | <p><u>Cytokinin</u>: BA 50 to 150 ppm OR BA+ GA 25 ppm (Promalin) OR PBA 150 ppm / Single foliar spray 1 week prior to inoculation</p> <p><u>Purpose</u>: Disease resistance – Can cytokinins help reduce fungal diseases?</p> <p><u>Effect</u>: No effect on the incidence of powdery mildew (<i>Erysiphe chicoracearum</i>)</p>   | (Sammons et al. 1981)   |
| <i>Begonia x hybrida</i> (Dragon Wing begonia)          | <p><u>Cytokinin</u>: BA 20 to 160 ppm (Configure) / Single foliar spray</p> <p><u>Purpose</u>: Branching agent – Height control – Can BA increase branching and/or reduce the height of greenhouse grown Dragon Wing begonias?</p> <p><u>Effect</u>: Slight increase in branch number but no decrease in height. Flowers emerged slightly earlier</p>   | [Ref. Chapter 7]        |
| <i>Begonia x tuberhybrida</i> (Tuberous rooted begonia) | <p><u>Cytokinin</u>: BA 0.5 to 1 ppm / in Agar</p> <p><u>Purpose</u>: Propagation – Can tuberous begonias be propagated via stem or leaf cuttings</p> <p><u>Effect</u>: BA 1 ppm caused adventitious buds to form in 25% of leaf cuttings.</p>  | (Shimada et al. 2005)   |
| <i>Begonia x tuberhybrida</i> (Tuberous rooted begonia) | <p><u>Cytokinin</u>: Kinetin 25 to 250 ppm / Single foliar spray application</p> <p><u>Purpose</u>: Height Control – Flower enhancer</p> <p><u>Effect</u>: Kinetin did not effect height or flowering</p>   | (Tonecki 1986)          |
| <i>Bletilla striata</i> (Hardy Orchid)                  | <p><u>Cytokinin</u>: BA 50 to 100 ppm, Kinetin 50 to 100 ppm / Soak pseudobulbs in solution for 30 min – 1 hr</p> <p><u>Purpose</u>: Growth control – Can cytokinins increase the rate of sprouting of pseudobulbs?</p> <p><u>Effect</u>: 50 ppm BA or Kinetin increased growth rate but only under low temperatures. 100 ppm BA inhibited sprouting.</p>   | (Yoon et al. 2002)      |
| <i>Boronia heterophylla</i> (Red Boronia)               | <p><u>Cytokinin</u>: BA, GA+BA (20 to 100 ppm) / 1 to 4 foliar spray applications</p> <p><u>Purpose</u>: Growth control – Flower control – Can cytokinins be used on field grown crops to alter harvest dates?</p> <p><u>Effect</u>: BA alone reduced flower number and did not affect harvest date. BA+GA 20 ppm delayed harvest date 6 days without affecting flowering. Higher rates reduced flowering. Application time was critical. All other PGR rates and timings had undesirable results.</p>  | (Plummer and Wann 1998) |

Table A1 Continued

| <b>Plant</b>                                    | <b>Notes</b>  | <b>Reference</b>        |
|---|---|-------------------------|
| <i>Boronia heterophylla</i><br>(Red Boronia)    | <u>Cytokinin</u> : BA 100 ppm / foliar spray every 3 days for 18 days on mature plants in mid fall OR 10 to 150 ppm / Foliar spray every 2 days for 4 to 8 days on rooted cuttings in mid fall<br><u>Purpose</u> : Branching agent – Can BA replace pinching for inducing branches?<br><u>Effect</u> : BA 100 ppm on mature plants vastly increased branching over pinching. Transient phytotoxicity noted. BA 50 ppm, 4 applications increased branching over pinching in rooted cuttings. Higher rates and more applications caused phytotoxicity and reduced flowering | (Richards 1985)         |
| <i>Boronia metastigma</i><br>(Brown Boronia)    | <u>Cytokinin</u> : BA 100 ppm / Foliar spray 3 times, 1 week apart – 2 months prior to taking cuttings<br><u>Purpose</u> : Branching agent / Propagation – Can BA increase branching on stock plants without affecting the rooting of the cuttings.<br><u>Effect</u> : BA increased branching but subsequent cuttings rooted very poorly compared to control.   | (Day and Loveys 1998)   |
| <i>Bougainvillea</i>                            | <u>Cytokinin</u> : BA rate not listed / Plant parts dipped in solution of BA during Long Days or Short Days<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : BA and Short Days promote flowering. The effect of BA and Short Days is completely inhibited by GA.  | (Even-Chen et al. 1979) |
| <i>Bougainvillea</i>                            | <u>Cytokinin</u> : PBA 500 ppm / Drops applied to terminal buds every 4 days<br><u>Purpose</u> : Flower enhancer - does PBA promote flowering?<br><u>Effect</u> : PBA increases the number of flowers that form and the shoot dry weight.   | (Ramina et al. 1979)    |
| <i>Bougainvillea</i>                            | <u>Cytokinin</u> : PBA 100 to 1000 $\mu\text{g}\cdot\text{g}^{-1}$ (100 to 1000 ppm) / 10 $\mu\text{l}$ droplets placed on terminal bud every 4 days during Long Day or Short Day<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : 100 $\mu\text{g}\cdot\text{g}^{-1}$ at start of Short Day promoted flowering by 3 days over control. Other rates were not statistically different. No effect on growth habit.  | (Tse et al. 1974)       |
| <i>Bracteantha</i><br>(Straw flower)            | <u>Cytokinin</u> : Thidiazuron 0.1 – 1.0 ppm / Single foliar spray applied in early July OR in early spring in combination with fertilizer toning<br><u>Purpose</u> : Senescence inhibitor – Can tDZ preserve plant quality of potted strawflowers?<br><u>Effect</u> : All rates of Thidiazuron reduced flower counts. Rates above 0.1 ppm caused severe phytotoxicity. Thidiazuron reduced Botrytis problems in cut flowers.   | (Beach 2005)            |
| <i>Brassaia actinophylla</i><br>(Umbrella tree) | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – How does PBA affect growth?<br><u>Effect</u> : No effect.   | (Henley and Poole 1974) |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>              |
|--|---|-------------------------------|
| <i>Bryophyllum marnierianum</i><br>(Marnier's Kalanchoe) | <u>Cytokinin</u> : Zeatin, Kinetin, BA 5 to 10 $\mu$ M (1 to 2 ppm) / Mixed into MS media upon which leaves were cultured<br><u>Purpose</u> : Growth control – Do cytokinins inhibit epiphyllus plantlet formation?<br><u>Effect</u> : Yes. All of the cytokinins prevented plantlets from forming at the margin of detached Kalanchoe leaves | (Kulka 2006)                  |
| <i>Caladium bicolor</i>                                  | <u>Cytokinin</u> : BA 250 to 4000 ppm, BA+GA (Promalin) / Pre-plant bulb soak for 1hr<br><u>Purpose</u> : Branching agent – Can BA replace de-eying by hand?<br><u>Effect</u> : BA delayed emergence and resulted in shorter plants and reduced branching to below that of non-de-eyed controls.  | (Whipker et al. 2005)         |
| <i>Calendula</i><br>(Pot Marigold)                       | <u>Cytokinin</u> : Kinetin, BA, KT 20 to 40 ppm each / Foliar sprays 3 times, one week apart in summer<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : Kinetin increased leaf number, increased leaf size & inhibited flowering.   | (Rounkova 1985)               |
| <i>Calendula officinalis</i><br>(Pot Marigold)           | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Significant phytotoxicity  | (Lieth and Dodge 2004)        |
| <i>Callistephus chinensis</i><br>(China Aster)           | <u>Cytokinin</u> : Kinetin 10 <sup>-4</sup> M (21.5 ppm) / Daily sprays for 10 days onto stems<br><u>Purpose</u> : Branching agent – Does Kinetin increase branching?<br><u>Effect</u> : Branching was increased. GA was antagonistic to this effect.   | (Lona and Bocchi 1957)        |
| <i>Campanula persicifolia</i><br>(Peach-leaf bellflower) | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Fascination did not increase branching or cause phytotoxicity. Increased flower stem length.   | (Lieth and Dodge 2004)        |
| <i>Capsicum annuum</i><br>(Ornamental Pepper)            | <u>Cytokinin</u> : BA 400 to 1200 ppm / Single Foliar spray onto pinched and un-pinched plants before, at, or after pinching<br><u>Purpose</u> : Branching agent – Can BA increase branching?<br><u>Effect</u> : No effect. No phytotoxicity at 1200 ppm.   | (Khademi and Khosh-Khui 1977) |
| <i>Caryopteris clandonensis</i><br>(Bluebeard)           | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Increased branching. Caused no phytotoxicity   | (Lieth and Dodge 2004)        |
| <i>Catharanthus roseus</i><br>(Madagascar Periwinkle)    | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)        |
| <i>Catharanthus roseus</i><br>(Madagascar Periwinkle)    | <u>Cytokinin</u> : BA 50 to 800 ppm (Configure) / Foliar spray or drench applied at 2 WAP, 2+3 WAP or 2+3+4 WAP.<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : BA increased branching   | [Ref. Chapter 7]              |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>   | <b>Reference</b>        |
|---|--|-------------------------|
| <i>Centaurea calcitrapa</i><br>(Red star thistle)                     | <u>Cytokinin</u> : Kinetin 10 <sup>-4</sup> M (21.5 ppm) / Daily sprays for 10 days onto stems<br><u>Purpose</u> : Branching agent – Does Kinetin increase branching?<br><u>Effect</u> : Branching was increased. GA was antagonistic to this effect.  | (Lona and Bocchi 1957)  |
| <i>Centaurea cyanus</i><br>(Bachelor's button)                        | <u>Cytokinin</u> : Kinetin 10 <sup>-4</sup> M (21.5 ppm) / Daily sprays for 10 days onto stems<br><u>Purpose</u> : Branching agent – Does Kinetin increase branching?<br><u>Effect</u> : Branching was increased. GA was antagonistic to this effect.  | (Lona and Bocchi 1957)  |
| <i>Centaurea montana</i><br>(Cornflower)                              | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity   | (Lieth and Dodge 2004)  |
| <i>Chamaecereus silvestri</i><br>(Succulent, Peanut Cactus)           | <u>Cytokinin</u> : BA, BA+GA 100 to 200 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA 200 ppm increased branching. BA+GA reduced shoot number  | (Sanderson et al. 1986) |
| <i>Chamaecereus silvestrii</i> f. <i>variegata</i><br>(Peanut Cactus) | <u>Cytokinin</u> : BA 1000 to 5000 ppm, Thidiazuron 150 ppm, CPPU / Application method not listed (abstract only)<br><u>Purpose</u> : Branching agent – Can cytokinins increase the number of offsets (tubercles) used for propagation material?<br><u>Effect</u> : Thidiazuron increased tubercles but they were too small to be used as scions in grafting. BA 5000 ppm worked well and the tubercles were large enough to use.  | (Cho et al. 2008)       |
| <i>Chrysanthemum</i>  | <u>Cytokinin</u> : PBA 250 to 750 ppm / Single Foliar spray application. Plants un-pinched or pinched<br><u>Purpose</u> : Branching agent – Height control – Flower enhancer - Postharvest<br><u>Effect</u> : 500 ppm PBA increased lateral shoot formation of un-pinched and pinched plants prior to flower induction. Effect was best when applied up to 1 week before the pinch. No delay in flower development or size. Phytotoxicity and leaf wilting occurred at 750 ppm and was worse in lower temperatures than higher ones but was reduced by transferring plants to higher temps. Effects lasted about 4 weeks. Cuttings taken less than 7 days after spraying with 250 ppm did not root well but after 7 days, cuttings rooted fine (it was 10 days at 500 ppm). PBA at 100 ppm applied to opening buds prior to floret formation resulted in larger flowers. | (Jeffcoat 1977)         |

Table A1 Continued

| <b>Plant</b>                    | <b>Notes</b>   | <b>Reference</b>              |
|---------------------------------|--|-------------------------------|
| <i>Chrysanthemum</i>            | <p><u>Cytokinin</u>: BA+GA<sub>4+7</sub> (Accel) 0.4% solution (74 ppm) / Single foliar spray at various times before or after pinch.</p> <p><u>Purpose</u>: Branching agent – Can BA increase branching of mums?</p> <p><u>Effect</u>: Accel had no effect or reduced flower production and delayed flowering compared to controls. There were cultivar differences. Generally, the earlier the Accel application (before the pinch) the more branching it triggered.</p> <p><u>Notes</u>: Authors suggest that Accel delays the growth stage transition from vegetative to flowering rather than simply affecting the buds.</p>                | (Pound and Tayama 1984)       |
| <i>Chrysanthemum</i>            | <p><u>Cytokinin</u>: PBA (Accel) 200 to 1200 ppm / single foliar spray 1 week prior to pinching.</p> <p><u>Purpose</u>: Branching agent – Will PBA increase branching?</p> <p><u>Effect</u>: 100 to 200 ppm PBA was effective at increasing branching</p>  | (Sanderson and Martin 1975)   |
| <i>Chrysanthemum</i>            | <p><u>Cytokinin</u>: PBA 100 to 200 ppm, BA 200 to 400 ppm / Single foliar spray 2w before pinch, at pinch, or 2w after pinch OR cuttings were sprayed before sticking</p> <p><u>Purpose</u>: Branching agent - Propagation</p> <p><u>Effect</u>: BA 400 ppm and PBA 200 ppm (at pinch) increased branching and was better than spraying 2w before or after pinch. PBA 200 was generally a little more effective than BA 400. PBA increased days to flower in 1 cultivar but BA did not. BA delayed rooting in cuttings for up to 4 weeks after spraying. PBA delayed rooting for up to 1 wk after spraying. PBA and BA reduced stem length.</p> | (Carpenter and Carlson 1972b) |
| <i>Chrysanthemum</i>            | <p><u>Cytokinin</u>: BA rate and application method not specified. Applied to flowering mums prior to moving them into low light storage areas</p> <p><u>Purpose</u>: Senescence inhibitor – Can BA increase flower longevity?</p> <p><u>Effect</u>: Ba increased flower longevity of plants stored in low light conditions from 4 to 7 days.</p>  | (Wesenberg 1963)              |
| <i>Chrysanthemum morifolium</i> | <p><u>Cytokinin</u>: PBA (SD8339 – Accel) 50 to 1000 ppm / Single foliar spray at various timings onto pinched or unpinched plants.</p> <p><u>Purpose</u>: Branching agent – Can PBA replace a pinch in mum production?</p> <p><u>Effect</u>: Accel 50 to 200 ppm was best at increasing branching and it works best when applied at the same time as a pinch. Flowering is delayed by 4 to 6d. Higher rates cause leaf yellowing but the plants recover. Accel 800 to 1000 ppm is best if the plants are not pinched but pinched plants are superior. Height is reduced by 8cm. Accel cannot replace a pinch.</p>                               | (Meyer 1974)                  |

Table A1 Continued

| <b>Plant</b>                    | <b>Notes</b>  | <b>Reference</b>      |
|---------------------------------|---|-----------------------|
| <i>Chrysanthemum morifolium</i> | <p><b>Cytokinin:</b> BA (1, 5, or 10 µg per plant) in combination with GA<sub>3</sub>, GA<sub>4+7</sub>, GA<sub>5</sub>, GA<sub>9</sub> (2 to 20 µg) / 10µL droplets placed onto terminal buds once per week under Short Days or Long Days.</p> <p><b>Purpose:</b> Flower enhancer – Can BA+GA trigger flowering under non-inductive long days of a Short Day cultivar of mum?</p> <p><b>Effect:</b> 10µg BA + 20 µg GA worked best. BA and GA<sub>5</sub> alone increased flower bud initiation. BA + any GA increased flower bud initiation much more. BA+ GA<sub>5</sub> increased flower bud initiation most Long Days. BA+GA<sub>3</sub>, &amp; BA+GA<sub>9</sub> both were second best. None of the initiated buds actually flowered under Long Days. Only Short Days actually caused the buds to open.</p> | (Pharis 1972)         |
| <i>Chrysanthemum morifolium</i> | <p><b>Cytokinin:</b> PBA (SD-8339) 0.5 to 2.0 oz /gal (rate?) / Single Foliar spray applications at various times before and after pinch.</p> <p><b>Purpose:</b> Branching agent</p> <p><b>Effect:</b> 2 oz per gallon caused some phytotoxicity. Spraying at pinch or later delayed flowering but there was no delay when spraying 1wk before pinch. There were only slight increases in lateral branching which were higher on plants sprayed after pinch than before and were highest at 2.0 oz / gallon.</p>  | (Quinn 1977)          |
| <i>Chrysanthemum morifolium</i> | <p><b>Cytokinin:</b> BA 50 to 150 ppm OR BA+GA 25 ppm (Promalin) OR PBA 150 ppm / Single foliar spray 1 week prior to inoculation</p> <p><b>Purpose:</b> Disease resistance</p> <p><b>Effect:</b> BA increased the incidence of Ascochyta ray blight 21 days after inoculation.</p>   | (Sammons et al. 1981) |
| <i>Chrysanthemum morifolium</i> | <p><b>Cytokinin:</b> BA 0.1 to 10 ppm / Three foliar sprays (planting day, at 5 open leaves. At 10 open leaves) in the early summer on field grown plants.</p> <p><b>Purpose:</b> Flower enhancer – Can BA influence flowering in summer to fall blooming mums (cut flower cultivars)?</p> <p><b>Effect:</b> 0.1 to 1.0 ppm BA caused plants to flower up to 3.9days earlier but stem lengths were unchanged. BA 10 ppm delayed flowering, stem lengths were shorter, leaves were larger and there was mild phytotoxicity.</p>  | (Sugiura 2004)        |
| <i>Clematis hybrids</i>         | <p><b>Cytokinin:</b> BA+GA (Fascination) 400 to 1600 ppm / Single foliar spray</p> <p><b>Purpose:</b> Branching agent – Can BA replace pinching in clematis production</p> <p><b>Effect:</b> Fascination 800 ppm increased branching and decreased leader length and caused phytotoxicity. New growth had long internodes. Atrimmec worked better.</p>  | (Puglisi et al. 2002) |

Table A1 Continued

| <b>Plant</b>                                  | <b>Notes</b>   | <b>Reference</b>         |
|---|--|--------------------------|
| <i>Clematis</i> spp.                          | <p><u>Cytokinin</u>: Single foliar sprays of BA alone, Fascination (BA+GA) 400 to 1600 ppm, DROPP 50 (Thidiazuron) 500 to 2000 ppm, BA+GA custom mixes 800 to 1600 ppm, CPPU 5 to 25 ppm</p> <p><u>Purpose</u>: Branching Agent – Can CK based PGRs eliminate the need to hand pinch Clematis vines</p> <p><u>Effect</u>: BA alone had no effect. Fascination 800 to 1200 ppm increased branching but also caused phytotoxicity, bud blast and tip dieback for 4 weeks after treatment and it delayed flowering. A 1:1 ratio of BA to GA was the most effective ratio of all the BA+GA mixes. Thidiazuron produced a short lived increase in branching and did not delay flowering but the effect did not last. CPPU had no effect. Atrimmec and Dikegulac were better branching agents than any CK product and were better than pinching.</p> | (Puglisi 2002)           |
| <i>Columnnea microphylla</i> (Goldfish plant) | <p><u>Cytokinin</u>: BA 5 to 50 ppm</p> <p><u>Purpose</u>: Branching agent - Can BA increase branching?</p> <p><u>Effect</u>: No effect</p>  | (Lyons and Hale 1987)    |
| <i>Cordyline terminalis</i> (Hawaiian Ti)     | <p><u>Cytokinin</u>: BA 100 to 500 ppm / Weekly foliar spray</p> <p><u>Purpose</u>: Branching agent – Can BA increase branching?</p> <p><u>Effect</u>: Both 100 and 500 ppm were very effective at increasing axillary shoots but 500 ppm reduced subsequent rooting percentages to 48% of control.</p>  | (Maene and Deburgh 1982) |
| <i>Coreopsis grandiflora</i> (Tickseed)       | <p><u>Cytokinin</u>: BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: Did not increase branching or cause phytotoxicity</p>   | (Lieth and Dodge 2004)   |
| <i>Coreopsis grandiflora</i> (Tickseed)       | <p><u>Cytokinin</u>: BA 50 to 1600 ppm (Configure) / Single Foliar spray applied 2WAP</p> <p><u>Purpose</u>: Branching agent – Does BA affect growth?</p> <p><u>Effect</u>: no effect</p>  | [Ref. Chapter 7]         |
| <i>Coreopsis tinctoria</i> (Golden tickseed)  | <p><u>Cytokinin</u>: Kinetin 50 mg/l (50 ppm) / Foliar spray every 5 days.</p> <p><u>Purpose</u>: Flower enhancer – Can kinetin influence the flowering of this Long Day plant under Short Days?</p> <p><u>Effect</u>: No effect on flowering. Kinetin caused phytotoxicity. Kinetin reduced flower size when applied to plants under Long Days.</p>   | (Das et al. 1977)        |
| <i>Coreopsis verticillata</i>                 | <p><u>Cytokinin</u>: BA</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>:</p>   | (Farris and Keever 2008) |
| <i>Crassula</i> (Succulent)                   | <p><u>Cytokinin</u>: BA 10 to 50 ppm</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: No effect</p>  | (Lyons and Hale 1987)    |
| <i>Crepis leontodontoide</i><br><i>s</i>      | <p><u>Cytokinin</u>: Kinetin 10<sup>-4</sup>M (21.5 ppm) / Daily sprays for 10 days onto stems</p> <p><u>Purpose</u>: Branching agent – Does Kinetin increase branching?</p> <p><u>Effect</u>: Branching was increased. GA was antagonistic to this effect. Flowering in Crepis (a Long Day plant) was delayed.</p>  | (Lona and Bocchi 1957)   |

Table A1 Continued

| <b>Plant</b>                                  | <b>Notes</b>   | <b>Reference</b>        |
|---|--|-------------------------|
| <i>Cyanotis kewensis</i><br>(Teddy Bear Vine) | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – How does PBA affect growth?<br><u>Effect</u> : PBA caused an decrease in stem elongation but did not increase branching  | (Henley and Poole 1974) |
| <i>Cyclamen persicum</i>                      | <u>Cytokinin</u> : BA 50 to 100 ppm / Foliar spray applications<br><u>Purpose</u> : Flower enhancer – Promote early flowering<br><u>Effect</u> : Flowering was advanced, especially at low temps. Flower malformations at high temps and when BA was applied with high levels of N. The treatment recommended is a benzyladenine spray at 50 to 100 p.p.m. applied after early October.  | (Sakai et al. 1979)     |
| <i>Dahlia</i>                                 | <u>Cytokinin</u> : BA 20 ppm / 5 Foliar sprays spaced 4 days apart onto rooted leaf cuttings under Long Day conditions<br><u>Purpose</u> : Growth control – Does BA influence tuberization in Dahlia?<br><u>Effect</u> : No effect   | (Biran et al. 1974)     |
| <i>Dahlia</i>                                 | <u>Cytokinin</u> : Kinetin, BA, KT 20 to 40 ppm each / Foliar sprays 3 times, one week apart in summer<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA and Kinetin increased lateral branching   | (Rounkova 1985)         |
| <i>Dendrobium</i><br>(Orchid)                 | <u>Cytokinin</u> : BA $10^{-3}$ M - $10^{-4}$ M (225 ppm-22.5 ppm), BA+GA ( $10^{-3}$ M + $10^{-4}$ M), BA+IAA ( $10^{-3}$ M + $10^{-5}$ M) / continuous injection into mature pseudobulbs for 5days - 5ml total<br><u>Purpose</u> : Flower enhancer - Can BA stimulate flowering?<br><u>Effect</u> : BA 225 ppm or BA+GA stimulated 6 to 8 flowers to develop 80 to 100% of the plants of two different cultivars within 2 weeks of application. BA+IAA did not stimulate flowering. Control plants did not flower at all during the experiment. GA enhanced the effect of BA but had no effect on its own. | (Goh and Yang 1978)     |
| <i>Dendrobium</i><br>(Orchid)                 | <u>Cytokinin</u> : BA $10^{-3}$ M - $10^{-4}$ M (225 ppm to 22.5 ppm), BA + GA ( $10^{-3}$ M + $10^{-4}$ M), / continuous injection into mature pseudobulbs for 5days – 5 ml total<br><u>Purpose</u> : Flower enhancer - Can BA stimulate flowering?<br><u>Effect</u> : BA 225 ppm stimulates flowering 9 to 10 days after injection. GA does not stimulate flowering but enhances the effect of BA. BA induced inflorescences were 20% longer and had 180% more flowers on them than inflorescences on control plants.  | (Goh 1979)              |
| <i>Dianthus</i><br>(Spray Carnation)          | <u>Cytokinin</u> : BA (50 ppm), Zeatin, Zeatin Riboside, Kinetin (all at 10 to 20 ppm) / 1 to 4 Foliar sprays during and after rooting of cuttings.<br><u>Purpose</u> : Branching agent – Can CKs eliminate the need for a pinch<br><u>Effect</u> : 100 ppm BA reduced rooting % and delayed branching. 50 ppm BA applied 1 time at callus formation was better than a hand pinch. Zeatin and Zeatin Riboside also increased branching but not as well as BA. Application timing is critical.  | (Accati et al. 1979)    |

Table A1 Continued

| <b>Plant</b>                                | <b>Notes</b>   | <b>Reference</b>             |
|---|--|------------------------------|
| <i>Dianthus caryophyllus</i><br>(Carnation) | <u>Cytokinin</u> : PBA (Accel) 200 to 500 ppm / Foliar spray<br><u>Purpose</u> : Branching Agent – Flower enhancer - Propagation<br><u>Effect</u> : PBA induced lateral shoots on pinched plants. Long term flower production was increased 20 to 40%. Long term cutting production from treated stock plants was increased 20 to 35%  | (Jackson 1975)               |
| <i>Dianthus caryophyllus</i><br>(Carnation) | <u>Cytokinin</u> : PBA 250 to 750 ppm / Single Foliar spray application - Plants un-pinched or pinched OR Application when flower buds first appeared<br><u>Purpose</u> : Branching agent – Height control – Flower enhancer - Postharvest<br><u>Effect</u> : 500 ppm PBA increased lateral shoot formation of un-pinched and pinched plants prior to flower induction. Effect was best when applied up to 1 week before the pinch. No delay in flower development or size. Phytotoxicity occurred at 750 ppm and was worse in lower temperatures than higher ones but was reduced by transferring plants to higher temps. Effects lasted about 4 weeks. Cuttings taken less than 7 days after spraying with 250 ppm did not root well but after 7 days, cuttings rooted fine (it was 10 days at 500 ppm). PBA or BA application at bud appearance resulted in larger but malformed flowers (calyx splitting). Applications after the bud started opening reduced the malformations and also the size increase. Only PBA 1000 ppm at early bud appearance delayed flowering. Flower response to PBA was poor in poor light conditions. On cut flowers, PBA at 500 ppm with sucrose extended vase life from 6.8 to 17.0 days. | (Jeffcoat 1977)              |
| <i>Dianthus caryophyllus</i><br>(Carnation) | <u>Cytokinin</u> : BA 25 to 800 ppm / Single Foliar spray onto stock plants<br><u>Purpose</u> : Branching agent – Propagation - Can BA increase the number of cuttings from a stock plant?<br><u>Effect</u> : BA 400 ppm increased the number of cuttings collected by 35% without inhibiting subsequent rooting.  | (Mynett 1977)                |
| <i>Dianthus caryophyllus</i><br>(Carnation) | <u>Cytokinin</u> : BA (50 to 100 ppm) / Cotton soaked and placed on flower buds of various sizes.<br><u>Purpose</u> : Flower enhancer – How does BA applied at different times affect flowering<br><u>Effect</u> : BA 100 ppm slightly promoted flower bud development and slightly increased flower diameter. Overall, the cotton drench method was not as effective as other methods.  | (Mynett 1979)                |
| <i>Dianthus caryophyllus</i><br>(Carnation) | <u>Cytokinin</u> : PBA (SD8339) 200 to 1000 ppm / Single foliar spray<br><u>Purpose</u> : Height control – Can PBA reduce the height of potted Dianthus?<br><u>Effect</u> : All rates caused significant phytotoxicity. Only 1000 ppm reduced height but it also reduced dry weight and width (toxic range)  | (Messinger and Holcomb 1986) |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>   | <b>Reference</b>        |
|---|--|-------------------------|
| <i>Dianthus caryophyllus</i><br>(Carnation)                         | <u>Cytokinin</u> : Kinetin, BA, KT 20 to 40 ppm each / Foliar sprays 3 times, one week apart in summer<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA and Kinetin increased lateral branching   | (Rounkova 1985)         |
| <i>Dianthus caryophyllus</i><br>(Carnation)                         | <u>Cytokinin</u> : BA 100 ppm / Single foliar spray at various times<br><u>Purpose</u> : Branching agent – Can BA increase branching?<br><u>Effect</u> : BA increased branching but the timing of the spray was very important. Plants sprayed at the 5 open leaf stage of development branched the most.  | (Yamaguchi 1987)        |
| <i>Dianthus caryophyllus</i><br>(Carnation),<br><i>D. chinensis</i> | <u>Cytokinin</u> : BA (ProShear) 100 to 200 ppm / Single foliar spray with or without a pinch 17 DAP<br><u>Purpose</u> : Branching agent – Can BA increase branching<br><u>Effect</u> : No effect on branching and when used in conjunction with a pinch, fewer axillary shoots were produced and flower was delayed by 13d.   | (Foley and Keever 1991) |
| <i>Dieffenbachia</i><br>(Dumb cane)                                 | <u>Cytokinin</u> : BA 250 to 750 ppm / 1 to 3 foliar sprays<br><u>Purpose</u> : Branching agent – Can BA increase branching in a non-branching cultivar?<br><u>Effect</u> : BA 750 ppm sprayed 3 times was best at inducing more basal branching.  | (Wilson and Nell 1983)  |
| <i>Dieffenbachia</i><br>hybrid<br>(Dumb cane)                       | <u>Cytokinin</u> : BA (ProShear) 200 to 1000 ppm, BA+GA (Promalin) 900 ppm / 3 foliar sprays at 4 day intervals.<br><u>Purpose</u> : Branching agent – Can BA increase branching?<br><u>Effect</u> : BA increased branching but the effect varied by cultivar. Some cultivars had increased branching early, but the controls caught up later. Other non-branching cultivars had increased branching over the controls at all recording dates. Promalin 900 ppm was better than ProShear 1000 ppm. | (Grønberg 1987)         |
| <i>Dieffenbachia</i><br>hybrid<br>(Dumb cane)                       | <u>Cytokinin</u> : BA 250 to 750 ppm custom formulation / Foliar spray 3 times on consecutive days<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : 750 ppm applied 3 times produced the most branches and reduced height. A commercial formulation of BA caused phytotoxicity at 500 ppm or more but the custom formulation used here did not.  | (Henny 1986)            |
| <i>Dieffenbachia maculata</i><br>(Dumb cane)                        | <u>Cytokinin</u> : BA 500 to 2000 ppm / Single foliar spray application<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA 500 ppm was the best rate. BA 2000 ppm caused phytotoxicity  | (Wilson and Nell 1983)  |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>            |
|--|---|-----------------------------|
| <i>Doritaenopsis</i><br>(Orchid)   | <p><u>Cytokinin</u>: BA 100 to 400 ppm, BA+GA 25 to 100 ppm each / 3 Foliar sprays on days 0, 7, 14 from the time they were moved into into an floral inductive environment. OR a single spray from -1 to +6 weeks after moving to an inductive environment.</p> <p><u>Purpose</u>: Flower enhancer – Can BA accelerate blooming?</p> <p><u>Effect</u>: BA 200 to 400 ppm sprayed 3 times caused flowering to occur 3 to 9 days earlier and produce 3 to 8 more flowers per plant than control. BA+GA had no effect. BA sprayed 1 week after the transfer to inductive conditions increased flowering the most. There is some evidence that BA caused flower deformations</p> | (Blanchard and Runkle 2008) |
| <i>Dracaena marginata</i><br>(Dragon tree)   | <p><u>Cytokinin</u>: BA or PBA 100 to 250 ppm / Foliar sprays once per month for 4 months.</p> <p><u>Purpose</u>: Branching agent – Propagation – Can cytokinins increase branching and produce more cuttings from stock plants?</p> <p><u>Effect</u>: 250 ppm PBA was best at increasing the number of cuttings per plant (148% of control). Subsequent rooting percentages were slightly lower but that was fixed by using rooting hormones.</p>  | (Criley 1980)               |
| <i>Dracaena marginata</i><br>(Dragon tree)   | <p><u>Cytokinin</u>: Kinetin 10 ppm-100 ppm / Foliar sprays prior to dark storage with or without wax sprays</p> <p><u>Purpose</u>: Reduce Senescence during simulated shipping</p> <p><u>Effect</u>: Kinetin at 10 ppm plus wax resulted in the least leaf senescence and the highest visual quality after 28 days in dark storage.</p>  | (Wijeratnam et al. 1995)    |
| <i>Echeveria setosa</i><br>(Firecracker plant)   | <p><u>Cytokinin</u>: BA (Exilis Plus) 50 to 400 ppm / Single foliar spray</p> <p><u>Purpose</u>: Branching agent – Propagation – Flower enhancer</p> <p><u>Effect</u>: 400 ppm Improved offsetting and accelerated flowering</p>  | (Carey et al. 2008)         |
| <i>Echium plantagineum</i><br>(Blueweed)   | <p><u>Cytokinin</u>: Kinetin 50 mg/l (50 ppm) / Foliar spray every 5 days.</p> <p><u>Purpose</u>: Flower enhancer – Can kinetin influence the flowering of this Long Day plant under Short Days?</p> <p><u>Effect</u>: No effect – Plants did not change from their rosette form under Short Days.</p>  | (Das et al. 1977)           |
| <i>Epipremnum aureum</i><br>(syn <i>Rhaphidophora aurea</i> , <i>Scindapsus aurea</i> )<br>(Golden Pothos) | <p><u>Cytokinin</u>: PBA 100 to 300 ppm / Weekly foliar sprays for 3 weeks.</p> <p><u>Purpose</u>: Branching agent – Can PBA induce more branching in Pothos?</p> <p><u>Effect</u>: Buds swelled but none grew out. Phytotoxicity in the form of leaf necrosis noted.</p>   | (McConnell and Poole 1972)  |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>             |
|--|---|------------------------------|
| <i>Epipremnum aureum</i><br>(syn <i>Rhaphidophora aurea</i> )<br>(Golden Pothos) | <u>Cytokinin</u> : BA 50 to 200 ppm / Foliar spray 3 times every two weeks starting 2w after potting.<br><u>Purpose</u> : Branching agent – Can BA increase the number of cuttings per stock plant?<br><u>Effect</u> : BA 200 ppm increased branching   | (Sieminska-Michalak 1989)    |
| <i>Epipremnum aureum</i><br>(syn <i>Rhaphidophora aurea</i> )<br>(Golden Pothos) | <u>Cytokinin</u> : BA 500 to 750 ppm / Soak basal end of cuttings for 5 min prior to sticking<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Shoot length reduced. Branching was not increased. Rooting was not affected.   | (Wang 1987)                  |
| <i>Euphorbia lathyris</i><br>(Caper spurge)                                      | <u>Cytokinin</u> : BA+GA <sub>4+7</sub> in various combinations (3 to 300 ppm each) OR Promalin (0 to 1200 ppm) / One or more foliar sprays at weekly intervals<br><u>Purpose</u> : Growth enhancer – Can BA + GA promote faster growth or more branching?<br><u>Effect</u> : BA 3 ppm + GA 300 ppm was best at increasing plant height and number of nodes per plant. BA 300 ppm alone followed by BA 30 ppm or 300 ppm + GA 3 ppm was best at stimulating lateral branching. The best Promalin rate was Promalin 600 ppm and 1200 ppm. 2 applications of Promalin were better than 1 or 3 weekly applications at promoting branching. Dry weight accumulated faster when Promalin applied to smaller plants rather than to larger plants. | (Preece 1990)                |
| <i>Euphorbia pulcherrima</i><br>(Poinsettia)                                     | <u>Cytokinin</u> : BA 1250 ppm / single drench when IBA treated cuttings were stuck in the mist bed.<br><u>Purpose</u> : Growth enhancer – Do BA drenches improve rooting of cuttings?<br><u>Effect</u> : BA increased the number of roots per cutting and the root fresh weight  | (Carlson and Carpenter 1972) |
| <i>Euphorbia pulcherrima</i><br>(Poinsettia)                                     | <u>Cytokinin</u> : PBA 250 to 750 ppm / Single Foliar spray application<br><u>Purpose</u> : Branching agent – Height control<br><u>Effect</u> : 500 ppm PBA increased lateral shoot formation of un-pinched plants prior to flower induction. No delay in flower development or size. Phytotoxicity occurred above 250 ppm and was worse in lower temperatures than higher ones but was reduced by transferring plants to higher temps. Effects lasted about 4 weeks.   | (Jeffcoat 1977)              |

Table A1 Continued

| <b>Plant</b>                              | <b>Notes</b>  | <b>Reference</b>              |
|---|---|-------------------------------|
| <i>Euphorbia pulcherrima</i> (Poinsettia) | <p><u>Cytokinin</u>: BA <math>10^{-6}</math>-<math>10^{-3}</math>M (.225 ppm - 225 ppm), OR m-OH-bzl6Ado <math>10^{-6}</math>-<math>10^{-4}</math>M (.373 ppm-37.3 ppm) / 5 foliar sprays at 15 day intervals starting 15DAP.</p> <p><u>Purpose</u>: Branching agent – Propagation – Can Cytokinins increase branching and thus production of cuttings in Poinsettia stock plants?</p> <p><u>Effect</u>: BA 22.5 increased the number of shoots by 42% and the cytokinin m-OH-bzl6Ado 37.3 ppm increased shoots by 66%. Neither of these rates affected subsequent rooting of the cuttings. BA 225 ppm reduced the number of cuttings produced below that of control and caused phytotoxicity and reduced the rooting percentage of the cuttings.</p> | (Kamínek et al. 1987)         |
| <i>Euphorbia pulcherrima</i> (Poinsettia) | <p><u>Cytokinin</u>: BA 100 ppm / Single foliar spray at the beginning of Bract necrosis</p> <p><u>Purpose</u>: Disease resistance</p> <p><u>Effect</u>: BA completely arrested the progress of Bract necrosis after symptoms appeared. Effect lasted for 34days</p>  | (McAvoy and Bible 1998)       |
| <i>Euphorbia pulcherrima</i> (Poinsettia) | <p><u>Cytokinin</u>: Kinetin 1 to 100 ppm / Lanolin paste on axillary buds</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: Kinetin at 1 ppm worked best at stimulating lateral shoots. Effect lasted about 24days</p>  | (Milbocker 1972)              |
| <i>Euphorbia pulcherrima</i> (Poinsettia) | <p><u>Cytokinin</u>: BA 50 to 150 ppm OR BA+GA 25 ppm (Promalin) OR PBA 150 ppm / Single foliar spray 1 week prior to inoculation</p> <p><u>Purpose</u>: Disease resistance</p> <p><u>Effect</u>: No effect on the incidence of grey mold (<i>Botrytis cinerea</i>)</p>   | (Sammons et al. 1981)         |
| <i>Euphorbia pulcherrima</i> (Poinsettia) | <p><u>Cytokinin</u>: BA 1 to 50 ppm / Lanolin paste applied to axillary buds</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: 50 ppm induced the most lateral shoots to develop. It also induced lateral shoots adjacent to the shoot it was applied to indicating a small amount of movement.</p> <p><u>Notes</u>: Article implies that lanolin paste better than foliar spray – does not cause rosetting or phytotoxicity.</p>  | (Semeniuk and Griesbach 1985) |
| <i>Euphorbia pulcherrima</i> (Poinsettia) | <p><u>Cytokinin</u>: PBA 100 to 300 ppm / Single foliar spray 1 to 5 weeks after sticking</p> <p><u>Purpose</u>: Disease resistance - Reduce splitting</p> <p><u>Effect</u>: PBA at 300 ppm 1wk after sticking induced juvenile leaves and reduced splitting but GA was more effective</p>  | (Siraj-Ali et al. 1990)       |
| <i>Euphorbia pulcherrima</i> (Poinsettia) | <p><u>Cytokinin</u>: PBA 250 ppm, BA 1000 ppm / Single foliar spray</p> <p><u>Purpose</u>: Stock plant maintenance – branching agent and subsequent rooting of cuttings</p> <p><u>Effect</u>: BA 1000 ppm stimulated the most lateral branches and the highest number of cuttings per plant but also had the highest days to root and the fewest roots. PBA 250 ppm was generally slightly less than BA for no. branches and cuttings, but did not effect subsequent rooting of cuttings taken from treated plants.</p>   | (Carpenter and Beck 1972)     |

Table A1 Continued

| <b>Plant</b>                                  | <b>Notes</b>   | <b>Reference</b>                      |
|---|--|---------------------------------------|
| <i>Euphorbia pulcherrima</i><br>(Poinsettia)  | <u>Cytokinin</u> : PBA 200 to 300 ppm OR BA 500 to 1000 ppm /<br>Two foliar spray applications in August<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Increased number of lateral branches induced. The effect did not continue after the second spray. Phytotoxicity noted. BA was worse than PBA. It took 3 weeks to disappear.  | (Carpenter et al. 1971)               |
| <i>Euphorbia pulcherrima</i><br>(Poinsettia)  | <u>Cytokinin</u> : BA 62.5 to 500 ppm / Foliar spray 2 times at 20 day intervals<br><u>Purpose</u> : Branching agent – Propagation – Stock plant maintenance - Produce more cuttings from stock plants without affecting subsequent rooting<br><u>Effect</u> : BA 125 ppm worked best at maximizing the number of cuttings produced on stock plants. Rooting percentage was not affected by this rate. 500 ppm BA delayed rooting in the cuttings.                 | (Witaszek 1989)                       |
| <i>Euphorbia pulcherrima</i><br>(Poinsettia)  | <u>Cytokinin</u> : BA 5 to 20 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Senescence inhibitor – Can BA reduce senescence during simulated shipping ?<br><u>Effect</u> : No effect   | [Ref. Chapter 7]                      |
| <i>Exacum affine</i><br>(Persian Violet)      | <u>Cytokinin</u> : BA 50 to 400 ppm (Configure) / Single Foliar spray applied twice at weekly interval<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : No effect on growth. Phytotoxicity at all rates. Severely delayed flowering   | [Ref. Chapter 7]                      |
| <i>Fosterella penduliflora</i><br>(Bromeliad) | <u>Cytokinin</u> : BA 200 to 800 ppm, Kinetin 200 to 400 / Single foliar spray on 9 month old plants 4 times at two week intervals<br><u>Purpose</u> : Branching agent – Propagation – Can CKs be used to increase offsets for use in propagation?<br><u>Effect</u> : BA 800 ppm increased lateral shoot production by 50% and is better than pinching. Kinetin 400 was the same as pinching. New shoots were shorter and not as thick.                            | (Pytlewski and Hetman 1985)           |
| <i>Freesia hybrida</i>                        | <u>Cytokinin</u> : BA 100 ppm / 30 min Vacuum infusion or 24hr Bulb soak with BA alone or in combination with GA <sub>3</sub> , Ethephon or Ethephon+GA <sub>3</sub> .<br><u>Purpose</u> : Growth enhancer – Does BA help corms sprout sooner (for more crops per year) or improve flower quality?<br><u>Effect</u> : BA does not influence sprouting or the number of days to flower. BA+GA+Eth delayed the time to sprout by 12 days.                            | (Gilbertson-Ferriss and Wilkins 1981) |
| <i>Fuchsia</i> hybrid                         | <u>Cytokinin</u> : PBA 250 to 750 ppm / Single Foliar spray application<br><u>Purpose</u> : Branching agent – Height control<br><u>Effect</u> : 500 ppm PBA increased lateral shoot formation of un-pinched plants prior to flower induction. No delay in flower development or size. Phytotoxicity occurred at 500 ppm and was worse in lower temperatures than higher ones but was reduced by transferring plants to higher temps. Effects lasted about 4 weeks. | (Jeffcoat 1977)                       |

Table A1 Continued

| <b>Plant</b>                                     | <b>Notes</b>  | <b>Reference</b>       |
|--|---|------------------------|
| <i>Fuchsia</i>                                   | <u>Cytokinin</u> : BA 250 ppm / Single foliar spray after pinching and after multiple GA applications.<br><u>Purpose</u> : Branching agent – Production - Produce standards faster. Induce top branching after growing the trunk.<br><u>Effect</u> : BA slightly increased branching, but GA applied within 5 weeks of the BA spray appeared to inhibit this.   | (Mynett 1985)          |
| <i>Gaillardia x grandiflora</i> (Blanket flower) | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Significant phytotoxicity  | (Lieth and Dodge 2004) |
| <i>Gaura lindheimeri</i> (Wandflower, Gaura)     | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity. Increased flower stem length.   | (Lieth and Dodge 2004) |
| <i>Gazania linearis</i> (Treasureflower)         | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004) |
| <i>Gerbera jamesonii</i> (Gerber Daisy)          | <u>Cytokinin</u> : BA $10^{-6}$ - $10^{-3}$ M (.225 ppm - 225 ppm), OR m-OH-bzl6Ado $10^{-6}$ - $10^{-4}$ M (.373 ppm-37.3 ppm) / dip the tops of cut-back plants into cytokinin solutions for 20min prior to planting and then follow up with 4 foliar sprays at 15 day intervals starting 15DAP.<br><u>Purpose</u> : Branching agent – Propagation – Can Cytokinins increase branching and thus production of cuttings?<br><u>Effect</u> : BA 2.25 ppm increased the number of shoots by 31% and the cytokinin m-OH-bzl6Ado 37.5 ppm increased shoots by 62%. Neither affected subsequent rooting of the cuttings. BA at 225 ppm reduced the number of cuttings produced below that of the control. No phytotoxicity reported at any rate. Stock plants that were not submerged in cytokinin solutions prior to planting did not produce as many cuttings as those that were. | (Kamínek et al. 1987)  |
| <i>Gerbera jamesonii</i> (Gerber Daisy)          | <u>Cytokinin</u> : BA, PBA 100 to 400 ppm each. / Plants defoliated and sprayed twice 6 weeks apart to induce new shoots.<br><u>Purpose</u> : Branching agent - Propagation<br><u>Effect</u> : 2 sprays of 200 ppm PBA or BA promoted more sprouting shoots harvested for cuttings. Large cultivar differences.   | (Zieslen et al. 1985)  |
| <i>Gerbera jamesonii</i> (Gerber Daisy)          | <u>Cytokinin</u> : BA 25 or 50 ppm (Configure) + GA 12.5 or 25 ppm / Single foliar spray<br><u>Purpose</u> : Flower enhancer – Can BA or BA + GA affect flower opening?<br><u>Effect</u> : No effect on height, branching, flower number or timing, or fasciation   | [Ref. Chapter 7]       |

Table A1 Continued

| <b>Plant</b>                                       | <b>Notes</b>  | <b>Reference</b>        |
|--|---|-------------------------|
| <i>Gladiolus</i><br>(Gladiola)                     | <u>Cytokinin</u> : BA 25 ppm / Corm or cormel pre=plant soak for 24 to 30hrs just after harvesting in April<br><u>Purpose</u> : Propagation – Does BA increase corm and cormel yield?<br><u>Effect</u> : BA decreased time to sprouting from 90 days to 10 days and increased the number of corms and slightly increased the number of cormels produced one year later.   | (Ahmad and Murty 1977)  |
| <i>Gladiolus</i><br>(Gladiola)                     | <u>Cytokinin</u> : BA 25 to 100 ppm / Pre-plant bulb soak for 24h<br><u>Purpose</u> : Propagation – Does BA increase corm and cormel yield?<br><u>Effect</u> : 25 ppm BA decreased the number days to sprouting by 10 days as well as increasing sprouting %. BA increased corm diameter and weight and cormel number and weight but it did none of these things as well as ethephon.                                       | (Ram et al. 2002)       |
| <i>Gladiolus</i><br>(Gladiola)                     | <u>Cytokinin</u> : Kinetin 25 to 50 ppm / Pre-plant Corm soak for 6h.<br><u>Purpose</u> : Flower enhancer – Does BA affect flowering?<br><u>Effect</u> : Kinetin 50 ppm increased the length of the flower stalk, and the flower and 25 ppm was best at increasing the number of flowers per spike (2.5 more than control). 25 ppm Kinetin resulted in an increase in corm size and production but not as much as ethephon. | (Roychowdhury 1989)     |
| <i>Gladiolus grandiflorus</i><br>(Gladiola)        | <u>Cytokinin</u> : BA $10^{-4}$ M / Corms grown in Petri dishes in sand that was wetted with the BA solution.<br><u>Purpose</u> : Dormancy control – can BA affect corm dormancy?<br><u>Effect</u> : BA replaced cold storage completely. In cold stored corms, BA reduced the number days to sprouting by at least 5d. BA and ABA antagonized each other   | (Ginzburg 1973)         |
| <i>Gladiolus hortorum</i><br>(Gladiola)            | <u>Cytokinin</u> : Kinetin 100 to 2000 ppm / 24hr pre-plant bulb soak<br><u>Purpose</u> : Flower enhancer – Does BA affect flowering?<br><u>Effect</u> : Kinetin stimulated axillary buds, but they were deformed and did not grow. Kinetin delayed bulb sprouting, inhibited flower spike formation and reduced cormel formation. Kinetin did not prevent bud blasting under low light conditions.                         | (Tonecki 1979)          |
| <i>Gynura sarmentosa</i><br>(Purple Passion Vine)  | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – How does PBA affect growth?<br><u>Effect</u> : No effect on height or on branching  | (Henley and Poole 1974) |
| <i>Gypsophila elegans</i><br>(Showy Baby's breath) | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)  |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>   | <b>Reference</b>          |
|---|--|---------------------------|
| <i>Gypsophila paniculata</i><br>(Baby's breath)                               | <u>Cytokinin</u> : BA 300 ppm / Single foliar spray at the beginning of the experiment.<br><u>Purpose</u> : Flower enhancer - To improve flowering times under varying day length and temperatures<br><u>Effect</u> : BA improved time to bud in Long Day but was not as good as vernalization. BA increased the time to anthesis in Long Day and Short Day. In one cultivar BA was the only treatment to cause the plants to flower during warm night growing conditions. BA increased branching but in this plant it was considered to reduce plant quality.                     | (Davies et al. 1996)      |
| <i>Hedera canariensis</i><br>(Algerian Ivy)                                   | <u>Cytokinin</u> : BA 50 to 200 ppm / Foliar spray 3 times every two weeks starting 2w after potting.<br><u>Purpose</u> : Branching agent – reduce the number of cuttings per pot<br><u>Effect</u> : BA 200 ppm increased branching  | (Sieminska-Michalak 1989) |
| <i>Hedera helix</i> &<br><i>H. canariensis</i><br>(English Ivy, Algerian Ivy) | <u>Cytokinin</u> : BA+GA (0 to 300 ppm in factorial) / Single foliar sprays onto potted plants<br><u>Purpose</u> : Branching agent – Production - Increase branching and growth for faster production<br><u>Effect</u> : BA 300 ppm + GA 200 ppm greatly increased branching. Results similar to Atrimmec but not quite as high as Atrimmec plus pinch.  | (Al-Juboory et al. 1997)  |
| <i>Hedera helix</i><br>(English Ivy)  | <u>Cytokinin</u> : BA 5µg / applied to scion tip daily OR 500 ppm sprayed on scion<br><u>Purpose</u> : Propagation – Grafting enhancer<br><u>Effect</u> : Either treatment increased assimilate transfer from rootstock to scion   | (Clark and Hackett 1980)  |
| <i>Hedera helix</i><br>(English Ivy)  | <u>Cytokinin</u> : BA 2.5 – 5µg every other day. BA dissolved in a methanol + water droplet and placed on the apical shoot tip of juvenile plants that had been root drenched with Ancymidol.<br><u>Purpose</u> : Growth Control – Can the combination of BA + Ancymidol trigger juvenile Hedera to enter the adult growth stage?<br><u>Effect</u> : BA alone reduced branching and increased stem diameter but did not effect any other measure. BA reversed the growth inhibiting effects of Ancymidol. Neither BA alone or in combination triggered adult growth phase changes. | (Clark and Hackett 1981)  |
| <i>Hedera helix</i><br>(English Ivy)  | <u>Cytokinin</u> : PBA 100 to 1000 ppm / Two foliar sprays 1 week apart onto newly pruned plants<br><u>Purpose</u> : Branching agent – Can PBA increase branching?<br><u>Effect</u> : No effect at these rates.  | (Lewnes and Moser 1976)   |
| <i>Hedera helix</i><br>(English Ivy)  | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Increased branching. Caused no phytotoxicity  | (Lieth and Dodge 2004)    |

Table A1 Continued

| <b>Plant</b>                                  | <b>Notes</b>  | <b>Reference</b>          |
|---|---|---------------------------|
| <i>Hedera helix</i><br>(English Ivy)          | <u>Cytokinin</u> : Kinetin 0.1 μmol / plant (21.5 μg) / Rubber tubing placed snugly over the cut end of a plant. Liquid solution placed into the tubing and is slowly absorbed into plant through the cut end.<br><u>Purpose</u> : Growth enhancer – Can Kinetin revert Hedera from Adult to juvenile growth phase?<br><u>Effect</u> : No | (Rogler and Hackett 1975) |
| <i>Helenium</i><br>(Sneezeweed)               | <u>Cytokinin</u> : Kinetin, BA, KT 20 to 40 ppm each / Foliar sprays 3 times, one week apart in summer<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : BA, Kinetin, BA+GA increased lateral branching but did not affect height. Delayed flowering but increased flower number                                   | (Rounkova 1985)           |
| <i>Helianthes annuus</i><br>(Sunflower)       | <u>Cytokinin</u> : BA, BA+GA 150 to 250 ppm / Single foliar spray 20 to 60 days after planting to field grown plants.<br><u>Purpose</u> : Yield enhancer – Can foliar spray applications of BA increase seed set and yield?<br><u>Effect</u> : BA 150 ppm applied 40DAT was best and increased seed set and yield by 25%                  | (Beltrano et al. 1994)    |
| <i>Helianthes annuus</i><br>(Sunflower)       | <u>Cytokinin</u> : BA 2 ppm / Seeds sowed in Petri dish with water and BA<br><u>Purpose</u> : Germination enhancer<br><u>Effect</u> : BA counteracted ABA's germination inhibition. BA enhanced germination % but not as well as Ethrel.  | (Kumar and Sastry 1974)   |
| <i>Helianthes annuus</i><br>(Sunflower)       | <u>Cytokinin</u> : Zeatin, Zeatin riboside $5.0 \times 10^{-5}$ M / Single foliar spray<br><u>Purpose</u> : Stress resistance – Stomatal opening<br><u>Effect</u> : Zeatin induces stomatal opening in 2 minutes. Zeatin Riboside has no effect.  | (Kuraishi et al. 1981)    |
| <i>Helianthes annuus</i><br>(Sunflower)       | <u>Cytokinin</u> : BA+GA 62.5 to 500 ppm / Single foliar spray at flowering<br><u>Purpose</u> : Senescence inhibitor<br><u>Effect</u> : Not effective at inhibiting leaf yellowing or increasing flower life. Caused plants to stretch  | (Pallez et al. 2002)      |
| <i>Helianthes annuus</i><br>(Sunflower)       | <u>Cytokinin</u> : Kinetin 15 ppm / single foliar spray 45 days after sowing<br><u>Purpose</u> : Yield enhancer - Does kinetin increase seed yield of the plants?<br><u>Effect</u> : Kinetin increased seed yield but not as much as TIBA or high N levels  | (Uppar and Kulkarni 1989) |
| <i>Helleborus × hybridus</i><br>(Lenten Rose) | <u>Cytokinin</u> : BA 50 to 800 ppm (Configure) / Foliar spray or drench applied every 2 weeks for 12 weeks during the summer<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : TBD – Increases branching. No phytotoxicity but leaves are feathered.   | [Ref. Chapter 6]          |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>         |
|--|---|--------------------------|
| <i>Hemerocallis</i> (Daylily)                                    | <u>Cytokinin</u> : BA 2500 ppm, 5000 ppm / Foliar spray for 1, 2, 3, 4, or 5 consecutive weeks<br><u>Purpose</u> : Branching agent - Propagation<br><u>Effect</u> : BA increased offset formation. Higher rates and more applications were generally best.  | (Amling et al. 2007)     |
| <i>Hemerocallis</i> (Daylily)                                    | <u>Cytokinin</u> : BA Foliar spray 1250, 2500, 3750 ppm applied twice in the summer<br><u>Purpose</u> : Branching agent – Propagation – Can BA sprayed at flowering increase offset formation?<br><u>Effect</u> : BA increased divisions by 20%. BA 2500 ppm equivalent to Cycocel 3000 ppm   | (Leclerc et al. 2006)    |
| <i>Hemerocallis</i> (Daylily)                                    | <u>Cytokinin</u> : BA Root dip 125, 250, 500 ppm<br><u>Purpose</u> : Branching agent - Propagation<br><u>Effect</u> : BA 500 ppm increased the number of growing points but not as much as Rossizing  | (Leclerc et al. 2003)    |
| <i>Heuchera micrantha</i> var. <i>diversifolia</i> (Coral Bells) | <u>Cytokinin</u> : BA 50 to 1600 ppm (Configure) / Single Foliar spray applied 2WAP<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : No effect. Phytotoxicity at 800 to 1600 ppm   | [Ref. Chapter 7]         |
| <i>Hosta</i>   | <u>Cytokinin</u> : BA 125 to 2000 ppm / Single foliar sprays OR drenches 5 to 80mg ai / pot onto newly transplanted plugs in summer<br><u>Purpose</u> : Branching agent – Propagation – Can BA increase offset formation?<br><u>Effect</u> : 80mg ai drench caused severe phytotoxicity. Foliar sprays had no effect and drenches caused a reduction of growth index but increased offsets. The best rates were 20mg ai drench & 2000 ppm sprays. Many of the initial buds that formed later aborted. | (Findley et al. 1994)    |
| <i>Hosta</i>   | <u>Cytokinin</u> : BA 1250 to 3750 ppm / Single foliar sprays in summer onto plants with 0, 1, 2, or 3 pre-existing offsets<br><u>Purpose</u> : Branching agent – Propagation – Can BA increase offset formation? What is the optimal size of plant to be treated?<br><u>Effect</u> : The best rate is 3750 ppm onto plants with 0 initial offsets.   | (Garner and Keever 1995) |
| <i>Hosta</i>   | <u>Cytokinin</u> : BA 3000 ppm / 1 to 4 Foliar sprays at 30 day intervals<br><u>Purpose</u> : Branching agent – Propagation – Can BA increase offset formation? What is the optimal number of BA applications to maximize offsets?<br><u>Effect</u> : 4 applications yielded the highest number of offsets.   | (Garner et al. 1996)     |
| <i>Hosta</i>   | <u>Cytokinin</u> : BA 1250 to 3750 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent – Propagation – Can BA increase offset formation?<br><u>Effect</u> : Best rate varies by cultivar. 10 cultivars trialed. BA improves offset number on all cultivars. No phytotoxicity was observed   | (Garner et al. 1997a)    |

Table A1 Continued

| <b>Plant</b> | <b>Notes</b>   | <b>Reference</b>             |
|--------------|--|------------------------------|
| <i>Hosta</i> | <u>Cytokinin</u> : BA Single foliar spray 1250, 2500, 3750 ppm /<br>Timing of sprays not listed<br><u>Purpose</u> : Branching agent – Propagation – Can BA increase the number of offsets that form?<br><u>Effect</u> : 3750 ppm worked best at increasing offsets. It increased offsets in half of the 10 cultivars tested.                                 | (Garner et al. 1997b)        |
| <i>Hosta</i> | <u>Cytokinin</u> : BA 3000 ppm / 1 to 4 foliar sprays at 30 day intervals<br><u>Purpose</u> : Branching agent – Propagation – Can BA increase the number of offsets that form?<br><u>Effect</u> : 4 sprays worked best.  | (Garner et al. 1998)         |
| <i>Hosta</i> | <u>Cytokinin</u> : BA 3000 ppm (BAP-10) / Single foliar spray in April<br><u>Purpose</u> : Branching agent – Propagation – How does BA effect formation of offsets in 11 different cultivars?<br><u>Effect</u> : Depending on cultivar, BA caused 3 to 7 offsets to form in 30 days versus 0 to 2 for control.   | (Hoover et al. 1998)         |
| <i>Hosta</i> | <u>Cytokinin</u> : BA 3000 ppm / Foliar spray or Crown spray or Crown + Foliar spray or Crown Drench, Root immersion, Crown+root immersion<br><u>Purpose</u> : Branching agent - How does timing and application method affect response.<br><u>Effect</u> : Foliar sprays were the least effective. Crown and Crown+Root immersions were the most effective. | (Keever and Warr 2005)       |
| <i>Hosta</i> | <u>Cytokinin</u> : BA Single foliar spray 125 to 4000 ppm, Drenches 5 to 120mg ai<br><u>Purpose</u> : Branching agent - Propagation<br><u>Effect</u> : 3000 to 4000 ppm causes foliar yellowing as do drenches above 80mg ai. 3000 ppm and 40mg ai are equivalent for offsets  | (Keever 1994)                |
| <i>Hosta</i> | <u>Cytokinin</u> : BA Single foliar spray 2500 ppm<br><u>Purpose</u> : Branching agent - Propagation<br><u>Effect</u> : BA accelerates offset SOD which accelerates propagation by division  | (Keever et al. 1995)         |
| <i>Hosta</i> | <u>Cytokinin</u> : BA Root dip 125, 250, 500 ppm<br><u>Purpose</u> : Height control<br><u>Effect</u> : BA 500 ppm produced more compact plants   | (Leclerc et al. 2003)        |
| <i>Hosta</i> | <u>Cytokinin</u> : BA Foliar spray 1250, 2500, 3750 ppm applied twice in the summer or Seaweed extract containing cytokinins<br><u>Purpose</u> : Branching agent – Propagation – Can BA alone or in seaweed extract increase offset formation in field grown <i>Hosta</i> ?<br><u>Effect</u> : No effect on number of divisions.                             | (Leclerc et al. 2006)        |
| <i>Hosta</i> | <u>Cytokinin</u> : BA 3000 ppm / Single foliar spray 0 to 6 weeks after potting<br><u>Purpose</u> : Branching agent – Does the timing of BA application affect offset formation?<br><u>Effect</u> : BA applied 3 to 4 weeks after potting maximized offset formation and minimized crop time. Plants that had formed surface roots formed more offsets.      | (Schultz et al. 2001a, 2000) |

Table A1 Continued

| <b>Plant</b>                 | <b>Notes</b>   | <b>Reference</b>                                 |
|------------------------------|--|--|
| <i>Hosta</i>                 | <u>Cytokinin</u> : BA Single foliar spray 3000 ppm + high night temps<br><u>Purpose</u> : Stress Resistance – Can BA alter the effects of high temps on growth of <i>Hosta</i> grown in the south?<br><u>Effect</u> : BA did not reduce the effect of 85°F night temps. BA did not help production in areas of the country with high night temps.  | (Schultz et al. 2001b, 2001c)                    |
| <i>Hosta</i>                 | <u>Cytokinin</u> : BA Single foliar spray 3000 ppm, 1 to 6 WAT<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA increased axillary growth only if sprayed 4 or more weeks after transplant  | (Schultz et al. 2001a)                           |
| <i>Hosta</i>                 | <u>Cytokinin</u> : BA Single foliar spray 3000 ppm in August<br><u>Purpose</u> : Stress Resistance – Can BA applied during the summer foliage decline of <i>Hosta</i> reduce the impact of heat?<br><u>Effect</u> : BA improved appearance during summer, reduced leaf senescence and increased offset formation   | (Schultz et al. 2001b)<br>(Schultz et al. 2001c) |
| <i>Hosta</i>                 | <u>Cytokinin</u> : BA 3000 ppm / Single foliar spray onto single eye plants with varying root masses.<br><u>Purpose</u> : Branching agent – Propagation – How does root mass of the propagule affect the variability of BA induced offset formation?<br><u>Effect</u> : The largest root masses produced 3x - 6x more offsets than the smallest ones with BA depending on cultivar.  | (Schultz et al. 2001d, 1998)                     |
| <i>Hosta</i>                 | <u>Cytokinin</u> : BA Drench 100 to 3000 ppm at division or 2 weeks later<br><u>Purpose</u> : Branching agent - Propagation – Is timing important to maximize offsets?<br><u>Effect</u> : Higher rates were better. Offsets were increased regardless of timing  | (Warr and Keever 2004)                           |
| <i>Hosta</i>                 | <u>Cytokinin</u> : BA 2500 ppm / Single foliar sprays. Offsets removed 3.5 weeks later and put into mist beds<br><u>Purpose</u> : Branching agent – Propagation – Can BA induced offsets be removed immediately after bud formation to speed propagation?<br><u>Effect</u> : Offsets removed soon after formation rooted much better if they had 2 or more fully opened leaves than those at an earlier stage. NAA improved rooting. | (Wilton et al. 1994)                             |
| <i>Hosta sieboldiana</i>     | <u>Cytokinin</u> : BA Single foliar spray 1250 to 3750 ppm onto plants with varying numbers of offsets already present<br><u>Purpose</u> : Branching agent – Can BA increase offset formation?<br><u>Effect</u> : BA 3750 ppm works best on plants with 0 or 1 offset initially present.   | (Keever and Brass 1998)                          |
| <i>Hyacinthus</i> (Hyacinth) | <u>Cytokinin</u> : BA, PBA, DMAA ( $10^{-8}$ to $10^{-5}$ g/ml) (.01 ppm – 100 ppm)<br><u>Purpose</u> : Propagation – Can cytokinins increase bulblet formation in Hyacinth scale segments?<br><u>Effect</u> : No effect at these rates at influencing bulblet growth.   | (Pierik and Steegmans 1975)                      |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>   | <b>Reference</b>              |
|--|--|-------------------------------|
| <i>Hylocereus trigonus</i><br>(Nightblooming Cactus) | <u>Cytokinin</u> : BA Dip the apical end of cuttings into 25 to 100 ppm solutions for 24h prior to planting<br><u>Purpose</u> : Branching agent - Stock Plant Management<br><u>Effect</u> : 100 ppm caused more lateral shoots to break, providing more shoots for propagation.  | (Shimomura and Fujihara 1980) |
| <i>Hylocereus undatus</i><br>(Red Pitaya)            | <u>Cytokinin</u> : 50 to 200 ppm CPPU, 100 ppm BA+GA foliar sprays applied monthly in spring<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : 50 ppm CPPU caused earlier flowering by 1.5 to 2.5 months and increased flower number in Long Day or increased branching in Short Day. BA+GA – no effect                                 | (Khaimov and Mizrahi 2006)    |
| <i>Hypericum calycinum</i><br>(St. John's Wort)      | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Increased branching. Caused no phytotoxicity  | (Lieth and Dodge 2004)        |
| <i>Hypericum calycinum</i><br>(St. John's Wort)      | <u>Cytokinin</u> : BA+GA (Promalin) / Single spray application either in spring or during the dormant period in winter<br><u>Purpose</u> : Branching agent – Can Promalin be used to increase branching in stock plants?<br><u>Effect</u> : Promalin 1000 ppm increased shoot length (26%) and branching (200%) but Atrimmec was better at inducing branching. | (Thomas et al. 1992)          |
| <i>Hypocalymma angustifolia</i><br>(White myrtle)    | <u>Cytokinin</u> : BA 100 ppm / Foliar spray 3 times, 1 week apart – 2 months prior to taking cuttings<br><u>Purpose</u> : Branching agent / Propagation – Can BA increase branching on stock plants without affecting the rooting of the cuttings.<br><u>Effect</u> : BA increased branching but subsequent cuttings rooted very poorly compared to control.  | (Day and Loveys 1998)         |
| <i>Iberis sempervirens</i><br>(Candytuft)            | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Significant phytotoxicity   | (Lieth and Dodge 2004)        |
| <i>Impatiens</i><br>(Touch-me-not)                   | <u>Cytokinin</u> : BA+GA BA 10 <sup>-6</sup> M, GA 10 <sup>-4</sup> M seed priming<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Improved dark germination over unprimed seeds   | (Finch-Savage et al. 1991a)   |
| <i>Impatiens</i><br>(Touch-me-not)                   | <u>Cytokinin</u> : BA+GA BA 10 <sup>-5</sup> M, GA 10 <sup>-4</sup> M / Seeds imbibed in solution prior to sowing<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Improved germination % in dark but % was less than that of germination in the light without PGRs   | (Finch-Savage et al. 1991b)   |
| <i>Impatiens</i><br>(Touch-me-not)                   | <u>Cytokinin</u> : BA+GA BA 10 <sup>-6</sup> M-10 <sup>-4</sup> M, GA 10 <sup>-5</sup> M-10 <sup>-3</sup> M / Seeds soaked in solution prior to sowing<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Improved germination % in dark but % was less than that of germination in the light without PGRs                              | (Finch-Savage et al. 1991c)   |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>   | <b>Reference</b>          |
|---|--|---------------------------|
| <i>Impatiens</i><br>× <i>hawkeri</i><br>(New Guinea<br>Impatiens) | <u>Cytokinin</u> : BA+GA 2 to 1 and 4 to 1 ratios of BA to GA with BA at 25 to 50 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Flower enhancer – Can BA accelerate the time to first flower?<br><u>Effect</u> : Insignificant but positive effect on accelerating days to flower. Increased branching.  | [Ref. Chapter 7]          |
| <i>Impatiens</i><br><i>balsamina</i><br>(Balsalm)                 | <u>Cytokinin</u> : Kinetin 1 to 10 mg·L <sup>-1</sup> / Applied to apices after Short Day induction<br><u>Purpose</u> : Flower enhancer<br><u>Effect</u> : No effect of floral induction under Long Days or Short Days.  | (Toky et al. 1969)        |
| <i>Ipomoea</i><br><i>batatas</i><br>(Ornamental<br>Sweet Potato)  | <u>Cytokinin</u> : BA 12.5 to 1600 ppm (Configure) / Two foliar sprays applied 30 days apart during winter production<br><u>Purpose</u> : Branching agent - Does BA cause sweet potato vines to branch?<br><u>Effect</u> : No effect   | [Ref. Chapter 7]          |
| <i>Iresine</i> hybrid<br>(Blood Leaf)                             | <u>Cytokinin</u> : BA 50 to 800 ppm (Configure) / Single Foliar spray applied 2WAP<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : No effect on growth. Some phytotoxicity at high rates   | [Ref. Chapter 7]          |
| <i>Iris</i><br>× <i>hollandica</i><br>(Dutch Iris)                | <u>Cytokinin</u> : BA 0.1g·L <sup>-1</sup> (100 ppm) / Rhizome soak for 1hr<br><u>Purpose</u> : Flower enhancer – will a rhizome soak cause earlier flowering<br><u>Effect</u> : 1hr BA soaks induced earlier flowering and higher % flowering on un-cooled iris rhizomes but the results were not as good as Ethylene gas for 3d.   | (Imanishi and Yue 1986)   |
| <i>Iris</i><br>× <i>hollandica</i><br>(Dutch Iris)                | <u>Cytokinin</u> : BA 0.1g ·L <sup>-1</sup> (100 ppm) / Rhizome soak for 6 hrs<br><u>Purpose</u> : Flower enhancer - Can BA increase flowering % in a low % flowering cultivar ('Blue Magic' 7cm rhizomes)<br><u>Effect</u> : BA increased flowering percentage a lot, but not as much as ethylene   | (Yue et al. 1988)         |
| <i>Iris</i><br>× <i>hollandica</i><br>(Dutch Iris)                | <u>Cytokinin</u> : BA, 2iP, Kinetin, Zeatin / 1ml of 10 <sup>-3</sup> - 10 <sup>-6</sup> M solution injected into the space between the flower bud and spathe in low light conditions<br><u>Purpose</u> : Flower enhancer – Can cytokinins prevent bud blast in low light conditions such as winter production<br><u>Effect</u> : BA and Zeatin at 10 <sup>-4</sup> M increased % of plants that flowered in low light (reduced bud blast). BA > Zeatin > Kinetin > 2iP. BA was only 7% below flowering under full light conditions. | (Mae and Vonk 1974)       |
| <i>Iris</i><br>× <i>hollandica</i><br>(Dutch Iris)                | <u>Cytokinin</u> : Zeatin 10 <sup>-4</sup> M (22 ppm) / 1mL injected into bud on plants that were grown in low light levels to induce blasting.<br><u>Purpose</u> : Senescence inhibitor – Can zeatin prevent bud blast?<br><u>Effect</u> : Zeatin reduced but did not eliminate blasting. It also reduced ABA level in the flowers.   | (Vonk and Ribot 1982)     |
| <i>Iris germanica</i><br>(Tall bearded<br>Iris)                   | <u>Cytokinin</u> : BA 100 to 200 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent - Flower enhancer<br><u>Effect</u> : BA 100 ppm slightly increased lateral branching on one cultivar. This resulted in more bloom stalks the following year.  | (Leeson and Harkess 2006) |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>           |
|--|---|----------------------------|
| <i>Jovibarba hirta</i><br>(Hens and Chicks)                                | <u>Cytokinin</u> : BA 50 to 1600 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Branching agent - Propagation - Can BA increase the number of offsets produced by stock plants?<br><u>Effect</u> : 1600 ppm increased offsetting best  | [Ref. Chapter 3]           |
| <i>Kalanchoe</i>   | <u>Cytokinin</u> : BA 10 to 50 ppm<br><u>Purpose</u> : Branching agent – Can BA replace pinching?<br><u>Effect</u> : 50 ppm increased branching above that of hand pinching   | (Lyons and Hale 1987)      |
| <i>Kalanchoe pinnata</i><br>(Cathedral Bells)                              | <u>Cytokinin</u> : Thidiazuron $10^{-12}$ to $10^{-6}$ M (0.22 ppt to 0.22 ppm) / Dispersed into agar in petri dishes where leaves were cultured<br><u>Purpose</u> : Growth control – Do cytokinins inhibit epiphyllus plantlet formation?<br><u>Effect</u> : Yes. Thidiazuron rates higher than 0.22 ppb inhibited plantlet root growth and shoot extension but also inhibited senescence of the cut leaves.   | (Jaiswal and Sawhney 2006) |
| <i>Lablab purpurea</i><br>(syn <i>Dolichos lablab</i> )<br>(Hyacinth Bean) | <u>Cytokinin</u> : BA, Kinetin 100 ppm / Single 30ml drench 14 or 18 days after germination<br><u>Purpose</u> : Growth enhancer - Induce indeterminate growth in a determinate plant<br><u>Effect</u> : Neither induced determinate growth. Kinetin increased plant height and number of nodes when applied at 14 days after germination. BA reduced height and number of nodes at both application times. Both induced lateral shoot growth. Kinetin induced flower formation. | (Kim and Okubo 1996)       |
| <i>Lamium maculatum</i><br>(Spotted Dead Nettle)                           | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)     |
| <i>Lantana camara</i>  | <u>Cytokinin</u> : BA 20 to 160 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Branching agent - Flower enhancer – Can BA increase branching or flowering?<br><u>Effect</u> : No effect  | [Ref. Chapter 7]           |
| <i>Lantana camara</i>  | <u>Cytokinin</u> : BA 50 to 3200 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Branching agent - Can BA increase branching?<br><u>Effect</u> : No effect. High rates reduced size, branching and caused phytotoxicity.  | [Ref. Chapter 7]           |
| <i>Lantana camara</i>  | <u>Cytokinin</u> : BA 800 to 1200 ppm (Configure) / Weekly foliar sprays for 3 weeks.<br><u>Purpose</u> : Branching agent – Does BA effect growth at all?<br><u>Effect</u> : BA increased branching   | [Ref. Chapter 7]           |
| <i>Lavandula</i><br>(Lavander)   | <u>Cytokinin</u> : Kinetin +GA+Ethrel 0.5 mM + 1 mM + 1 mM / Pre-germination seed soak<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Promoted germination at below and above normal temperatures but not as well as 10 mM GA alone  | (Persson 1993)             |

Table A1 Continued

| <b>Plant</b>                                     | <b>Notes</b>  | <b>Reference</b>               |
|--|---|--------------------------------|
| <i>Lavandula</i><br>(Lavander)                   | <u>Cytokinin</u> : Kinetin + Brassinosteroid 20 to 40 ppm each / 2 applications of each at 5 days interval.<br><u>Purpose</u> : Growth enhancer – Can Kinetin+Br influence growth or essential oil content?<br><u>Effect</u> : Kinetin 40 ppm resulted in increase 3 days branching and increased oil yield per plant. Kinetin 40 + BR 20 ppm was the most effective  | (Youssef and Talaat 1998)      |
| <i>Lavandula angustifolia</i><br>(Lavender)      | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)         |
| <i>Lavandula vera</i><br>(English lavender)      | <u>Cytokinin</u> : Kinetin (1 to 4 ppm), DPU (2.5 to 10 ppm), BA (1 to 4 ppm), Zeatin (1 to 4 ppm) / 4 Foliar sprays at 1 week intervals<br><u>Purpose</u> : Growth Control – Yield enhancer – Can cytokinins alter the growth or improve the yield of essential oils of plants in family Lamiaceae?<br><u>Effect</u> : No effect on growth. Cytokinins reduced the time to flower by 7 to 10 days. The ratios of components in the essential oils was altered. DPU 10 ppm increase essential oil yield by almost 200%. | (El-Keltawi and Croteau 1987a) |
| <i>Leucanthemum x superbum</i><br>(Shasta Daisy) | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity. Increased flower stem length  | (Lieth and Dodge 2004)         |
| <i>Leucospermum</i><br>(Pincushion)              | <u>Cytokinin</u> : BA 50 to 300 ppm foliar sprayed once or 200 ppm applied 1 to 4 times in late summer to fall<br><u>Purpose</u> : Flower enhancer<br><u>Effect</u> : 200 ppm applied once in late summer increased the number of florets and increased flower stem diameter  | (Napier et al. 1986)           |
| <i>Liatris</i><br>(Gayfeather)                   | <u>Cytokinin</u> : BA 50 ppm (Configure) + Topflor 2.5 to 50 ppm / 5 minute pre-plant bulb soak<br><u>Purpose</u> : Height Control – Flower enhancer - Can BA + Topflor reduce stem height without affecting flower size for time to emergence<br><u>Effect</u> : BA had no effect. Topflor delayed flower emergence  | [Ref. Chapter 7]               |
| <i>Liatris spicata</i><br>(Gayfeather)           | <u>Cytokinin</u> : BA 10 ppm, BA+GA 10 ppm+500 ppm / 1hr bulb soak after cold storage is finished.<br><u>Purpose</u> : Flower enhancer - To speed the time to flower.<br><u>Effect</u> : BA or BA+GA had no effect on time to flower in Long Day, but reduced time to flower in Short Day grown plants.   | (Moe and Berland 1986)         |

Table A1 Continued

| <b>Plant</b>                           | <b>Notes</b>   | <b>Reference</b>            |
|--|--|-----------------------------|
| <i>Lilium</i><br>(Lily)                | <p><u>Cytokinin</u>: BA+GA (Promalin) 90 to 180 ppm + 1-MCP 500nl·L<sup>-1</sup> for 18hr / Promalin foliar spray applied pre-ship and 1-MCP applied immediately post-ship</p> <p><u>Purpose</u>: Senescence inhibitor – Does Promalin + 1-MCP reduce leaf yellowing and flower senescence</p> <p><u>Effect</u>: Promalin 180 ppm alone delayed leaf, flower and bud senescence but some flowers were malformed. 1-MCP alone delayed flower senescence better than Promalin and did not induce malformations. Promalin + 1-MCP delayed leaf senescence the most.</p>             | (Çelikel et al. 2002)       |
| <i>Lilium</i><br>(Lily)                | <p><u>Cytokinin</u>: BA 5µM (1 ppm), BA+NAA each 5µM / 12hr bulb soak prior to scaling</p> <p><u>Purpose</u>: Propagation – Can cytokinins increase the number of bulbets produced from scaling?</p> <p><u>Effect</u>: BA+NAA only effective at increasing bulbets (20%) if the treatment is done on post-flowering bulbs, not post cold treatment or post senescence bulbs. There were large cultivar differences and generally, normally low bulblet producing cultivars increased the most and high bulblet producing cultivars were actually decreased by the treatment.</p> | (Simmonds and Cumming 1976) |
| <i>Lilium</i><br>(Asiatic Hybrid Lily) | <p><u>Cytokinin</u>: BA+GA (Promalin) 100 ml / L (1800 ppm BA &amp; GA) / 48hr pre-plant bulb soak</p> <p><u>Purpose</u>: Flower Enhancer – Does Promalin promote flowering?</p> <p><u>Effect</u>: Promalin inhibited stem elongation, leaf unfolding, root elongation and greatly delayed flower bud formation</p>  | (Zhang et al. 1990)         |
| <i>Lilium</i><br>(Asiflorum Lily)      | <p><u>Cytokinin</u>: BA+GA (Promalin) (Accel) 50 to 500 ppm / Single foliar spray prior to cold storage</p> <p><u>Purpose</u>: Senescence inhibitor – Does CK inhibit leaf yellowing?</p> <p><u>Effect</u>: Promalin 250 ppm was better than Accel and greatly reduced leaf yellowing.</p>   | (Funnell and Heins 1998)    |
| <i>Lilium</i><br>(Oriental Lily)       | <p><u>Cytokinin</u>: BA 100 ppm, BA+GA (Promalin, Accel) 100 ppm (effective BA) / Pre-storage foliar sprays</p> <p><u>Purpose</u>: Senescence inhibitor – Does BA or BA+GA reduce leaf yellowing and flower senescence?</p> <p><u>Effect</u>: BA+GA prevented leaf yellowing but BA alone did not. Promalin was better than Accel. All combinations of BA+GA improved flower longevity, but Promalin was best.</p>   | (Ranwala and Miller 1998)   |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>  | <b>Reference</b>          |
|---|---|---------------------------|
| <i>Lilium</i><br>(Oriental,<br>Asiatic, and<br>LA Hybrid)   | <p><u>Cytokinin</u>: BA+GA (Promalin, Accel, Fascination) 25 to 100 ppm / Foliar sprays at various stages from 1 to 2 times.</p> <p><u>Purpose</u>: Senescence inhibitor – Does BA+GA reduce leaf yellowing, bud abortion and improve flower longevity in cold stored flowers?</p> <p><u>Effect</u>: Promalin 100 ppm and Accel 1000 ppm both reduce cold storage induced leaf yellowing and bud abortion. Promalin 100 ppm and Fascination 25 ppm both improved flower longevity of cold stored lilies but not match non-cold stored plants. Promalin applied just prior to cold storage was much better than Promalin applied 2 to 4 weeks prior to cold storage.</p> | (Ranwala and Miller 2005) |
| <i>Lilium lancifolium</i> ,<br><i>L. longiflorum</i> ,<br><i>L. speciosum</i> ,<br><i>L. platyphyllum</i> ,<br><i>L. hansonii</i><br>(Tiger Lily,<br>Easter Lily) | <p><u>Cytokinin</u>: BA Riboside 10 to 1000 ppm / Capillary thread tied around the upper part of the stem and placed in a vial of BA to draw it up via capillary action.</p> <p><u>Purpose</u>: Propagation – Do CKs induce bubil formation</p> <p><u>Effect</u>: BA did not induce bubil formation in non-bubil forming species but it did very well in bubil forming species. The effective rate varied by species from 10 to 1000 ppm. Bubils formed at or above point of application. Two applications produced more bubils than one. Some phytotoxicity and growth inhibition noted</p>  | (Iizuka et al. 1978)      |
| <i>Lilium longiflorum</i><br>(Easter Lily)  | <p><u>Cytokinin</u>: BA+GA (Promalin) 100 ppm / Single foliar spray prior to cold storage</p> <p><u>Purpose</u>: Flower enhancer - Senescence inhibitor – Does CK inhibit leaf yellowing or effect flower longevity?</p> <p><u>Effect</u>: Promalin reduced leaf yellowing and increased flower life in cold stored lilies</p>  | (Ranwala and Miller 2000) |
| <i>Lilium longiflorum</i><br>(Easter Lily)  | <p><u>Cytokinin</u>: BA+GA (Promalin) (Accel) / Single foliar spray 62 to 70 DAP.</p> <p><u>Purpose</u>: Senescence inhibitor &amp; Height control – What rate and application method of BA + GA is ideal to prevent leaf yellowing and minimize stem elongation</p> <p><u>Effect</u>: No combination of BA + GA prevented leaf yellowing and resulted in no stem elongation. Reducing spray volume to minimize runoff into the media resulted in less stem stretch as GA in the media contributes to stem length but less so to preventing yellowing. Promalin 50 ppm (1:1 BA:GA) worked better than other BA+GA combinations (10:1, 100:1).</p>                       | (Ranwala et al. 2003)     |
| <i>Lilium longiflorum</i><br>(Easter Lily)  | <p><u>Cytokinin</u>: BA+GA (Promalin) 100 ppm / Foliar sprays at various times; 36, 55, 80, 90 DAP</p> <p><u>Purpose</u>: Senescence inhibitor – Height control – What is the best timing for applying Promalin during production?</p> <p><u>Effect</u>: At 80DAP Promalin does not affect height and it results in the longest flower life, but by 80DAP, some leaf yellowing has already started. Promalin increases height at 36 or 55 DAP. All timings reduced leaf yellowing, but at 80DAP some leaf yellowing had already started and could not be prevented.</p>   | (Ranwala and Miller 1999) |

Table A1 Continued

| <b>Plant</b>                               | <b>Notes</b>  | <b>Reference</b>      |
|--|---|-----------------------|
| <i>Lilium longiflorum</i><br>(Easter Lily) | <u>Cytokinin</u> : BA, BA+GA 500 ppm / Leaf dip at various times<br><u>Purpose</u> : Senescence inhibitor – Does CK inhibit leaf yellowing by reducing respiration?<br><u>Effect</u> : BA and BA+GA inhibited leaf yellowing. and appeared to lower respiration rates for almost 10 days following application.   | (Franco and Han 1997) |
| <i>Lilium longiflorum</i><br>(Easter Lily) | <u>Cytokinin</u> : BA, GA+BA 50 to 1000 ppm / Single foliar spray or leaf dip prior to cold storage treatment<br><u>Purpose</u> : Senescence inhibitor – Does CK inhibit leaf yellowing?<br><u>Effect</u> : BA+GA 1000 ppm reduced leaf yellowing the most. BA alone was not quite as good as GA alone  | (Han 1995)            |
| <i>Lilium longiflorum</i><br>(Easter Lily) | <u>Cytokinin</u> : BA 25 to 500 ppm, BA+GA <sub>3</sub> 500 ppm, BA+GA <sub>4+7</sub> (Promalin) 50 to 1000 ppm / Foliar sprays at various times followed by dark storage<br><u>Purpose</u> : Senescence inhibitor – Do CKS reduce leaf yellowing?<br><u>Effect</u> : Promalin was better than others at reducing leaf yellowing. 50 ppm was a good rate. Promalin can be used after the onset of yellowing and will halt all further development but does not reverse it.  | (Han 1997)            |
| <i>Lilium longiflorum</i><br>(Easter Lily) | <u>Cytokinin</u> : BA 50 ppm, BA+GA 25 ppm / Single foliar sprays 40DAE or 55DAE or at various stages of bud growth<br><u>Purpose</u> : Senescence inhibitor – Height control – Flower enhancer – Can BA or BA+GA reduce leaf yellowing, control height, or increase flower size? Can BA+GA offset close spacing or lack of fungicide treatment?<br><u>Effect</u> : BA or BA+GA did not offset the height increase due to close spacing but can reduce leaf yellowing. BA or BA+GA did not offset the leaf yellowing due to root rot (no fungicide) but they did reduce it compared to controls. BA or BA+GA did not affect flowering at all. | (Han 2000)            |
| <i>Lilium longiflorum</i><br>(Easter Lily) | <u>Cytokinin</u> : Kinetin 0.1 to 1.0% (1000 to 10000 ppm), PBA (SD8339) 0.05% (500 ppm), BA 0.1 to 1.0% (1000 to 10000 ppm) / Mixed into a lonolin paste and applied to style of flower.<br><u>Purpose</u> : Propagation – Can cytokinins help the plants overcome self-incompatibility of pollination?<br><u>Effect</u> : BA 0.1% was ineffective. BA 1% overcame self-incompatibility the best. PBA 0.5% was less active than BA 1%.   | (Matsubara 1973)      |

Table A1 Continued

| <b>Plant</b>                                   | <b>Notes</b>   | <b>Reference</b>       |
|--|--|------------------------|
| <i>Lilium longiflorum</i><br>(Easter Lily)     | <p><u>Cytokinin</u>: BA+GA (Promalin, Accel) 100 to 400 ppm BA equivalent / Foliar spray early in production 1 time or 2 times 3 weeks apart followed by cold storage. Sprays restricted to lower portions of the plant</p> <p><u>Purpose</u>: Senescence inhibitor – Which PGR is better at reducing senescence</p> <p><u>Effect</u>: Promalin 400 ppm 1x or 100 ppm 2x was better at reducing senescence than BA equivalent rates of Accel. Promalin and Accel treated plants initially grew faster than control but only Promalin plants remained taller than control at harvest but 2 sprays @ 100 ppm were shorter than 1 spray @ 400 ppm. Neither influenced malformed or aborted buds in cold stored plants</p>   | (Whitman et al. 2001)  |
| <i>Lilium longiflorum</i><br>(Easter Lily)     | <p><u>Cytokinin</u>: PBA 500 ppm / Single foliar spray application when buds reached a certain size and placed into low light</p> <p><u>Purpose</u>: Flower enhancer – Does PBA assist flower development under low light</p> <p><u>Effect</u>: Under low lights, PBA did not prevent flower bud abortion. Under high light it resulted in slightly larger flowers but delayed anthesis. PBA caused some flower malformations.</p>   | (Wang 1996)            |
| <i>Lilium speciosum</i><br>(Lily)              | <p><u>Cytokinin</u>: BA 100 ppm, GA<sub>4/7</sub> + BA, GA<sub>3</sub> + BA both at (100 ppm + 100 ppm) / 48hr bulb soaks after varying amounts of cold storage. Treated plants then planted in either Long Days or Short Days.</p> <p><u>Purpose</u>: Dormancy Release – Flower enhancer – What is the relationship of BA and GAs on dormancy release and flowering?</p> <p><u>Effect</u>: If plants had no cold storage, then only GA<sub>4/7</sub> alone and GA<sub>4/7</sub> + BA would trigger stem elongation. Stems stayed very short. At 30 days of cold storage then only GA<sub>4/7</sub> alone and GA<sub>4/7</sub> + BA would trigger flower differentiation. At 60 days cold storage, GA<sub>4/7</sub> + BA was best at reducing time to emergence, time to flowering, stem length and increasing the number of flower buds over BA alone, GA<sub>3</sub> + BA, and GA alone.</p> | (Ohkawa 1979)          |
| <i>Lilium x formolongi</i><br>(Lily)           | <p><u>Cytokinin</u>: BA 100 ppm / 24 pre-plant seed soak – BA trialed alone or in combination with GA, IAA, or GA+IAA</p> <p><u>Purpose</u>: Propagation – Seed Germination</p> <p><u>Effect</u>: BA 100 ppm increased germination % by 20%, and reduced germination time by 3d</p>  | (Roh and Sim 1996)     |
| <i>Liriope muscari</i><br>(Lily turf)          | <p><u>Cytokinin</u>: Kinetin or GA + Kinetin 30 to 90 ppm each</p> <p><u>Purpose</u>: Germination enhancer - Propagation – Can Kinetin improve seed germination?</p> <p><u>Effect</u>: No effect on seed germination</p>   | (Fagan et al. 1981)    |
| <i>Lobelia cardinalis</i><br>(Cardinal flower) | <p><u>Cytokinin</u>: BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: Increased branching. Caused no phytotoxicity</p>  | (Lieth and Dodge 2004) |

Table A1 Continued

| <b>Plant</b>                               | <b>Notes</b>   | <b>Reference</b>               |
|--|--|--------------------------------|
| <i>Lupinus</i><br>(Lupine)                 | <u>Cytokinin</u> : Kinetin 30 ppm / Single foliar spray<br><u>Purpose</u> : Growth promoter – Does Kinetin induce nodule formation in legumes, and subsequent growth?<br><u>Effect</u> : Increased nodules, but the nodules were smaller.  | (Artamonov 1975)               |
| <i>Lupinus angustifolius</i><br>(Lupine)   | <u>Cytokinin</u> : BA 2mol / m <sup>3</sup> (450 ppm), Zeatin Riboside (Zeatin Riboside), Dihydrozeatin riboside (DHZ), plus other experimental synthetic cytokinins / solution brushed onto flowers once or daily from start of flowering to anthesis<br><u>Purpose</u> : Senescence inhibitor – Propagation - Does BA reduce flower senescence or increase seed yield?<br><u>Effect</u> : All the cytokinins had similar results. BA greatly reduced floral senescence and increased seed pod set on the main stem. However, the increased pod set on the main stem led to lower pod set on axillary stems. The overall seed yield was not different from control. The number of simultaneously open flowers on the stem was increased by BA. BA applied to pedicels stimulated more flower development than when applied to petals. Racemes were thicker and there was more secondary xylem formed. | (Atkins and Pigeaire 1993)     |
| <i>Lupinus angustifolius</i><br>(Lupine)   | <u>Cytokinin</u> : BA 2 mM (450 ppm) / Painted onto flowers daily until senescence with a paint brush<br><u>Purpose</u> : Yield enhancer – Does BA increase seed set?<br><u>Effect</u> : BA increased the number of seed pods set, but reduced the number of seeds per pod. Overall seed production increased 11%.   | (Liu and Longnecker 2001)      |
| <i>Majorana hortensis</i><br>(Majoram)     | <u>Cytokinin</u> : Kinetin 4 ppm, DPU 10 ppm / Foliar sprays onto plants grown with high saline (CaCl & NaCl) irrigation<br><u>Purpose</u> : Stress reducer – Can cytokinins reduce the drop in yield caused by saline conditions?<br><u>Effect</u> : DPU 10 ppm was slightly better than Kinetin 4 ppm at reducing the drop in plant height, plant weight, leaf area, essential oil yield and essential oil composition caused by high saline conditions. Saline grown plants were 74% as tall as control plants. DPU+Saline resulted in plants 102% as tall as control.  | (El-Keltawi and Croteau 1987b) |
| <i>Mammillaria elongata</i><br>(Succulent) | <u>Cytokinin</u> : BA, BA+GA 100 to 200 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA 200 ppm increased branching (linearly with rate). BA+GA reduced shoot number.  | (Sanderson et al. 1986)        |

Table A1 Continued

| <b>Plant</b>                             | <b>Notes</b>  | <b>Reference</b>               |
|--|---|--------------------------------|
| <i>Mentha piperita</i><br>(Peppermint)   | <p><u>Cytokinin</u>: Kinetin (1 to 4 ppm), DPU (2.5 to 10 ppm), BA (1 to 4 ppm), Zeatin (1 to 4 ppm) / 4 Foliar sprays at 1 week intervals</p> <p><u>Purpose</u>: Growth Control – Yield enhancer – Can cytokinins alter the growth or improve the yield of essential oils of plants in family Lamiaceae?</p> <p><u>Effect</u>: Kinetin was best at increasing many growth characteristics including total fresh weight, fresh leaf weight, leaf length, number of leaves per branch, stem weight &amp; length, number of internodes and internode length. Other cytokinins had similar results but were less effective. DPU decreased internode length. BA was similar to Kinetin but not quite as good. Zeatin was the least effective. Cytokinins had no effect on time to flower. The ratios of components in the essential oils was altered. DPU 10 ppm increase essential oil yield by almost 300%.</p> | (El-Keltawi and Croteau 1987a) |
| <i>Mentha spicata</i><br>(Spearmint)     | <p><u>Cytokinin</u>: Kinetin (1 to 4 ppm), DPU (2.5 to 10 ppm), BA (1 to 4 ppm), Zeatin (1 to 4 ppm) / 4 Foliar sprays at 1 week intervals</p> <p><u>Purpose</u>: Growth Control – Yield enhancer – Can cytokinins alter the growth or improve the yield of essential oils of plants in family Lamiaceae?</p> <p><u>Effect</u>: Kinetin was best at increasing many growth characteristics including total fresh weight, fresh leaf weight, leaf length, number of leaves per branch, stem weight &amp; length, number of internodes and internode length. Other cytokinins had similar results but were less effective. DPU decreased internode length. BA was similar to Kinetin but not quite as good. Zeatin was the least effective. Cytokinins had no effect on time to flower. DPU 10 ppm increase essential oil yield by almost 250%.</p>   | (El-Keltawi and Croteau 1987a) |
| <i>Mentha spicata</i><br>(Spearmint)     | <p><u>Cytokinin</u>: Kinetin 4 ppm, DPU 10 ppm / Foliar sprays onto plants grown with high saline (CaCl &amp; NaCl) irrigation</p> <p><u>Purpose</u>: Stress reducer – Can cytokinins reduce the drop in yield caused by saline conditions?</p> <p><u>Effect</u>: DPU 10 ppm was slightly better than Kinetin 4 ppm at reducing the drop in plant height, plant weight, leaf area, essential oil yield and essential oil composition caused by high saline conditions. Saline grown plants were 74% as tall as control plants. DPU+Saline resulted in plants 84% as tall as control.</p>  | (El-Keltawi and Croteau 1987b) |
| <i>Mentha suaveolens</i><br>(Apple mint) | <p><u>Cytokinin</u>: Kinetin (1 to 4 ppm), DPU (2.5 to 10 ppm), BA (1 to 4 ppm), Zeatin (1 to 4 ppm) / 4 Foliar sprays at 1 week intervals</p> <p><u>Purpose</u>: Growth Control – Yield enhancer – Can cytokinins alter the growth or improve the yield of essential oils of plants in family Lamiaceae?</p> <p><u>Effect</u>: No effect on growth. Cytokinins reduced the time to flower by 7 to 10 days. DPU 10 ppm increase essential oil yield by almost 80%.</p>  | (El-Keltawi and Croteau 1987a) |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>               |
|--|---|--------------------------------|
| <i>Mesembryanthemum crystallinum</i><br>(Ice Plant)                | <u>Cytokinin</u> : Zeatin, 2iP, BA rates unlisted / Applied via hydroponic solution<br><u>Purpose</u> : Stress resistance<br><u>Effect</u> : Exogenous cytokinins induce ice plants to initiate salt stress resistance responses.   | (Adams et al. 1991)            |
| <i>Miltoniopsis</i><br>(Orchid)                                    | <u>Cytokinin</u> : BA 25 to 50 mM OR BA+GA 25 to 50 mM+2.5 to 5 mM / Single Substrate drenches (50ml)<br><u>Purpose</u> : Flower enhancer – Can BA replace the cold period and Short Day needed to stimulate flowering<br><u>Effect</u> : BA promoted vegetative growth and inhibited flowering.  | (Matsumoto 2006)               |
| <i>Monarda didyma</i><br>(Scarlet beebalm)                         | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)         |
| <i>Monstera siltepecana</i><br>(Swiss cheese plant)                | <u>Cytokinin</u> : Thidiazuron (Dropp 50) 1 to 100 ppm / Solution applied to base of plant at potting time.<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : 10 ppm produced the most lateral branches. Higher rates caused abnormal buds. Most of the lateral branches failed to grow out.   | (Henny and Fooshee 1990c)      |
| <i>Muscari armeniacum</i><br><i>M. comosum</i><br>(Grape hyacinth) | <u>Cytokinin</u> : BA 1000 to 5000 ppm / BA mixed with lanolin paste and applied to basal plants of 6 to 7 cm bulbs<br><u>Purpose</u> : Propagation – increase bulblet production<br><u>Effect</u> : All rates increased bulblet formation 30x over control in <i>M. armeniacum</i> , 3x over control in <i>M. comosum</i> , and              | (Saniewski and Puchalski 1983) |
| <i>Muscari botryoides</i><br>(Grape hyacinth)                      | <u>Cytokinin</u> : 0.3% BA in lanolin paste / Applied to basal plate of pre-chilled bulbs.<br><u>Purpose</u> : Propagation – increase bulblet production<br><u>Effect</u> : BA increases bulblet production   | (Puchalski et al. 1979)        |
| <i>Narcissus</i><br>(Daffodil)                                     | <u>Cytokinin</u> : Kinetin 1 to 100 ppm / 32ml solution added to the vermiculite that the scales were stored in<br><u>Purpose</u> : Propagation – Can BA improve the yield of twin scaling of <i>Narcissus</i> ?<br><u>Effect</u> : Kinetin 10 ppm tripled the number of bulbils that sprouted and increased the bulbil weight over controls. | (Hanks and Rees 1977a)         |
| <i>Nepeta cataria</i><br>(Catnip)                                  | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)         |
| <i>Nephrolepis exaltata</i><br>(Boston Fern)                       | <u>Cytokinin</u> : BA 50 to 150 ppm / Single foliar spray 4w after planting.<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA reduced frond length but did not stimulate more fronds.  | (Carter et al. 1996)           |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>   | <b>Reference</b>        |
|--|--|-------------------------|
| <i>Nicotiana</i><br>(Tobacco)                            | <u>Cytokinin</u> : Kinetin +GA+Ethrel 0.5 mM + 1 mM + 1 mM / Pre-germination seed soak<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Promoted germination at above normal temperatures but not as well as 10 mM GA alone   | (Persson 1993)          |
| <i>Oenothera<br/>fruticosa<br/>youngii</i><br>(Sundrops) | <u>Cytokinin</u> : BA 50 to 1600 ppm (Configure) / Single Foliar spray applied 2WAP<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : No effect  | [Ref. Chapter 7]        |
| <i>Opuntia</i><br>(Pricklypear cactus)                   | <u>Cytokinin</u> : Kinetin 200 to 800 µM (43 to 172 ppm) / 2mL injected at 7 locations into detached cladodes weekly.<br><u>Purpose</u> : Branching agent – Propagation – Can cytokinins increase cladode production?<br><u>Effect</u> : Kinetin 172 ppm cause new cladodes to form 4 weeks earlier than in control and also increase production by 57%, double the fresh weight and did not affect dry weight.  | (Nobel 1996)            |
| <i>Opuntia<br/>basilarus</i><br>(Pricklypear cactus)     | <u>Cytokinin</u> : PBA & PBA+GA 100 to 400 ppm / Weekly Foliar sprays<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : 400 ppm PBA produced the most shoots. PBA + GA also effective. 4 or more weekly applications needed   | (White et al. 1978)     |
| <i>Opuntia<br/>microdasys</i><br>(Pricklypear cactus)    | <u>Cytokinin</u> : BA, BA+GA 100 to 200 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : No effect   | (Sanderson et al. 1986) |
| <i>Ornithogalum</i><br>(Star of Bethlehem)               | <u>Cytokinin</u> : BA+GA (Fascination) 100 to 200 ppm / Application method not listed<br><u>Purpose</u> : Break Dormancy – Can BA break bulb dormancy for early flower production?<br><u>Effect</u> : Fascination accelerated the time to flower in chilled and unchilled bulbs by 2 to 21 days. High rates caused flower bud abortion. Results were similar to ProGibb.   | (Wang and Walter 2006)  |
| <i>Ornithogalum</i><br>(Star of Bethlehem)               | <u>Cytokinin</u> : BA+GA (Fascination) 100 ppm<br><u>Purpose</u> : Flower enhancer – Can Fascination improve flowering?<br><u>Effect</u> : 100 ppm sped up time to flower by 6d. Higher rates caused phytotoxicity.  | (Wang and Walter 2006)  |
| <i>Paeonia</i><br>(Peony)                                | <u>Cytokinin</u> : BA 100 to 1600 ppm (Configure) / 5 minute pre-plant bulb soaks in the fall<br><u>Purpose</u> : Branching agent - Dormancy Release - Does BA increase branching or cause early sprouting the next spring?<br><u>Effect</u> : BA caused buds to sprout earlier and closer together. Without BA, bud emergence occurred over a longer period of time. With BA bud emergence was more synchronized and overall, the bud emergence dates per plant were about 20 days earlier. | [Ref. Chapter 4]        |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>           |
|--|---|----------------------------|
| <i>Paphiopedilum</i><br>(Ladyslipper<br>Orchid)  | <u>Cytokinin</u> : BA 500 ppm – alone or in combination with GA <sub>3</sub> or NAA / Single foliar spray or drench onto 4 year old plants<br><u>Purpose</u> : Flower enhancer – Can BA trigger flowering?<br><u>Effect</u> : BA alone or in any combination did not trigger flowering.   | (Criley 2008)              |
| <i>Pelargonium</i><br>(Geranium)   | <u>Cytokinin</u> : Kinetin 10 <sup>-4</sup> M (ppm) / Cuttings dipped into solution prior to storage<br><u>Purpose</u> : Reduce senescence – improve storage time of geranium cuttings without effecting subsequent rooting<br><u>Effect</u> : Kinetin reduced senescence of cuttings in storage but strongly inhibited rooting and was not recommended for use. GA and STS had the same effect.  | (Steinitz et al. 1987)     |
| <i>Pelargonium</i><br>(Geranium – <i>P. x hortorum</i> , <i>P. domesticum</i> , <i>P. graveolens</i> ) | <u>Cytokinin</u> : Thidiazuron 1 to 30 µM (.22 ppm – 6 ppm) / 250ml Drenches 2 times per week for 18days<br><u>Purpose</u> : Branching agent – Can Thidiazuron induce adventitious shoots?<br><u>Effect</u> : 4 ppm was best at stimulating adventitious shoots. 6 ppm caused phytotoxicity.  | (Murch et al. 1997)        |
| <i>Pelargonium</i><br>(Geranium)   | <u>Cytokinin</u> : Kinetin & BA 10 to 80 ppm / Single foliar spray to stock plants 24h prior to taking cuttings followed by warm storage<br><u>Purpose</u> : To reduce senescence of cuttings in storage<br><u>Effect</u> : BA at all rates was worse than control. Kinetin reduced yellowing (during warm storage) and increased subsequent cutting growth but silver nitrate was better.  | (Carow and Bahnemann 1980) |
| <i>Pelargonium x hortorum</i><br>(Geranium)  | <u>Cytokinin</u> : Thidiazuron 0.125 ppm – 0.5 ppm / Foliar spray onto unrooted cuttings pre-ship OR pre & post-ship<br><u>Purpose</u> : Senescence inhibitor – Can CKs reduce yellowing in geranium cuttings shipped from out of the country to rooting stations in the US<br><u>Effect</u> : Thidiazuron 0.25 ppm sprayed pre-ship or Thidiazuron 0.125 ppm sprayed pre and post ship can prevent senescence for up to 4 days in simulated shipping. This rate also improves subsequent rooting.  | (Emino et al. 2002)        |
| <i>Pelargonium x hortorum</i><br>(Geranium)  | <u>Cytokinin</u> : BA+GA (Promalin) 75 to 1200 ppm, PBA (Accel) 37.5 to 600 ppm, BA (Pro-shear) 75 to 600 ppm / Foliar sprays Expt 1 - once (2 days after transplanting seedlings) OR Expt 2 - twice (2 days after transplanting, and 4w later just after the first harvest of cuttings) OR Expt 3 1 to 4 foliar sprays at 2w intervals.<br><u>Purpose</u> : Branching agent – Propagation – Can cytokinins increase production of stock plants<br><u>Effect</u> : ProShear and Accel generally had little effect and underperformed compared to the industry standard Florel. However, Promalin applied at 75 ppm two times at biweekly intervals doubled or tripled the number of single node cuttings produced and exceeded Florel. Promalin cuttings were longer and had a greater caliper too. | (Foley and Keever 1992)    |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>              |
|--|---|-------------------------------|
| <i>Pelargonum x hortorum</i><br>(Geranium)   | <u>Cytokinin</u> : BA 1000 ppm, PBA 75 ppm / Single foliar sprays applied 2w before, during, or 2w after a soft pinch.<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA and PBA applied at pinch increased branching of Geranium but not quite as well as Ethephon. BA, and PBA applied at pinch delayed flowering 2 to 5 days but less than Ethephon 2 to 16d.  | (Carpenter and Carlson 1972a) |
| <i>Pellionia pulchra</i> (Satin Pellionia)   | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – How does PBA affect growth?<br><u>Effect</u> : No effect on height. More than doubled the number of branches that formed  | (Henley and Poole 1974)       |
| <i>Penstemon</i><br>(Beard tongue)   | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity. Increased flower stem length  | (Lieth and Dodge 2004)        |
| <i>Pentas lanceolata</i>   | <u>Cytokinin</u> : BA(Configure) 50 to 400 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent – Does BA control growth?<br><u>Effect</u> : No effect   | [Ref. Chapter 7]              |
| <i>Peperomia obtusifolia</i><br>(Baby rubber plant)  | <u>Cytokinin</u> : BA 250 to 1000 ppm / Single foliar spray at planting<br><u>Purpose</u> : Branching agent – eliminate the need for multiple liners per pot.<br><u>Effect</u> : 1000 ppm BA resulted in more than double the number of lateral branches and a reduction in plant height and internode length. No phytotoxicity noted. Custom solution of BA used, not commercial mix. Effects lasted about 12 weeks.   | (Henny 1985)                  |
| <i>Perilla frutescens</i><br>(syn. <i>Perilla ocymoides</i> var. <i>nankinensis</i> )<br>(Beefsteak plant) | <u>Cytokinin</u> : Kinetin $10^{-4}$ M (21.5 ppm) / Daily sprays for 10 days onto stems<br><u>Purpose</u> : Branching agent – Does Kinetin increase branching?<br><u>Effect</u> : Branching was increased. GA was antagonistic to this effect. Flowering in <i>Perilla</i> (a short day plant) required 3 fewer inductive short says to trigger flowering.  | (Lona and Bocchi 1957)        |
| <i>Perovskia atriplicifolia</i><br>(Russian sage)  | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)        |
| <i>Petunia</i>   | <u>Cytokinin</u> : Kinetin or BA at $10^{-4}$ - $10^{-6}$ M (22.5 to 0.225 ppm) / Supplied as a liquid nutrient solution to whole plant or cut leaf petioles.<br><u>Purpose</u> : Disease resistance<br><u>Effect</u> : $10^{-4}$ , $10^{-5}$ M BA and Kinetin were phytotoxic to leaf petiole cuttings. $10^{-6}$ M nutrient solution to whole plants caused chlorosis. BA applied to plants prior to TSWV or TMV inoculation reduced the number of lesions. | (Aldwinkle and Selman 1967)   |
| <i>Petunia</i>   | <u>Cytokinin</u> : BA $10^{-5}$ M – $10^{-4}$ M (2.25 – 22.5 ppm) / Seeds imbibed in solution prior to sowing<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Delayed germination and reduced % germination   | (Finch-Savage et al. 1991c)   |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>   | <b>Reference</b>        |
|--|--|-------------------------|
| <i>Petunia</i>   | <p><u>Cytokinin</u>: PBA 250 to 750 ppm / Single Foliar spray application</p> <p><u>Purpose</u>: Branching agent – Height control</p> <p><u>Effect</u>: 500 ppm PBA increased lateral shoot formation of un-pinched plants prior to flower induction. No delay in flower development or size. Phytotoxicity occurred at 250 ppm and was worse in lower temperatures than higher ones but was reduced by transferring plants to higher temps. Effects lasted about 4 weeks.</p>   | (Jeffcoat 1977)         |
| <i>Petunia</i>   | <p><u>Cytokinin</u>: CPPU 0.32 to 10<math>\mu</math>M (0.08 to 2.47 ppm), BA 10 to 1000 <math>\mu</math>M (2.25 to 225 ppm), Zeatin 10 to 1000 <math>\mu</math>M (2.19 to 219 ppm) / 4<math>\mu</math>L drops placed onto corolla every other day starting when the corolla was 2mm long and ending when the flowers began to open</p> <p><u>Purpose</u>: Flower enhancer – Can cytokinins increase flower size?</p> <p><u>Effect</u>: CPPU 2.47 ppm increased corolla area over control but the flower was distorted (ruffled). 0.8 ppm increased corolla area 2.4x without distortion. 22.5 ppm BA increased corolla area 2.2x without distortion. BA 225 ppm caused distortion. Zeatin 219 ppm increased corolla area by 1.9x without distortion.</p> | (Nishijima et al. 2006) |
| <i>Petunia</i><br>$\times$ <i>hybrida</i>                  | <p><u>Cytokinin</u>: BA 20 to 160 ppm / foliar spray 1 to 2 times</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: 80 ppm applied twice was best at increasing branching, improving shape, increasing flowering. Transient phytotoxicity noted at 160 ppm.</p>   | (Carey et al. 2007)     |
| <i>Petunia</i><br>$\times$ <i>hybrida</i>                  | <p><u>Cytokinin</u>: Kinetin 50 mg/l (50 ppm) / Foliar spray every 5 days.</p> <p><u>Purpose</u>: Flower enhancer – Can kinetin influence the flowering of this Long Day plant under Short Days?</p> <p><u>Effect</u>: Kinetin caused 20% of the plants under Short Days to flower. Flowering took 23 to 28 days longer than control plants under Long Days. Under Long Day Kinetin resulted in longer shoots and more flower buds.</p>  | (Das et al. 1977)       |
| <i>Petunia</i><br>$\times$ <i>hybrida</i><br>(Wave series) | <p><u>Cytokinin</u>: BA 100 to 160 ppm (Configure) / foliar spray 1 to 2 times or drench 1 to 2 times or fertigation</p> <p><u>Purpose</u>: Branching agent - Does BA alter growth?</p> <p><u>Effect</u>: No effect</p>  | [Ref. Chapter 2]        |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>   | <b>Reference</b>            |
|--|--|-----------------------------|
| <i>Phalaenopsis</i><br>(Orchid)                            | <p><u>Cytokinin</u>: BA 100 to 400 ppm, BA+GA 25 to 100 ppm each / 3 Foliar sprays on days 0, 7, 14 from the time they were moved into an inductive environment. OR a single spray from -1 to +6 weeks after moving to an inductive environment.</p> <p><u>Purpose</u>: Flower enhancer – Can BA accelerate blooming?</p> <p><u>Effect</u>: BA 200 to 400 ppm sprayed 3 times caused flowering to occur 3 to 9 days earlier and produce 3 to 8 more flowers per plant than control. BA+GA had no effect. BA sprayed 1 week after the transfer to inductive conditions increased flowering the most. There is some evidence that BA caused flower deformations</p>  | (Blanchard and Runkle 2008) |
| <i>Phalaenopsis</i><br>(Orchid)                            | <p><u>Cytokinin</u>: BA 1 to 5 <math>\mu\text{g} \cdot \mu\text{l}^{-1}</math> / 1 <math>\mu\text{l}</math> injected into the cavity of the second bud scale below the shoot apex 4 days before or 4 days after GA had been similarly injected OR BA (same rates as above) applied at various timings to various flower development stages after GA application</p> <p><u>Purpose</u>: Flower enhancer – will BA undo the malformations caused by GA that was applied to increase flower production at high temps.</p> <p><u>Effect</u>: BA did restore flower morphology when applied at 5 <math>\mu\text{g}</math>, 4 days after GA was applied. BA had no effect on the size of the shoot. BA increased flower count very slightly at one particular stage and timing and reduced flower counts at others</p> | (Chen et al. 1997)          |
| <i>Phalaenopsis</i><br>(Orchid)                            | <p><u>Cytokinin</u>: BA 0.5% in a granular mix with fertilizers, fungicides and IAA / powder inserted into the detached flower stem</p> <p><u>Purpose</u>: Propagation</p> <p><u>Effect</u>: Induced 1 to 3 keikis per node on the stem</p>  | (Smeltz 1995)               |
| <i>Philodendron oxycardium</i><br>(Heartleaf Philodendron) | <p><u>Cytokinin</u>: PBA 200 ppm / Single foliar spray.</p> <p><u>Purpose</u>: Branching agent – How does PBA affect growth?</p> <p><u>Effect</u>: No effect</p>   | (Henley and Poole 1974)     |
| <i>Phlox</i>   | <p><u>Cytokinin</u>: Kinetin, BA, KT 20 to 40 ppm each / Foliar sprays 3 times, one week apart in summer</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: BA and Kinetin increased lateral branching. No effect on flowering</p>   | (Rounkova 1985)             |
| <i>Phlox divaricata laphamii</i><br>(Lapham's phlox)       | <p><u>Cytokinin</u>: BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: Increased branching. Caused no phytotoxicity</p>  | (Lieth and Dodge 2004)      |
| <i>Physostegia virginiana</i><br>(Obedient plant)          | <p><u>Cytokinin</u>: BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: Significant phytotoxicity</p>   | (Lieth and Dodge 2004)      |

Table A1 Continued

| <b>Plant</b>                                    | <b>Notes</b>   | <b>Reference</b>        |
|---|--|-------------------------|
| <i>Pilea cadierei</i><br>(Aluminum plant)       | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – Can PBA increase branching?<br><u>Effect</u> : PBA caused 50% more shoots than control but inhibited flower development. No effect on height.  | (Henley and Poole 1974) |
| <i>Pilea involucrata</i><br>(Panamiga)          | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – How does PBA affect growth?<br><u>Effect</u> : Decreased stem elongation but did not increase branching  | (Henley and Poole 1974) |
| <i>Pilea microphylla</i><br>(Artillary plant)   | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – How does PBA affect growth?<br><u>Effect</u> : Decreased stem elongation more than 40%   | (Henley and Poole 1974) |
| <i>Pimelea ferruginea</i><br>(Pink rice flower) | <u>Cytokinin</u> : BA 50 ppm / Single Foliar spray applied during growth phase (for branching) or when flowers first opened (for flower life)<br><u>Purpose</u> : Branching agent – Flower enhancer – Can BA improve the shape of the plants and help potted plants' flowers last longer?<br><u>Effect</u> : BA more than doubled the number of branches. BA was ineffective at improving flower life as was STS<br><u>Notes</u> : Author suggests more studies of BA in controlling flowering | (King et al. 1992)      |
| <i>Pimelea rosea</i>                            | <u>Cytokinin</u> : BA 50 ppm / Single Foliar spray applied during growth phase (for branching) or when flowers first opened (for flower life)<br><u>Purpose</u> : Branching agent – Flower enhancer – Can BA improve the shape of the plants and help potted plants' flowers last longer?<br><u>Effect</u> : BA was ineffective at improving flower life as was STS<br><u>Notes</u> : Author suggests more studies of BA in controlling flowering  | (King et al. 1992)      |
| <i>Platycodon</i><br>(Balloon flower)           | <u>Cytokinin</u> : Kinetin +GA+Ethrel 0.5 mM + 1 mM + 1 mM / Pre-germination seed soak<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Promoted germination at below and above normal temperatures but not as well as 10 mM GA alone   | (Persson 1993)          |
| <i>Podocarpus macrophyllus</i><br>(Yew Pine)    | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – How does PBA affect growth?<br><u>Effect</u> : No effect   | (Henley and Poole 1974) |
| <i>Polianthes tuberosa</i><br>(Tube Rose)       | <u>Cytokinin</u> : Kinetin 200µg / injected into the apex of a corm at various times during floral bud initiation<br><u>Purpose</u> : Flower promoter – Can Kinetin promote flowering in the day neutral plant Polianthes?<br><u>Effect</u> : Kinetin increases floral primordia when applied at any time, but promotes it most when applied at the early floral initiation stage.   | (Chang et al. 1999)     |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>   | <b>Reference</b>                 |
|---|--|----------------------------------|
| <i>Portulaca grandiflora</i><br>(Moss rose)                 | <u>Cytokinin</u> : 62.5 to 250 ppm BA (ProShear). 125 to 500 ppm BA+GA (Promalin) / Single foliar spray<br><u>Purpose</u> : Branching agent – Height control – Can BA increase branching and reduce the incidence of long prostrate shoots?<br><u>Effect</u> : 250 ppm ProShear reduced shoot length by 25%, increased branching by 143%, and caused a more prostrate habit. Promalin caused an upright habit. | (Banko and Stefani 1997b)        |
| <i>Portulaca oleracea</i><br>(Moss rose)                    | <u>Cytokinin</u> : BA 50 to 400 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Branching agent – Does BA effect growth at all?<br><u>Effect</u> : BA increases branching of one of two cultivars tested   | [Ref. Chapter 7]                 |
| <i>Primula</i>  | <u>Cytokinin</u> : BA+GA BA 10 <sup>-6</sup> M-10 <sup>-5</sup> M, GA 10 <sup>-4</sup> M-10 <sup>-3</sup> M / Seeds soaked in solution prior to sowing<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Improved germination % in dark but % was less than that of germination in the light without PGRs. BA caused root abnormalities  | (Finch-Savage et al. 1991a)      |
| <i>Pseuderanthe mum atropurpureum</i><br>(false eranthemum) | <u>Cytokinin</u> : PBA 200pppm / Dip cuttings into solution for 10sec prior to rooting<br><u>Purpose</u> : Height Control of rooted cuttings<br><u>Effect</u> : Cuttings were 25% shorter than control. PBA was better than daminozide, ancymidol, chlormequat, and ethephon   | (Sanderson et al. 1987)          |
| <i>Pseuderanthe mum atropurpureum</i><br>(false eranthemum) | <u>Cytokinin</u> : BA 50 to 800 ppm (Configure) / Single Foliar spray applied 2WAP<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : No effect   | [Ref. Chapter 7]                 |
| <i>Rebutia violaciflora</i><br>(Cactus)                     | <u>Cytokinin</u> : BA 10 to 100 ppm / Applied 1 to 3 times<br><u>Purpose</u> : Flower enhancer - To improve flower production under weak inductive conditions.<br><u>Effect</u> : 100 ppm sprayed 3 times induces more flower buds but many of these buds die.   | (Runger and Patzer 1986)         |
| <i>Rhipsalidopsis gaertneri</i><br>(Thanksgiving Cactus)    | <u>Cytokinin</u> : BA 200 to 1000 ppm single foliar spray soon after propagation OR 10 to 200 ppm single foliar spray 3 or 6 mo after planting<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : BA applied soon after propagation does not influence later flower numbers and is not cost effective. 200 ppm on older plants increases branching and improves appearance.              | (Boyle 1992)                     |
| <i>Rhipsalidopsis gaertneri</i><br>(Thanksgiving Cactus)    | <u>Cytokinin</u> : BA 14 days after start of Long Day, 100 ppm single foliar spray + 2 to 5nM STS.<br><u>Purpose</u> : Flower enhancer<br><u>Effect</u> : BA slightly delayed flowering but increased flower buds number. STS reduced the number of bud abortions  | (Boyle et al. 1988)              |
| <i>Ricinus</i><br>(Castor Bean)                             | <u>Cytokinin</u> : BA 50 to 75 ppm, Kinetin 25 to 50 ppm applied to buds 0 to 8 days after formation<br><u>Purpose</u> : Flower enhancer (sex)<br><u>Effect</u> : BA 75 ppm at 4 to 8 days after bud formation causes the normally monocious flowers to become perfect   | (Sindagi and Puttarudrappa 1972) |

Table A1 Continued

| <b>Plant</b>               | <b>Notes</b>  | <b>Reference</b>             |
|----------------------------|---|------------------------------|
| <i>Rosa</i><br>(Pot roses) | <u>Cytokinin</u> : BA 0.02 to 0.44 mM (5 to 100 ppm) with or without STS 0.2 mM / Single Foliar spray in winter OR single flower spray in spring followed by simulated shipping<br><u>Purpose</u> : Senescence inhibitor – Can BA inhibit flower senescence and leaf abscission in simulated shipping?<br><u>Effect</u> : BA had no effect and did not enhance the effect of STS.   | (Cushman and Pemberton 1994) |
| <i>Rosa</i><br>(Rose)      | <u>Cytokinin</u> : tZ, BA, Promalin 25 to 100 ppm / Single foliar spray just prior to shipping<br><u>Purpose</u> : Senescence inhibitor – decrease senescence during shipping of potted roses<br><u>Effect</u> : All cytokinins were better than control. BA 100 ppm worked best at reducing leaf yellowing and maintaining the highest visual quality rating after shipping<br><u>Notes</u> : Try higher rates and try applying BA 1 or more days prior to shipping.   | (Clark et al. 1991)          |
| <i>Rosa</i><br>(Pot roses) | <u>Cytokinin</u> : BA 62.5 to 2000 ppm / Injected into stem (10µl drops)<br><u>Purpose</u> : Propagation – Does BA affect rooting and sprouting of softwood rose cuttings<br><u>Effect</u> : BA reduced sprout length linearly with concentration. BA reduced rooting % at 125 ppm and higher. BA 62.5 increased root weight but higher concentrations decreased it. BA increased the number of sprouts growing from the cutting with a maximum at 2000 ppm.  | (de Vries and Dubois 1988)   |
| <i>Rosa</i><br>(Rose)      | <u>Cytokinin</u> : BA 0.1 to 1.0 mM (22.5 to 225 ppm) / Single foliar spray 1 hour prior to inoculation<br><u>Purpose</u> : Disease control – Can BA reduce Botrytis (Gray Mold)?<br><u>Effect</u> : BA 225 ppm reduced Botrytis severity on flowers and leaves by 39%. It reduces the plants sensitivity to ethylene but does not affect the plants production of ethylene   | (Elad 1993)                  |
| <i>Rosa</i><br>(Rose)      | <u>Cytokinin</u> : PBA (SD8339) 10 to 400 ppm / Sprayed onto flower buds during floral growth 3 times during the fall and following spring OR sprayed onto plants soon after potting under various day lengths OR drenched onto plants soon after potting under various day lengths<br><u>Purpose</u> : Flower enhancer / Branching agent – Can PBA increase flowering or induce branching?<br><u>Effect</u> : PBA did not increase the number of flowers when applied during the cropping period. It insignificantly increased the number of blind shoots. Drenches (10 to 40 ppm) did not increase branching but sprays (400 ppm) did increase branching significantly 20 to 60% depending on cultivar. | (Holcomb et al. 1987)        |

Table A1 Continued

| <b>Plant</b>               | <b>Notes</b>   | <b>Reference</b>                |
|----------------------------|--|---------------------------------|
| <i>Rosa</i><br>(Pot roses) | <u>Cytokinin</u> : BA 0.2 to 0.8 mM (45 to 180 ppm) / Single foliar spray followed by simulated shipping<br><u>Purpose</u> : Senescence inhibitor – Can BA inhibit flower senescence and leaf abscission in simulated shipping?<br><u>Effect</u> : BA 0.8 mM was nearly as good as STS for flower longevity.   | (Serek and Anderson 1993, 1995) |
| <i>Rosa</i><br>(Rose)      | <u>Cytokinin</u> : BA 500 ppm / Foliar spray once or twice 10 days apart in May<br><u>Purpose</u> : Branching agent – Can BA replace a hand pinch?<br><u>Effect</u> : By itself, BA was not as effective as Ethephon. 2 sprays of BA worked better than one. BA sprays plus IBA 500 ppm sprays 10 days later were as effective as hand pinching or Ethephon. BA+IBA caused some branches to form at the graft union while pinching did not.  | (Marczynski et al. 1979)        |
| <i>Rosa</i><br>(Rose)      | <u>Cytokinin</u> : BA 0.2 mM / 3 foliar sprays (on the lower shoots only) over 14 days.<br><u>Purpose</u> : Flower enhancer – can BA increase flower production from shoots further down the plant that are shaded by the ones above it?<br><u>Effect</u> : 100% of lower shoots sprayed with BA formed flowers versus 42% for unsprayed. If BA was sprayed on the upper shoots then flowering was inhibited on the lower shoots.  | (Mor and Halevy 1984)           |
| <i>Rosa</i><br>(Rose)      | <u>Cytokinin</u> : BA 0.125 - 0.5% / Lanolin paste applied to cut surface near the bud at various times.<br><u>Purpose</u> : Dormancy release - Flower enhancer – can BA stimulate the upper most axillary bud to grow after a harvest in a cultivar where buds go dormant after harvest.<br><u>Effect</u> : BA 0.25% applied to the stem after a harvest stimulated the buds that normally remained dormant to grow, increasing saleable flowers by 78%. BA 0.5% increased the number of blind buds. BA paste applied to the buds directly cause phytotoxicity. BA did not appear to move more than 1.5cm from where the paste was applied. BA paste applied after the final pinch but before first harvest induced phytotoxicity in the stem and reduced total season flower production. . | (Ohkawa 1984)                   |
| <i>Rosa</i><br>(Rose)      | <u>Cytokinin</u> : BA 100 ppm / Foliar spray 2 to 32 times<br><u>Purpose</u> : Branching agent – Can BA substitute for a hand pinch in nursery grown crops<br><u>Effect</u> : Slight increase in branching and increase in the length of the side branches. Subsequent flowering was increased too. Effect was better than pinching.   | (Richards and Wilkinson 1984)   |
| <i>Rosa</i><br>(Rose)      | <u>Cytokinin</u> : BA 50 to 150 ppm OR BA+GA 25 ppm (Promalin) OR PBA 150 ppm / Single foliar spray 1 week prior to inoculation<br><u>Purpose</u> : Disease resistance<br><u>Effect</u> : No effect on the incidence of powdery mildew ( <i>Sphaerotheca pannosa</i> )   | (Sammons et al. 1981)           |

Table A1 Continued

| <b>Plant</b>                                  | <b>Notes</b>   | <b>Reference</b>               |
|---|--|--------------------------------|
| <i>Rosa</i><br>(Rose)                         | <u>Cytokinin</u> : BA+GA (Promalin) 50 ppm applied monthly for 7 months or 200 ppm applied twice 3 months apart.<br><u>Purpose</u> : Yield enhancer – Can cytokinins improve flower yield of greenhouse roses?<br><u>Effect</u> : Promalin increased the stem length but reduced the number of flowers produced. The effects were statistically insignificant in all cultivars except one.   | (Shanks and Mityga 1985)       |
| <i>Rosa</i><br>(Pot roses)                    | <u>Cytokinin</u> : BA 100 $\mu$ l•L <sup>-1</sup> (22.5 ppm) with or without 1 mM STS / Single foliar spray<br><u>Purpose</u> : Senescence inhibitor – Can BA inhibit flower senescence and leaf abscission in simulated shipping?<br><u>Effect</u> : BA alone delayed leaf senescence but had little effect on flower senescence but BA+STS was better than STS alone on flowers.   | (Tjosvold et al. 1995b, 1995a) |
| <i>Rosa</i><br>(Rose)                         | <u>Cytokinin</u> : PBA (250 to 500 ppm), BA (500 to 1000 ppm) / Two foliar sprays OR lanolin paste on buds OR oasis foam soaked in solution placed onto cut stems<br><u>Purpose</u> : Branching agent – Stock plant maintenance - Can CKs increase basal branching of greenhouse roses grown for cut flowers<br><u>Effect</u> : BA and PBA sprays increased the number of shoots from axillary buds. BA and PBA paste applied directly to buds increased shoot formation. BA and PBA in floral foam increased axillary shoots, flowering shoots, and blind shoots that formed but initial growth had slight phytotoxicity. No treatment increase renewal (basal) shoot growth. | (Carpenter and Rodriguez 1971) |
| <i>Rosa</i><br>(Rose)                         | <u>Cytokinin</u> : PBA 0.25 to 0.75% in lanolin paste / Direct application to secondary buds<br><u>Purpose</u> : Flower enhancer – Can BA promote additional flowering in shoots that normally will not sprout or will produce blind flowers?<br><u>Effect</u> : PBA 0.75% does induce sprouting and results in more flowers per plant   | (Zieslin et al. 1985)          |
| <i>Rosa multiflora</i><br>(Multiflora rose)   | <u>Cytokinin</u> : BA (200 ppm), Promalin (1000 ppm) / Single foliar spray or 3 foliar sprays onto 6 to 10cm rooted cuttings<br><u>Purpose</u> : Growth inhibitor – Can BA be used to affect height and habit?<br><u>Effect</u> : BA alone had little effect but Promalin resulted in greater overall growth. Plants sprayed 3x had a greater response.  | (Grzesik and Rudnicki 1985)    |
| <i>Rudbeckia fulgida</i><br>(Blackeyed susan) | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity. Increased flower stem length.  | (Lieth and Dodge 2004)         |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>   | <b>Reference</b>             |
|--|--|------------------------------|
| <i>Rudbeckia hirta</i><br>(syn. <i>R. bicolor</i> )<br>(Blackeyed susan) | <u>Cytokinin</u> : BA 20 to 50µg ai / Pipetted onto apical meristem at start of Long Day<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : No effect on flowering. Reduced branching  | (Harkess and Lyons 1994)     |
| <i>Rudbeckia hirta</i><br>(syn. <i>R. bicolor</i> )<br>(Blackeyed susan) | <u>Cytokinin</u> : BA 50 to 1600 ppm (Configure) / Single Foliar spray applied 2WAP<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : Height reduced. 1600 ppm caused phytotoxicity.   | [Ref. Chapter 7]             |
| <i>Rudbeckia hirta</i> (syn. <i>R. bicolor</i> )                         | <u>Cytokinin</u> : BA 0.1 to 100 ppm / Foliar spray applied every day for several weeks during non-inductive SDs (Abstract only)<br><u>Purpose</u> : Flower enhancer – Can BA induce flowering of this LD plant under non-inductive SDs?<br><u>Effect</u> : BA 10 to 100 ppm induced short flower stems to form in adult (4 to 5 mo. old) plants. Leaves were wrinkled and pale. | (Kochankov 1989)             |
| <i>Saintpaulia ionantha</i><br>(African Violet)                          | <u>Cytokinin</u> : Kinetin 1 ppm / Foliar spray 2 times with 3 week interval.<br><u>Purpose</u> : Flower enhancer - Increase number of flower stalks per plant<br><u>Effect</u> : No effect  | (Dvorská 1979)               |
| <i>Saintpaulia ionantha</i><br>(African Violet)                          | <u>Cytokinin</u> : PBA 100 ppm, GA + PBA 50 ppm+100 ppm<br><u>Purpose</u> : Branching agent - Propagation<br><u>Effect</u> : GA + PBA increased the number of propagules formed from leaf cuttings   | (Sanderson and McGuire 1988) |
| <i>Salvia</i>  | <u>Cytokinin</u> : BA $10^{-5}$ M – $10^{-4}$ M / Seeds imbibed in solution prior to sowing<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Delayed germination and reduced % germination  | (Finch-Savage et al. 1991c)  |
| <i>Salvia splendens</i><br>(Scarlet sage)                                | <u>Cytokinin</u> : BA applied to LD plants growing under SDs (No other details given)<br><u>Purpose</u> : Flower enhancer - Can BA induce flowering in non-inductive SDs?<br><u>Effect</u> : Some floral promotion but not as much as GA or estrogen-like substances   | (Zimmer and Junker 1986)     |
| <i>Salvia farinacea</i><br>(Mealy sage)                                  | <u>Cytokinin</u> : BA 250 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent – Height control<br><u>Effect</u> : Decreased height and increased branching on par with Florel 500 ppm  | (Banko and Stefani 1991)     |
| <i>Salvia leucantha</i><br>(Mexican sage)                                | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Increased branching. Caused no phytotoxicity  | (Lieth and Dodge 2004)       |

Table A1 Continued

| <b>Plant</b>                                     | <b>Notes</b>   | <b>Reference</b>               |
|--|--|--------------------------------|
| <i>Salvia nemorosa</i>                           | <p><u>Cytokinin</u>: BA 50 to 800 ppm (Configure) / Single Foliar spray applied 2WAP</p> <p><u>Purpose</u>: Branching agent – Does BA affect growth?</p> <p><u>Effect</u>: Branching increased and flowering delayed with increasing rates. 400 ppm was best.</p>  | [Ref. Chapter 5]               |
| <i>Salvia officinalis</i><br>(Culinary sage)     | <p><u>Cytokinin</u>: Kinetin (1 to 4 ppm), DPU (2.5 to 10 ppm), BA (1 to 4 ppm), Zeatin (1 to 4 ppm) / 4 Foliar sprays at 1 week intervals</p> <p><u>Purpose</u>: Growth Control – Yield enhancer – Can cytokinins alter the growth or improve the yield of essential oils of plants in family Lamiaceae?</p> <p><u>Effect</u>: Kinetin was best at increasing many growth characteristics including total fresh weight, fresh leaf weight, leaf length, number of leaves per branch, stem weight &amp; length, number of internodes and internode length. Other cytokinins had similar results but were less effective. DPU decreased internode length. BA was similar to Kinetin but not quite as good. Zeatin was the least effective. Cytokinins had no effect on time to flower. The ratios of components in the essential oils was altered. DPU 10 ppm increase essential oil yield by almost 200%</p> | (El-Keltawi and Croteau 1987a) |
| <i>Salvia splendens</i><br>(Scarlet sage)        | <p><u>Cytokinin</u>: BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21</p> <p><u>Purpose</u>: Branching agent</p> <p><u>Effect</u>: Increased branching. Caused no phytotoxicity</p>  | (Lieth and Dodge 2004)         |
| <i>Salvia splendens</i><br>(Scarlet sage)        | <p><u>Cytokinin</u>: BA 50 to 800 ppm (Configure) / Single Foliar spray applied 2WAP</p> <p><u>Purpose</u>: Branching agent – Does BA affect growth?</p> <p><u>Effect</u>: Growth index decreased with increasing rates</p>  | [Ref. Chapter 7]               |
| <i>Sanchezia speciosa</i><br>(Shrubby whitevein) | <p><u>Cytokinin</u>: PBA 200pppm / Dip cuttings into solution for 10sec prior to rooting</p> <p><u>Purpose</u>: Height Control of rooted cuttings</p> <p><u>Effect</u>: No difference from control</p>   | (Sanderson et al. 1987)        |
| <i>Scabiosa caucasica</i><br>(Pincushion flower) | <p><u>Cytokinin</u>: BA 50 to 800 ppm (Configure) / Single Foliar spray applied 2WAP</p> <p><u>Purpose</u>: Branching agent – Flower enhancer – Does BA affect growth or time to flower?</p> <p><u>Effect</u>: No effect</p>   | [Ref. Chapter 7]               |
| <i>Schlumbergera</i><br>(Christmas Cactus)       | <p><u>Cytokinin</u>: BA High temperatures + Foliar sprays 10 to 100 ppm at beginning of Short Day or 10 to 20 days later.</p> <p><u>Purpose</u>: Flower enhancer</p> <p><u>Effect</u>: BA inhibits flower production if applied at beginning of Short Day. At temps above 20C it is best applied 10 to 20 days after Short Day.</p>  | (Runger 1984)                  |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>            |
|--|---|-----------------------------|
| <i>Schlumbergera</i><br>(Christmas<br>Cactus)                            | <u>Cytokinin</u> : BA Foliar spray 100 to 1000 ppm / During Long Day as well as 5 to 10 days after start of Short Day<br><u>Purpose</u> : Flower enhancer – Branching agent<br><u>Effect</u> : Under Long Day 100 to 200 ppm was ideal for increasing phylloclade branching. From 5 to 10 days after start of Short Day, BA caused more flowers per phylloclade and flowering occurred 10 days sooner. BA also induced flowering on immature plants under Short Days when Short Days alone did not. | (Yonemura 1979)             |
| <i>Schlumbergera truncata</i><br>(Christmas<br>Cactus)                   | <u>Cytokinin</u> : BA Single foliar spray 100 to 800 ppm 5 to 10 days after start of Short Day<br><u>Purpose</u> : Flower enhancer<br><u>Effect</u> : BA hastens time to flower and increases number of flowers. BA 100 to 200 ppm works best   | (Yonemura and Higuchi 1978) |
| <i>Schlumbergera truncata</i><br>(Thanksgiving<br>Cactus)                | <u>Cytokinin</u> : BA 100 ppm single foliar spray 2 weeks after start of short days or during long days<br><u>Purpose</u> : Branching agent – Flower enhancer - Can BA increase flower or branch number?<br><u>Effect</u> : Applications at 2 weeks after beginning of Short Day increased number of flower buds by 40%. Applications during Long Day – increased phylloclade numbers by 150%   | (Heins et al. 1981)         |
| <i>Schlumbergera truncata</i><br>(Thanksgiving<br>Cactus)                | <u>Cytokinin</u> : BA Single foliar spray 100 to 200 ppm alone or mixed with GA 25 to 100 ppm<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : Under Long Day, BA increased number of phylloclades. Under Short Day BA 200 ppm increased flower buds and induced earlier flowering. BA+GA under Short Day initiated lower buds and lateral phylloclades   | (Ho et al. 1985)            |
| <i>Scutellaria</i><br>(Skullcap)   | <u>Cytokinin</u> : BA 50 to 800 ppm / Single Foliar spray applied 2WAP<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : No effect  | [Ref. Chapter 7]            |
| <i>Sedum</i><br>(Stonecrop)  | <u>Cytokinin</u> : BA 8 to 500 ppm / Leaf cuttings soaked for 10min prior to rooting<br><u>Purpose</u> : Branching agent - Propagation. Can BA stimulate shoot formation from leaf cuttings?<br><u>Effect</u> : BA at all rates tested increased shoot formation. Plants produced more shoots but not as many as with ethephon. Final plants were well branched. BA inhibited root formation.   | (Boe et al. 1972)           |
| <i>Sedum spurium</i><br>(Stonecrop)                                      | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity  | (Lieth and Dodge 2004)      |
| <i>Selenicereus megalanthus</i><br>(Queen of the<br>night,<br>Succulent) | <u>Cytokinin</u> : 50 to 200 ppm CPPU, 100 ppm BA+GA foliar sprays applied monthly in spring<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : 50 ppm CPPU caused earlier flowering by 1.5 months. No increase in flower number.   | (Khaimov and Mizrahi 2006)  |

Table A1 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>         |
|--|---|--------------------------|
| <i>Sempervivum cantabricum</i> x <i>montanum</i> var <i>striatum</i> (Hens and Chicks) | <u>Cytokinin</u> : BA 50 to 400 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent - Propagation - Can BA cause stock plants to produce more offsets?<br><u>Effect</u> : 400 ppm increased offsetting best   | [Ref. Chapter 3]         |
| <i>Sempervivum</i> spp. (Hens and Chicks)  | <u>Cytokinin</u> : BA 50 to 400 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Branching agent - Propagation<br><u>Effect</u> : 400 ppm increased offsetting best and did not affect subsequent rooting of offsets. Cultivar differences in number of offsets  | (Carey et al. 2008)      |
| <i>Senecio cinerea</i> (Dusty Miller)  | <u>Cytokinin</u> : BA 50 to 400 ppm (Configure) / Foliar spray or drench applied at 2 WAP, 2+3 WAP or 2+3+4 WAP.<br><u>Purpose</u> : Branching agent – Does BA affect growth?<br><u>Effect</u> : BA decreased the size of the plants  | [Ref. Chapter 7]         |
| <i>Senecio</i> sp.   | <u>Cytokinin</u> : BA 0.1 to 1.0 mM (22.5 to 225 ppm) / Single foliar spray 1 hour prior to inoculation<br><u>Purpose</u> : Disease control – Can BA reduce Botrytis (Gray Mold)?<br><u>Effect</u> : BA 225 ppm reduced Botrytis severity on flowers and leaves by 99%. It reduces the plants sensitivity to ethylene but does not affect the plants production of ethylene | (Elad 1993)              |
| <i>Skimmia reevesiana</i> (Reeves skimmia)   | <u>Cytokinin</u> : BA+GA (Promalin) 250 ppm – 1000 ppm / Single foliar spray application on rooted cuttings<br><u>Purpose</u> : Branching agent – Increase number of shoots and possibly plant size<br><u>Effect</u> : All rates increased height and branching. No rate difference.  | (Grzesik et al. 1990)    |
| <i>Solenostemon scutellarioides</i> (syn <i>Coleus blumei</i> ) (Coleus)               | <u>Cytokinin</u> : BA 400 to 1200 ppm<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : 800 ppm BA increased branching and height of pinched and un-pinched coleus   | (Khosh-Khui et al. 1978) |
| <i>Solenostemon scutellarioides</i> (syn <i>Coleus blumei</i> ) (Coleus)               | <u>Cytokinin</u> : BA 20 to 160 ppm (Configure) / Single foliar spray applied 1wk after a pinch<br><u>Purpose</u> : Branching agent - Height Control<br><u>Effect</u> : No effect on branching or growth at these rates   | [Ref. Chapter 7]         |
| <i>Solenostemon scutellarioides</i> (syn <i>Coleus blumei</i> ) (Coleus)               | <u>Cytokinin</u> : BA 100 to 3200 ppm (Configure) / Single foliar spray applied 2 WAP.<br><u>Purpose</u> : Branching agent - Height Control<br><u>Effect</u> : BA reduced plant size in one of 2 cultivars tested.  | [Ref. Chapter 7]         |
| <i>Solenostemon scutellarioides</i> (syn <i>Coleus blumei</i> ) (Coleus)               | <u>Cytokinin</u> : Kinetin 9 ppm / Cut stems placed in liquid solutions that also contained IAA.<br><u>Purpose</u> : Branching agent – Can Kinetin overcome IAA's apical dominance in Coleus?<br><u>Effect</u> : Kinetin reverses auxin's inhibition of branching. About 3x the rate of kinetin has to be used to overcome auxin.   | (Thimann et al. 1971)    |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>  | <b>Reference</b>         |
|---|---|--------------------------|
| <i>Solenostemon scutellarioides</i> (syn <i>Coleus blumei</i> , Coleus) | <u>Cytokinin</u> : Kinetin, BA 20 ppm / Leaves brushed with solution every day for 9 days and then were detached and debladed.<br><u>Purpose</u> : Senescence inhibitor – Can cytokinins reduce petiole senescence in debladed leaves?<br><u>Effect</u> : BA+IAA or BA alone greatly increased time to petiole senescence.  | (Viswanath et al. 1971)  |
| <i>Solidago rugosa</i> (Goldenrod)                                      | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity. Increased flower stem length  | (Lieth and Dodge 2004)   |
| <i>Spathiphyllum</i> cv. (Peace lily)                                   | <u>Cytokinin</u> : BA 500 ppm / Soil drench to plants of varying ages 16 to 32 weeks<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA increased branching in all plants but plant age 24 to 32 weeks resulted in the greatest number of shoots   | (Fooshee and Henny 1986) |
| <i>Spathiphyllum</i> cv. (Peace lily)                                   | <u>Cytokinin</u> : BA 250 to 1000 ppm / Soil drench 10ml OR Single foliar spray<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Drench at 1000 ppm resulted in the greatest number of lateral shoots and reduced overall height. All drench rates were better than any foliar rate.<br><u>Notes</u> : Article implies that another drench 8 weeks later would help improve branching more. | (Henny and Fooshee 1985) |
| <i>Spathiphyllum</i> cv. (Peace lily)                                   | <u>Cytokinin</u> : BA, Kinetin, 2iP 125 to 500 ppm / 10ml solution drenches<br><u>Purpose</u> : Branching agent – How does BA compare to Kinetin and 2iP as a branching agent when applied as a drench?<br><u>Effect</u> : BA 500 ppm was much better at increasing branching than Kinetin and 2iP.   | (Henny and Fooshee 1986) |
| <i>Spathiphyllum</i> cv. (Peace lily)                                   | <u>Cytokinin</u> : Thidiazuron 2 to 10 ppm / 10ml drench onto newly potted tissue culture plants<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : 4 to 10 ppm produced statistically similar increases in branching without affecting height, fresh weight, root or leaf size.  | (Henny 1995)             |
| <i>Stachys byzantia</i> (Lamb's ear)                                    | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Increased branching. Caused no phytotoxicity   | (Lieth and Dodge 2004)   |
| <i>Stipa bigeniculata</i> (Spear grass)                                 | <u>Cytokinin</u> : Kinetin $10^{-4}$ M (21.5 ppm) / Application method not described.<br><u>Purpose</u> : Germination Promoter / Dormancy release – Does Kinetin increase germination percentage?<br><u>Effect</u> : Kinetin increased the germination % from 3% to 51%. Kinetin was equivalent to GA.  | (Hagon 1976)             |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>   | <b>Reference</b>          |
|---|--|---------------------------|
| <i>Strobilanthes dyeranus</i><br>(Persian Shield)   | <u>Cytokinin</u> : PBA 200pppm / Dip cuttings into solution for 10sec prior to rooting<br><u>Purpose</u> : Height Control of rooted cuttings<br><u>Effect</u> : Cuttings were 75% shorter than control. PBA was better than daminozide, ancymidol, chlormequat, and ethephon   | (Sanderson et al. 1987)   |
| <i>Sutera</i><br>(Bacopa)                           | <u>Cytokinin</u> : BA 20 to 160 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Height Control<br><u>Effect</u> : No effect  | [Ref. Chapter 7]          |
| <i>Syngonium</i><br>(Arrowhead vine)                | <u>Cytokinin</u> : BA (500 ppm), Thidiazuron (Dropp 50) 1 to 100 ppm / Solution placed at the base of the plant at potting.<br><u>Purpose</u> : Branching agent – Can Thidiazuron increase basal branching in the cultivar ‘Maya Red’<br><u>Effect</u> : BA is ineffective at these rates. All Thidiazuron rates were effective at increasing branching, reducing height and fresh weight. Thidiazuron 50 ppm stimulated the most branching, but killed the roots. All Thidiazuron rates above 5 ppm caused some injury. Only 1 ppm Thidiazuron increased branching but did not cause injury.  | (Henny and Fooshee 1990b) |
| <i>Syngonium podophyllum</i><br>(African evergreen) | <u>Cytokinin</u> : PBA 200 ppm / Single foliar spray.<br><u>Purpose</u> : Branching agent – Can PBA increase branching?<br><u>Effect</u> :   | (Henley and Poole 1974)   |
| <i>Syngonium podophyllum</i><br>(Arrowhead vine)    | <u>Cytokinin</u> : PBA 400 – 800 ppm / Cuttings dip for 5 min OR BA 250 to 1000 ppm Single foliar spray onto rooted cuttings at the 1 leaf stage OR BA 250 to 2000 ppm Single foliar spray onto rooted cuttings at the 3 or 5 leaf stage. OR BA 200 to 800 ppm Single foliar spray onto plants that had already started branching<br><u>Purpose</u> : Branching agent to increase cuttings for propagation.<br><u>Effect</u> : PBA on cuttings resulted in smaller plants with fewer branches. BA at the 1 leaf stage had no effect on branching. BA at the 3 to 5 leaf stage resulted in earlier development of lateral shoots and shorter bushier plants. Total number of lateral shoots at harvest was unaffected though. 3 to leaf stage plant height affect more than 5-leaf stage. BA sprays onto already branching plants had no overall effect but reduced internode length on the top nodes by 25%. | (Wang and Boogher 1987)   |

Table A1 Continued

| <b>Plant</b>  | <b>Notes</b>  | <b>Reference</b>          |
|---|---|---------------------------|
| <i>Syngonium podophyllum</i><br>(Arrowhead vine)  | <p><u>Cytokinin</u>: PBA 400 to 800 ppm / Cuttings soaked for 5 min prior to sticking in a mist bed OR BA 250 to 2000 ppm single foliar spray onto rooted cuttings</p> <p><u>Purpose</u>: Branching agent – Can BA increase branching?</p> <p><u>Effect</u>: Initial plant growth was stimulated, but after 2 weeks plant growth was delayed by all rates of PBA. Cuttings did not root well. BA sprayed at the 1 leaf stage did not affect branching. BA sprayed at the 3 or 5 leaf stages induced lateral shoot formation in 1 week. All rates had similar results. The main stem elongation was reduced too. BA sprayed onto plants that had formed lateral branches already did not increase branching.</p> | (Wang 1988)               |
| <i>Tagetes erecta</i><br>(Marigold)   | <p><u>Cytokinin</u>: Kinetin 50 mg/l (50 ppm) / Foliar spray every 5 days.</p> <p><u>Purpose</u>: Flower enhancer – Can kinetin influence the flowering of this Long Day plant under Short Days?</p> <p><u>Effect</u>: Kinetin did not stimulate flowering under Short Day, but slightly reduced the time to flower under Long Days and slightly increased shoot length.</p>  | (Das et al. 1977)         |
| <i>Tecoma stans</i><br>(Texas star)   | <p><u>Cytokinin</u>: BA (FAL-457) 125 to 500 ppm, BA+GA (Fresco) 125 to 500 ppm / 4 foliar sprays at 2 week intervals following a hard pinch</p> <p><u>Purpose</u>: Branching agent – Propagation – Does BA improve cutting production on stock plants?</p> <p><u>Effect</u>: Fresco caused phytotoxicity and stretching. BA increased the number of cuttings but reduced rooting percentage.</p>   | (Whipker and Gibson 2007) |
| <i>Thalictrum</i><br>(Meadow rue)   | <p><u>Cytokinin</u>: Kinetin +GA+Ethrel 0.5 mM + 1 mM + 1 mM / Pre-germination seed soak</p> <p><u>Purpose</u>: Germination enhancer - Propagation</p> <p><u>Effect</u>: Promoted germination at below and above normal temperatures but not as well as 10 mM GA alone</p>  | (Persson 1993)            |
| <i>Tillandsia butzii</i><br><i>T. aeranthis</i><br><i>T. cacticola</i><br>(Succulent / Bromeliad) | <p><u>Cytokinin</u>: BA 1 to 50 ppm Applied 2 to 3 times per week for 2 to 10 weeks Foliar spray OR cuttings dipped 1 to 3 times for 1 to 24 hr</p> <p><u>Purpose</u>: Branching agent - Propagation</p> <p><u>Effect</u>: 25 to 50 ppm sprays and 1hr dips greatly increased offsets</p>   | (Bessler 1997)            |

Table A1 Continued

| <b>Plant</b>                                  | <b>Notes</b>  | <b>Reference</b>              |
|---|---|-------------------------------|
| <i>Torenia fournieri</i><br>(Wishbone flower) | <p><b>Cytokinin:</b> CPPU 0.3 to 30 <math>\mu</math>M (0.074 - 7.4 ppm), BA 1000 <math>\mu</math>M (225 ppm), Zeatin 1000 <math>\mu</math>M (217 ppm) / 8 <math>\mu</math>L droplets placed onto the apex of an inflorescence at various times during flower formation.</p> <p><b>Purpose:</b> Flower enhancer – Can cytokinins alter flower morphology?</p> <p><b>Effect:</b> CPPU at 0.74 and 7.4 ppm caused morphological changes that varied based on the time of application and included dentate petals, and double flowering. 8 different morphologies identified. Neither BA or Zeatin caused any changes.</p> <p><b>Notes:</b> Author indicates that the results of a spray program would be inconsistent because of the different stages of each bud on a flower at application time.</p> | (Nishijima and Shima 2006)    |
| <i>Tulipa</i><br>(Tulip)                      | <p><b>Cytokinin:</b> BA 1 to 100 ppm, Kinetin 100 ppm / Applied via injecting bulbs OR buds with 0.5ml or 100 ppm solution OR single foliar spray OR single soil drench</p> <p><b>Purpose:</b> Senescence inhibitor – Can CKs prevent bud blasting?</p> <p><b>Effect:</b> Kinetin, BA reduced bud blasting. BA was better than Kinetin. 1 ppm BA 10 ppm was better than 1 ppm and the same as 100 ppm. BA was even better than GA<sub>4+7</sub>. BA reduced the time to flowering but not as much as GA. BA increased the flower size, reduced the bulblet size and hastened the exhaustion of the mother bulb.</p>   | (de Munk and Gijzenberg 1977) |
| <i>Tulipa</i><br>(Tulip)                      | <p><b>Cytokinin:</b> Kinetin 100 ppm or Kinetin+GA<sub>4+7</sub> / Inject bud with 0.5ml of solution</p> <p><b>Purpose:</b> Senescence inhibitor – Can CKs prevent bud blasting?</p> <p><b>Effect:</b> Kinetin+GA works better than Kinetin or GA alone in inhibiting the effects of ethylene, ABA or temperature on bud blasting</p>   | (de Munk and Hoogeterp 1975)  |
| <i>Tulipa</i><br>(Tulip)                      | <p><b>Cytokinin:</b> BA 1 to 100<math>\mu</math>g / Injected into pre-cooled bulbs pre-plant</p> <p><b>Purpose:</b> Flower enhancer – Does BA affect flower fresh weight?</p> <p><b>Effect:</b> BA increases flower fresh weight but not dry weight. Flowers were thicker and higher quality</p>  | (Franssen and Voskens 1997)   |
| <i>Tulipa</i><br>(Tulip)                      | <p><b>Cytokinin:</b> Kinetin rate not listed / Injected into flower stalk</p> <p><b>Purpose:</b> Flower enhancer – Does Kinetin reduce bud blasting?</p> <p><b>Effect:</b> Kinetin reduces the incidence of blasting.</p>   | (Hanks and Rees 1977b)        |
| <i>Tulipa</i><br>(Tulip)                      | <p><b>Cytokinin:</b> Kinetin OR Kinetin+GA<sub>4+7</sub> 0.05mg / Injected into pre-cooled bulbs in 1ml of water prior to forcing</p> <p><b>Purpose:</b> Senescence inhibitor – Can CKs prevent bud blasting?</p> <p><b>Effect:</b> GA+Kinetin worked better than GA or Kinetin alone in reducing bud blasting in CEPA induced tulips but did not influence sucrose mobilization into the bud.</p>  | (Moe 1979)                    |

Table A1 Continued

| <b>Plant</b>                                 | <b>Notes</b>  | <b>Reference</b>                |
|--|---|---------------------------------|
| <i>Tulipa</i><br>(Tulip)                     | <u>Cytokinin</u> : BA 2000 ppm in lanolin paste applied to flower bud<br><u>Purpose</u> : Height control – Can BA control flower stem height?<br><u>Effect</u> : BA had no effect on ultimate height even when mixed with GA or IAA. Author conjectures that BA improves assimilate flow to the flower.   | (Saniewski and De Munk 1981).   |
| <i>Tulipa</i><br>(Tulip)                     | <u>Cytokinin</u> : BA 0.05, 0.1, 0.25 % / Lanolin paste applied to basal end of dormant bulbs in July<br><u>Purpose</u> : Flower enhancer – Can BA alter flower morphology?<br><u>Effect</u> : BA caused “parrot”-like flowers. BA caused shorter stems and delayed flowering by a few days. Also, daughter bulbs sprouted leaves. Timing was important. BA in August did not affect flowering. BA altered stigma and carpel morphology and number. Effect only lasts one season. | (Saniewski and Mynett 1977)     |
| <i>Tulipa</i><br>(Tulip)                     | <u>Cytokinin</u> : BA+GA (Promalin) 200 ppm / 1ml solution injected into pre-cooled bulbs pre-plant OR injected into buds 2WAP<br><u>Purpose</u> : Flower enhancer – Height Control – Can BA alter flowering time or stem length?<br><u>Effect</u> : Promalin injected before potting accelerated blooming, reduced stem length, and prevented bud blasting in bulbs cooled for only 6 weeks. Injecting flower buds with Promalin delayed flowering.                              | (Suh 1997)                      |
| <i>Tulipa</i><br>(Tulip)                     | <u>Cytokinin</u> : BA 0.1 mg / Injected into bulbs<br><u>Purpose</u> : Propagation – does BA affect bulblet formation<br><u>Effect</u> : No effect  | (van Bragt and van Gelder 1979) |
| <i>Tulipa gesneriana</i><br>(Didier's tulip) | <u>Cytokinin</u> : BA 0.25% / Lanolin paste applied to basal end of dormant tulip bulbs in July<br><u>Purpose</u> : Flower enhancer – Can BA alter flower morphology?<br><u>Effect</u> :  | (Saniewski and Puchalski 1997)  |
| <i>Verbena</i>                               | <u>Cytokinin</u> : BA+GA BA $10^{-6}$ M- $10^{-5}$ M, GA $10^{-4}$ M- $10^{-3}$ M / Seeds soaked in solution prior to sowing<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Improved germination % but effect was less than GA alone   | (Finch-Savage et al. 1991a)     |
| <i>Verbena</i>                               | <u>Cytokinin</u> : BA 20 to 160 ppm (Configure) / Single foliar spray onto rooted plants<br><u>Purpose</u> : Branching agent - Height Control - Does BA affect growth?<br><u>Effect</u> : No effect of branching, height, or flowering  | [Ref. Chapter 7]                |
| <i>Verbena</i> ×<br><i>hybrida</i>           | <u>Cytokinin</u> : BA 30 to 300 ppm single foliar spray onto new cuttings<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : 30 ppm BA applied at cutting improved rooting after 12 days and improved branching after 24d   | (Svenson 1991)                  |

Table A1 Continued

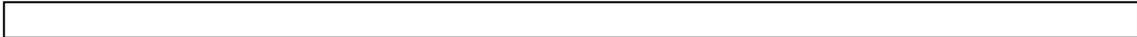
| <b>Plant</b>                                      | <b>Notes</b>  | <b>Reference</b>            |
|---|---|-----------------------------|
| <i>Verbena bonariensis</i><br>(Brazilian verbena) | <u>Cytokinin</u> : Kinetin +GA+Ethrel 0.5 mM + 1 mM + 1 mM / Pre-germination seed soak<br><u>Purpose</u> : Germination enhancer - Propagation<br><u>Effect</u> : Promoted germination at below and above normal temperatures but not as well as 1 mM or 10 mM GA alone  | (Persson 1993)              |
| <i>Verbena canadensis</i><br>(Clump verbena)      | <u>Cytokinin</u> : BA (ProShear) 250 to 1000 ppm / Single foliar sprays immediately after pinching<br><u>Purpose</u> : Growth reduction – Can BA reduce shoot elongation?<br><u>Effect</u> : 1000 ppm ProShear reduced shoot elongation by 19% which was less than Florel.  | (Banko and Stefani 1997a)   |
| <i>Verbena canadensis</i><br>(Clump verbena)      | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Increased branching. Caused no phytotoxicity   | (Lieth and Dodge 2004)      |
| <i>Vinca minor</i><br>(Periwinkle)                | <u>Cytokinin</u> : BA 62.5 to 250 ppm, PBA+GA 62.5 to 250 ppm, BA+GA 125 to 500 ppm / foliar spray. BA+GA 250 to 1000 ppm / foliar spray 2 times 7 weeks apart<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : BA+GA (Promalin) at 1000 ppm applied 2 times increased branching and stem length making for more marketable plants  | (Foley and Keever 1993)     |
| <i>Viola ×wittrockiana</i><br>(Pansy)             | <u>Cytokinin</u> : BA 50 to 800 ppm (Configure) / Single foliar spray<br><u>Purpose</u> : Branching agent - Flower enhancer<br><u>Effect</u> : Small decrease in plant height and small increase in branching. Delayed flowering. Phytotoxicity above 100 ppm. There were cultivar differences with Violas being more tolerant than Pansies   | [Ref. Chapter 7]            |
| <i>Viola tricolor</i><br>(Pansy)                  | <u>Cytokinin</u> : BA+GA (20 ppm + 1 ppm) / Single foliar spray after spent plants have been cut back<br><u>Purpose</u> : Growth enhancer – Can BA+GA be used to regenerate old pots of Viola that have been cut back to the ground?<br><u>Effect</u> : BA + GA can be used to rejuvenate pots of Violas.   | (Zhao-wu and Lang-tao 2002) |
| <i>Zantedeschia</i><br>(Calla Lily)               | <u>Cytokinin</u> : BA+GA. 200 ppm + 200 ppm / Bulb dips in GA once and BA every two weeks during storage. OR foliar spray w/ BA 2x per week and GA 2 times during flower growth<br><u>Purpose</u> : Branching agent – Flower enhancer<br><u>Effect</u> : BA or BA+GA increased number of shoots in bulb dips and even more for foliar sprays. BA+GA increased flower numbers in both. | (Naor et al. 2005)          |

Table A1 Continued

| <b>Plant</b>                                   | <b>Notes</b>   | <b>Reference</b>      |
|--|--|-----------------------|
| <i>Zantedeschia aethiopica</i><br>(Calla Lily) | <p><u>Cytokinin</u>: BA 250 to 350 ppm OR BA+GA 350 ppm each / Pre-plant Rhizome dip 20 min OR dip plus foliar GA 350 ppm sprays 5 and 8 weeks later</p> <p><u>Purpose</u>: Flower enhancer - Increase flower production for cut flower industry</p> <p><u>Effect</u>: BA 350 ppm or BA+GA 350 ppm increased total flowers produced. BA caused some flower abnormalities but BA+GA caused more. GA sprays. Increasing flower production in one year reduces future production from the rhizome</p>   | (Luria et al. 2005)   |
| <i>Zantedeschia aethiopica</i><br>(Calla Lily) | <p><u>Cytokinin</u>: BA 150 ppm soil drench 3x/wk for 6wk or 1 time every 2wk for 8wk soil drench or foliar spray, OR GA<sub>3</sub>+BA (250 ppm + 150 ppm) 3x/wk for 6wk, OR TIBA+BA, KNA+BA</p> <p><u>Purpose</u>: Branching agent – Can BA enhance branching of rhizomes in production?</p> <p><u>Effect</u>: BA+GA was best at triggering the most side shoots but the majority of them did not develop into leaves. Decapitation was best at developing side shoots that later developed into leaves. BA+TIBA was not effective</p>   | (Ngamu 2001)          |
| <i>Zantedeschia aethiopica</i><br>(Calla Lily) | <p><u>Cytokinin</u>: HBAP, HBARP 10<sup>-8</sup>M – 10<sup>-4</sup>M / 5ml solutions every 48hr placed into a cotton plug that was placed at the inflorescence.</p> <p><u>Purpose</u>: Flower enhancer – Do artificially created versions of endogenous cytokinins cause spathe greening?</p> <p><u>Effect</u>: HBARP 10<sup>-8</sup>M was best at preventing spathe senescence and caused it to turn green better than the other rates.</p>   | (Pais and Neves 1982) |
| <i>Zinnia</i>                                  | <p><u>Cytokinin</u>: PBA 250 to 750 ppm / Single Foliar spray application</p> <p><u>Purpose</u>: Branching agent – Height control – Flower enhancer</p> <p><u>Effect</u>: 750 ppm PBA increased lateral shoot formation of un-pinched plants prior to flower induction. No delay in flower development or size. Phytotoxicity occurred at 750 ppm and was worse in lower temperatures than higher ones but was reduced by transferring plants to higher temps. Effects lasted about 4 weeks. Applications of PBA to flowers at various stages of development did not affect flower size or timing.</p> | (Jeffcoat 1977)       |
| <i>Zinnia</i>                                  | <p><u>Cytokinin</u>: BA 100 to 200 ppm / Single foliar spray</p> <p><u>Purpose</u>: Flower enhancer</p> <p><u>Effect</u>: BA 100 ppm reduced time from bud emergence to flowering by 7d.</p>   | (Miyajima 2000)       |
| <i>Zinnia</i>                                  | <p><u>Cytokinin</u>: BA 0.4 to 1.0 mM / single foliar spray followed by simulated shipping</p> <p><u>Purpose</u>: Senescence inhibitor - Can BA reduce senescence on potted Zinnias in an indoor (home) environment</p> <p><u>Effect</u>: No effect on senescence</p>  | (Pinto et al. 2005)   |

Table A1 Continued

| <b>Plant</b>          | <b>Notes</b>   | <b>Reference</b>  |
|-----------------------|--|-------------------|
| <i>Zinnia elegans</i> | <p><u>Cytokinin</u>: Kinetin 50 mg/l (50 ppm) / Foliar spray every 5 days.</p> <p><u>Purpose</u>: Flower enhancer – Can kinetin influence the flowering of this Short Day plant under Long Days?</p> <p><u>Effect</u>: Kinetin increased the percentage of plants that flowered under Long Days from 15% (control) to 35%. IAA was a little better than Kinetin.</p>                   | (Das et al. 1977) |
| <i>Zinnia elegans</i> | <p><u>Cytokinin</u>: BA 20 to 800 ppm (Configure) / 1, 2, or 3 Foliar sprays applied 1 week apart starting 1 week after potting up seedlings OR fertigation daily for 3 weeks 1 to 16 ppm</p> <p><u>Purpose</u>: Branching agent – Height control – Flower enhancer - Does BA have any affect on growth?</p> <p><u>Effect</u>: BA increased branching, decreased internode length.</p> | [Ref. Chapter 7]  |



### A1.2 Effects of Cytokinins on Postharvest / Cut Flower Ornamental Plants.

The following table summarizes the research efforts in the area of cut flower and cut greens production. The following table briefly summarizes the research efforts for cut flowers. The goal of this table is to show a representation of a wide variety of crops. Some crops have extensive research behind them (i.e., alstroemeria, anthurium, carnation, chrysanthemum, lily, rose) and are summarized here with only a few entries that represent the methods used in the wider research.

Table A2: Research efforts for exogenous cytokinins on cut flower crops

| Plant   | Notes  | Reference                    |
|---|--|------------------------------|
| <i>Adiantum cuneatum</i>                          | <u>Cytokinin</u> : BA 10 <sup>-3</sup> M / Stem pulse dip for 2 min<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life?<br><u>Effect</u> : No positive effects.  | (Heide and Oydvin 1969)      |
| <i>Alpinia purpurata</i><br>(Red and Pink Ginger) | <u>Cytokinin</u> : BA 100 to 200 ppm / 10sec-1min Dip or spray applied to cut stems. Stems then packed and simulated shipped 2 to 12 days at various temperatures. Stems unpacked and vase life determined.<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life?<br><u>Effect</u> : BA increased vase life of leaves and flowers by 1.3x over control.  | (Paull and Chantrachit 2001) |
| <i>Alpinia purpurea</i><br>(Pink ginger)          | <u>Cytokinin</u> : BA 200 ppm / Single stem spray<br><u>Purpose</u> : Senescence inhibitor – Delay flower senescence<br><u>Effect</u> : BA increases vase life   | (Jaroenkit and Paull 2003)   |
| <i>Alstroemeria</i><br>(Peruvian lily)            | <u>Cytokinin</u> : Zeatin riboside (10 ppm), Kinetin (2 ppm), BA (100 ppm) / Continuous dip<br><u>Purpose</u> : Senescence inhibitor – decrease leaf yellowing and petal drop.<br><u>Effect</u> : Zeatin Riboside worked best at delaying both petal drop and leaf yellowing by 3 to 7d. BA was second best 3 to 4 days and was equivalent to OF or Chrysal SVB. But on leaf yellowing alone, OFP + GA was best (10d). | (Dai and Paull 1991)         |
| <i>Alstroemeria</i><br>(Peruvian lily)            | <u>Cytokinin</u> : Thidiazuron 1 µM continuous or 10 µM pulse for 24h<br><u>Purpose</u> : Senescence inhibitor – decrease leaf yellowing<br><u>Effect</u> : Either rate reduces leaf yellowing   | (Ferrante et al. 2002a)      |

| Table A2 Continued  |   |                              |
|---|---|------------------------------|
| Plant   | Notes   | Reference                    |
| <i>Alstroemeria</i><br>(Peruvian lily)                                    | <u>Cytokinin</u> : BA or BA+GA 12.5 to 50 ppm / Stem pulse dip for 4hr<br><u>Purpose</u> : Senescence inhibitor – decrease leaf yellowing<br><u>Effect</u> : BA reduced leaf yellowing  | (Hicklenton 1991)            |
| <i>Alstroemeria aurantiaca</i><br>(Peruvian lily)                         | <u>Cytokinin</u> : BA+GA (Accel) 25 to 100 ppm / Continuous vase treatment<br><u>Purpose</u> :<br><u>Effect</u> : Accel 25 ppm best at increasing flower longevity (by 4d), and reducing leaf yellowing. BA caused florets to open more slowly.   | (Mutui et al. 2001)          |
| <i>Alstroemeria pelegrina</i><br>(Peruvian lily)                          | <u>Cytokinin</u> : Kinetin $10^{-7}$ to $10^{-4}$ M (22.5ppb-22.5 ppm) / 20h Pulse or Continuous treatment in vase solution.<br><u>Purpose</u> : Senescence inhibitor – Can cytokinins reduce leaf yellowing in cut branches?<br><u>Effect</u> : Kinetin was only effective in reducing yellowing at 22.5 ppm as a continuous treatment. Kinetin was not as effective as GA pulses or continuous treatments.  | (van Doorn et al. 1992)      |
| <i>Anthurium</i><br>(Cockscomb)   | <u>Cytokinin</u> : BA 200 ppm / Post importation spray<br><u>Purpose</u> : Senescence inhibitor – Delay flower senescence with post-shipping applications in summer and winter<br><u>Effect</u> : Increased vase life 1.3 to 1.7x. Much more effective in summer than winter. Packing the flowers together in the vase negated the effect of BA.  | (Fukui et al. 2005)          |
| <i>Anthurium andraeanum</i><br>(Cockscomb)                                | <u>Cytokinin</u> : BA 100 to 200 ppm / 10sec-1min Dip or spray applied to cut stems. Stems then packed and simulated shipped 2 to 12 days at various temperatures. Stems unpacked and vase life determined.<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life?<br><u>Effect</u> : BA 200 ppm increased vase life of flowers and leaves. Wide variation in cultivar response – 1.4 to 2.4x control. In some cultivars 100 ppm was better and in others all rates reduced vase life. Author evaluated 15 cultivars | (Paull and Chantrachit 2001) |
| <i>Arundina bambusifolia</i><br>(Bamboo orchid)                           | <u>Cytokinin</u> : BA 100 to 200 ppm / 10sec-1min Dip or spray applied to cut stems. Stems then packed and simulated shipped 2 to 12 days at various temperatures. Stems unpacked and vase life determined.<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life?<br><u>Effect</u> : BA decreased vase life by 30%  | (Paull and Chantrachit 2001) |
| <i>Asparagus densiflorus</i> and <i>A. setaceus</i><br>(Asparagus greens) | <u>Cytokinin</u> : BA 0.1 mM / dm <sup>-1</sup> 24 hr pulse or BA 1.0 mM / dm <sup>-1</sup> dip for several seconds<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life of cut asparagus greens?<br><u>Effect</u> : BA increased the vase-life of all taxa tested. In <i>A. densiflorus</i> BA was not as good as other preservatives such as Chrysal RVB but it was the only chemical trialled that improved vase life of <i>A. setaceus</i>  | (Skutnik et al. 2006)        |

| Table A2 Continued  |  |                            |
|---|--|----------------------------|
| Plant   | Notes  | Reference                  |
| <i>Chrysanthemum</i>  | <p><u>Cytokinin</u>: Thidiazuron 10 to 100 <math>\mu\text{M}</math> / 24hr pulse after cutting</p> <p><u>Purpose</u>: Senescence inhibitor</p> <p><u>Effect</u>: Thidiazuron 100 <math>\mu\text{M}</math> delayed leaf yellowing and stem elongation in the cut flowers but did not increase vase life of the flower.</p>  | (Ferrante et al. 2003)     |
| <i>Chrysanthemum</i>  | <p><u>Cytokinin</u>: BA <math>10^{-3}\text{M}</math> (225 ppm) / Stem Pulse dip for 2 min</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: BA reduced leaf yellowing but did not affect flower life.</p>   | (Heide and Oydvin 1969)    |
| <i>Chrysanthemum morifolium</i>                             | <p><u>Cytokinin</u>: BA 10 to 20 ppm / flower dip</p> <p><u>Purpose</u>: Senescence inhibitor – Can BA reduce respiration in cut mums?</p> <p><u>Effect</u>: BA at either rate was effective at reducing respiration over control (13%). Respiration rates dropped for 4 days before rising.</p>   | (MacLean and Dedolph 1962) |
| <i>Dendranthema grandiflora</i><br>( <i>Chrysanthemum</i> ) | <p><u>Cytokinin</u>: BA 5 to 20 ppm / 24h Pulse treatment</p> <p><u>Purpose</u>: Senescence inhibitor – Can BA increase vase life?</p> <p><u>Effect</u>: BA 10 ppm was best at increasing vase life (20 days over control)</p>   | (Petridou et al. 2001)     |
| <i>Dianthus caryophyllus</i><br>(Carnation)                 | <p><u>Cytokinin</u>: Kinetin 0.045 mM (9.68 ppm) + AOA 0.8 mM / 24hr stem pulse dip</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life. Also, can AOA+Kinetin replace STS?</p> <p><u>Effect</u>: AOA+Kinetin increased vase life by 14d. This experiment did not compare this result to STS though.</p>  | (Harkema et al. 1991)      |
| <i>Dianthus caryophyllus</i><br>(Carnation)                 | <p><u>Cytokinin</u>: BA <math>10^{-5}</math> to <math>10^{-3}\text{M}</math> / Pulsed dip of stem or flower for 2min – 12hr on cold stored flowers and fresh flowers,</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: BA increases vase life by 3 to 5days. The best doses and times were : <math>10^{-3}\text{M}</math> for 2 min, <math>10^{-4}\text{M}</math> for 50min <math>10^{-5}\text{M}</math> for 12hr. 12hr at <math>10^{-3}\text{M}</math> was detrimental. BA worked better when applied after cold storage rather than before. A flower dip caused color changes in the flower (but was not attributed to BA itself) so a stem dip is recommended. Stems cut in June kept better than November cut stems. BA lowered respiration rates.</p> | (Heide and Oydvin 1969)    |
| <i>Dianthus caryophyllus</i><br>(Carnation)                 | <p><u>Cytokinin</u>: Kinetin <math>5 \cdot 10^{-7}\text{M}</math> to <math>5 \cdot 10^{-4}\text{M}</math> / Applied as a spray or continuous dip OR BA <math>5 \cdot 10^{-6}\text{M}</math> to <math>10^{-4}\text{M}</math> / Applied as spray every 2 days OR Stem &amp; leaf immersion 50min OR continuous dip</p> <p><u>Purpose</u>: Delay Senescence – increase vase life</p> <p><u>Effect</u>: BA and Kinetin increased vase life but not as much as floral preservatives</p> <p><u>Notes</u>: Author gives an opinion that the uses of cytokinins in cut flowers is limited</p>  | (Paulin and Muloway 1979)  |

| Table A2 Continued  |  |                               |
|---|--|-------------------------------|
| Plant   | Notes  | Reference                     |
| <i>Dianthus caryophyllus</i> (Carnation)                                  | <u>Cytokinin</u> : cis & trans Zeatin, DHZ $4 \times 10^{-5}$ M (9 ppm) / 2min petal dip<br><u>Purpose</u> : Senescence inhibitor – Can Zeatin increase vase life?<br><u>Effect</u> : DHZ delayed senescence. tZ accelerated senescence, cZ had no effect.   | (Upfold and Van Staden 1990)  |
| <i>Dianthus caryophyllus</i> (Carnation)                                  | <u>Cytokinin</u> : BA $4.44 \times 10^{-5}$ M to $2.22 \times 10^{-4}$ M (10 ppm-50 ppm) / 2min petal dip<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life?<br><u>Effect</u> : 10 ppm decreases vase life by 3d. 25 & 50 ppm increases vase life by 2d.  | (van Staden and Joughin 1988) |
| <i>Dianthus caryophyllus</i> (Carnation)                                  | <u>Cytokinin</u> : 2iP and derivatives $4 \times 10^{-6}$ M (0.9 ppm) / 2min petal dip<br><u>Purpose</u> : Senescence inhibitor – Can 2iP increase vase life?<br><u>Effect</u> : 2iP and derivatives delay senescence but do not increase vase life.   | (van Staden et al. 1990)      |
| <i>Dianthus caryophyllus</i> (Carnation)                                  | <u>Cytokinin</u> : BA 100 $\mu$ M (22.5 ppm) / Continuous dip<br><u>Purpose</u> : Flower enhancer – Does BA stimulate bud opening in cut carnations?<br><u>Effect</u> : BA stimulates bud opening and delays senescence  | (Wong et al. 1989)            |
| <i>Dianthus caryophyllus</i> (Carnation)                                  | <u>Cytokinin</u> : Kinetin ( $4.6 \times 10^{-3}$ mM to $4.6 \times 10^{-2}$ mM) (1 to 10 ppm) +AOA ( $9 \times 10^{-3}$ mM to 4.6 mM) (2.6 ppm – 1205 ppm) + Triton X-100 as 22h Pulse treatments OR Kinetin ( $4.6 \times 10^{-8}$ mM to $4.6 \times 10^{-6}$ mM) (10ppb-1 ppm) +AOA (0.1 mM to 1 mM) (29 ppm – 291 ppm) vase solutions<br><u>Purpose</u> : Senescence inhibitor – Can Kinetin + AOA increase vase life in cut carnations?<br><u>Effect</u> : Kinetin+AOA+Triton was 80% better than control but only 60% as good as STS. Kinetin by itself was worse than control. Holding solution and pulse treatments were very similar. | (Bichara and Van Staden 1993) |
| <i>Dianthus caryophyllus</i> (Carnation)                                  | <u>Cytokinin</u> : BA 10 to 20 ppm / flower dip<br><u>Purpose</u> : Senescence inhibitor – Can BA reduce respiration rate in cut carnations?<br><u>Effect</u> : BA at either rate was effective at reducing respiration over control (22%). Respiration rates dropped for 3 days before rising.  | (MacLean and Dedolph 1962)    |
| <i>Dicranopteris linearis</i> (Uluhe fern curls)                          | <u>Cytokinin</u> : BA 100 to 200 ppm / 10sec-1min Dip or spray applied to cut stems. Stems then packed and simulated shipped 2 to 12 days at various temperatures. Stems unpacked and vase life determined.<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life?<br><u>Effect</u> : No effect (a slight but insignificant drop in vase life)  | (Paull and Chantrachit 2001)} |
| <i>Eucalyptus parviflora</i> (syn. <i>E. parvula</i> ) (Small leaved gum) | <u>Cytokinin</u> : Thidiazuron 10, 50, 100 $\mu$ M (2.2 ppm – 220 ppm) or BA 85, 130, 260 $\mu$ M (5.8 ppm – 58.5 ppm) / 24hr pulse dip<br><u>Purpose</u> : Senescence inhibitor – decrease leaf yellowing and increase vase life<br><u>Effect</u> : BA reduced vase life. Thidiazuron slightly increased vase life and decreased chlorophyll degradation.   | (Ferrante et al. 2002b)       |

| Table A2 Continued   |  |                              |
|--|--|------------------------------|
| Plant  | Notes  | Reference                    |
| <i>Eustoma grandiflorum</i> (Lisianthus)                           | <p><u>Cytokinin</u>: BA 50 ppm with or without sucrose / 24 hr pulse dip</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: A BA pulse followed by a 4% sucrose pulse increased vase life by 8 days and was better than the two applied at the same time or sucrose followed by BA. BA increased ethylene production in the plant and sucrose decreased it. Mixes of the 2 were intermediate in ethylene production and were similar to control. BA and sucrose increased respiration.</p> | (Huang and Chen 2002)        |
| <i>Freesia</i>   | <p><u>Cytokinin</u>: BA, PBA, Kinetin 50 ppm / 24h pulse dip with or without STS 0.2 mM 30min after cutting and transporting.</p> <p><u>Purpose</u>: Flower Enhancer – Delay Senescence – Does STS or BA or a combination increase vase life, and increase the flowering %.</p> <p><u>Effect</u>: All the cytokinins were equivalent to STS. The combination of BA+STS was best and increased vase life by 1 to 4 days but did not significantly increase flowering %.</p>   | (Systema 1986)               |
| <i>Gloriosa</i> (Gloriosa lily)                                    | <p><u>Cytokinin</u>: BA 100 ppm, BA+GA 100 ppm / Stem dip pulse 24hr.</p> <p><u>Purpose</u>: Senescence inhibitor - Can cytokinins improve vase life</p> <p><u>Effect</u>: BA alone cause phytotoxicity. BA+GA caused deeper green leaves. Neither impacted flower longevity. Nor did STS –but it caused leaf yellowing. Gloriosa is not ethylene sensitive</p>  | (Tabuchi et al. 2005)        |
| <i>Grevillea</i> (Kahiliflower)                                    | <p><u>Cytokinin</u>: BA 0.01 to 10 mM (2.25 to 2250 ppm) / BA placed into vase solution or flowers dipped in solution for 1 min.</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: Vase solutions did not increase vase life but dipping in 2250 ppm increased vase life by 1.3x over control.</p>  | (Setyadjit et al. 2004)      |
| <i>Heliconia</i> (Lobster claw)                                    | <p><u>Cytokinin</u>: BA 200 ppm / Single stem spray</p> <p><u>Purpose</u>: Senescence inhibitor – Delay flower senescence</p> <p><u>Effect</u>: BA increases vase life</p>   | (Jaroenkit and Paull 2003)   |
| <i>Heliconia latispatha</i> (Lobster claw)                         | <p><u>Cytokinin</u>: BA 100 to 300 ppm / Inflorescences sprayed twice within 1hr after harvest.</p> <p><u>Purpose</u>: Senescence inhibitor – Flower enhancer – Can BA increase vase life and cause more bracts to open</p> <p><u>Effect</u>: BA 300 ppm increased vase life 1.8x but did not increase the number of bracts that opened.</p>   | (de Moraes et al. 2005)      |
| <i>Heliconia psittacorum</i> , <i>H. chartacea</i> (Parrot's beak) | <p><u>Cytokinin</u>: BA 100 to 200 ppm / 10sec-1min Dip or spray applied to cut stems. Stems then packed and simulated shipped 2 to 12 days at various temperatures. Stems unpacked and vase life determined.</p> <p><u>Purpose</u>: Senescence inhibitor – Can BA increase vase life?</p> <p><u>Effect</u>: BA increased flower and leaf vase life (8 to 18d), delayed bract darkening and abscission. Spraying worked better than dipping.</p>   | (Paull and Chantrachit 2001) |

| Table A2 Continued                         |  |                         |
|--|--|-------------------------|
| Plant                                      | Notes  | Reference               |
| <i>Hemerocallis fulva</i><br>(Daylily)     | <u>Cytokinin</u> : Kinetin, BA, DPU 0.5 mM (around 100 ppm each) continuous dip with or without Cycloheximide 0.5 mM spray<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life in daylily<br><u>Effect</u> : BA+CHI markedly delayed senescence   | (Gulzar et al. 2005)    |
| <i>Iris</i>                                | <u>Cytokinin</u> : Kinetin 2 ppm with or without GA 10 ppm / 1.5hr or 3 days pulse dip<br><u>Purpose</u> : Senescence inhibitor – Delay flower senescence<br><u>Effect</u> : Kinetin 3 days dip increased % of flowers that opened and increased vase life by 0.75d. A 1.5h dip had no effect on vase life.  | (Swart 1986)            |
| <i>Iris ×hollandica</i><br>(Dutch Iris)    | <u>Cytokinin</u> : BA, BA+GA (Promalin) 50 ppm / Stem dip or stem spray<br><u>Purpose</u> : Senescence inhibitor – Delay flower senescence and leaf yellowing<br><u>Effect</u> : Sprays worked better than dips. BA & Promalin delayed flower senescence and leaf yellowing. Promalin resulted in the highest quality flower.  | (Lee et al. 2005)       |
| <i>Lilium</i><br>(Lily)                    | <u>Cytokinin</u> : CPPU / rates and application method unknown<br><u>Purpose</u> : Growth enhancer<br><u>Effect</u> : CPPU caused thicker stems due to enhanced cell division  | (Arima et al. 1995)     |
| <i>Lilium</i><br>(Oriental & Asiatic Lily) | <u>Cytokinin</u> : BA+GA 25 ppm / Sprayed before or after cold storage OR pulse dip for 4h.<br><u>Purpose</u> : Senescence inhibitor – Delay flower senescence and leaf yellowing.<br><u>Effect</u> : Spraying before or after cold storage inhibited leaf yellowing, bud blast and increased flower longevity. Putting it into the dip solution decreased yellowing but induced bud blast.  | (Han 2001)              |
| <i>Lilium</i><br>(Oriental & Asiatic Lily) | <u>Cytokinin</u> : BA 50 to 100 ppm, BA+GA (Promalin) 50 to 100 ppm / Foliar spray or 20m pulse dip<br><u>Purpose</u> : Senescence inhibitor – Delay flower senescence and leaf yellowing<br><u>Effect</u> : Promalin pulse dip of 100 ppm and spray 50 ppm were the two most effective treatments at extending vase life followed by GA <sub>4+7</sub> alone, BA alone, and finally GA <sub>3</sub> alone. STS dips and sprays were equivalent to BA alone. | (Kim et al. 2005)       |
| <i>Lilium</i><br>(Oriental Lily)           | <u>Cytokinin</u> : Thidiazuron 10 µM (2 ppm), BA+GA (Chrysal BVB 1 to 2 ppm, Fascination 5.4 ppm) / 1hr pulse dip<br><u>Purpose</u> : Senescence inhibitor – Delay leaf yellowing – How do several commercial preparations compare?<br><u>Effect</u> : Chrysal BVB was the most effective followed by Fascination and Thidiazuron.   | (Leonard and Nell 2004) |

| Table A2 Continued                             |  |                              |
|--|--|------------------------------|
| Plant  | Notes  | Reference                    |
| <i>Lilium</i><br>(Lily)                        | <p><u>Cytokinin</u>: BA 10 to 20 ppm, Kinetin 10 to 20 ppm, GA 20 ppm + 10 ppm Kinetin or BA / Continuous dips starting at various times during bud development</p> <p><u>Purpose</u>: Flower enhancer – Can CKs improve flower characteristics?</p> <p><u>Effect</u>: Cytokinins caused a slightly darkened flower color and decreased the % of buds that opened but did not affect flower longevity or leaf yellowing. BA+GA improved flower longevity and prevented leaf yellowing.</p> | (Nowak and Mynett 1985)      |
| <i>Lilium</i><br>(Asiatic Lily)                | <p><u>Cytokinin</u>: GA+BA (Promalin) 100 ppm / Single stem, leaf and bud spray</p> <p><u>Purpose</u>: Senescence inhibitor – Delay flower senescence and leaf yellowing</p> <p><u>Effect</u>: Promalin spray was as effective as GA pulse dip in preventing leaf chlorosis and increasing flower longevity</p>  | (Ranwala and Miller 2002)    |
| <i>Lilium longiflorum</i><br>(Easter Lily)     | <p><u>Cytokinin</u>: BA+GA (Accel) 25 to 75 ppm / Continuous treatment in vase solution to flowers cut at puffy bud stage.</p> <p><u>Purpose</u>: Senescence inhibitor – Can Accel increase vase life or reduce lower leaf yellowing</p> <p><u>Effect</u>: Accel at all rates delayed the onset of leaf yellowing by 12 days over control and also delayed flower senescence. Author suggests 50 ppm as the best rate.</p>   | (Emongor et al. 2004)        |
| <i>Lupinus hvardii</i><br>(Lupine)             | <p><u>Cytokinin</u>: BA+GA (Fascination) 6 to 96 ppm / Placed into vase solution</p> <p><u>Purpose</u>: Senescence inhibitor – Can Fascination delay senescence and increase vase life?</p> <p><u>Effect</u>: 6 to 12 ppm slightly delayed senescence while higher doses promoted it and caused phytotoxicity in some cultivars. GA alone worked better.</p>   | (MacKay et al. 2003)         |
| <i>Lycopodium cernuum</i><br>(Club moss fern)  | <p><u>Cytokinin</u>: BA 100 to 200 ppm / 10sec-1min Dip or spray applied to cut stems. Stems then packed and simulated shipped 2 to 12 days at various temperatures. Stems unpacked and vase life determined.</p> <p><u>Purpose</u>: Senescence inhibitor – Can BA increase vase life?</p> <p><u>Effect</u>: BA decreased vase life of leaves by 30%</p>   | (Paull and Chantrachit 2001) |
| <i>Narcissus pseudonarcissus</i><br>(Daffodil) | <p><u>Cytokinin</u>: BA <math>6.5 \times 10^{-4}</math>M (Verdan) (146 ppm), Kinetin <math>5 \times 10^{-4}</math>M (110 ppm) / Entire flower submerged for 5 sec or continuous stem dip</p> <p><u>Purpose</u>: Senescence inhibitor – Delay flower senescence</p> <p><u>Effect</u>: Verdan and Kinetin flower submergence delayed senescence by 1 day which was better than other PGRs trialed. Continuous dip was ineffective.</p>   | (Ballantyne 1963)            |

| Table A2 Continued                          |   |                                  |
|---|---|----------------------------------|
| Plant                                       | Notes   | Reference                        |
| <i>Narcissus pseudonarcissus</i> (Daffodil) | <p><u>Cytokinin</u>: BA (<math>5 \times 10^{-4}</math>M) (112 ppm) mixed with various combinations of 2,4-D (<math>10^{-5}</math>M to <math>10^{-3}</math>M) (2.21 to 221 ppm) / 5sec floral dips after cutting</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: By themselves, BA and 2,4-D slightly delayed senescence. Together, they were synergistic and had a large effect on fresh weight after 6days. The best combination was 112 ppm BA + 22.1 ppm 2,4-D.</p> | (Ballantyne 1965)                |
| <i>Narcissus pseudonarcissus</i> (Daffodil) | <p><u>Cytokinin</u>: BA + 2,4-D (<math>5 \times 10^{-4}</math>M + <math>10^{-4}</math>M) / Fresh cut flowers dipped in solution.</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: BA alone increase vase life by 1 day. BA+2,4-D increased it by 2 days. 2,4-D alone did nothing. BA alone or with 2,4-D reduced respiration rates for 6 days</p>   | (Ballantyne 1966)                |
| <i>Nephrolepis exaltata</i> (Boston Fern)   | <p><u>Cytokinin</u>: BA – rate or application method not listed</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: BA improved longevity of leaves.</p>   | (Skutnik and Rabiza-Swider 2005) |
| <i>Nerium oleander</i> (Oleander)           | <p><u>Cytokinin</u>: BA (FAL-457) 125 to 500 ppm, BA+GA (Fresco) 125 to 500 ppm / 4 foliar sprays at 2 week intervals following a hard pinch</p> <p><u>Purpose</u>: Branching agent – Propagation – Does BA improve cutting production on stock plants?</p> <p><u>Effect</u>: Fresco caused phytotoxicity and stretching. BA increased the number of cuttings but reduced rooting percentage.</p>   | (Whipker and Gibson 2007)        |
| <i>Phlox paniculata</i> (Tall garden phlox) | <p><u>Cytokinin</u>: CPPU 10 to 50 <math>\mu</math>M (2.47 to 12.35 ppm) / Continuous dip</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: Increased vase life by 5 days over control.</p>  | (MacKay et al. 2002)             |
| <i>Phlox paniculata</i> (Tall garden phlox) | <p><u>Cytokinin</u>: Thidiazuron 5 to 45 <math>\mu</math>M (1.1 to 9.9 ppm) / Continuous dip</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: Increased vase life by 5 days over control.</p>   | (MacKay et al. 2003)             |
| <i>Polianthes tuberosa</i> (Tuberose)       | <p><u>Cytokinin</u>: BA 25 to 100 ppm / Pulse or in vase solution</p> <p><u>Purpose</u>: Senescence inhibitor – Can BA increase flower life?</p> <p><u>Effect</u>: BA 25 to 50 ppm increased vase life over control (by 3d) but 75 to 100 ppm did not. BA also caused more florets to open. BA not as good as STS.</p>  | (Hutchinson et al. 2003)         |
| <i>Rosa</i> (Rose)                          | <p><u>Cytokinin</u>: Kinetin, BA 25 to 50 ppm / Single foliar spray of cut stems OR continuous dip</p> <p><u>Purpose</u>: Senescence inhibitor – increase vase life</p> <p><u>Effect</u>: Kinetin had no significant increase in vase life. BA 25 ppm spray with Tween increased vase life by 1.2 days which was better than BA with ethanol or BA continuous dip.</p>  | (del Rio et al. 1989)            |

| Table A2 Continued                                      |  |                                     |
|---|--|-------------------------------------|
| Plant   | Notes  | Reference                           |
| <i>Rosa</i><br>(Rose)                                   | <u>Cytokinin</u> : 2iP 10 <sup>-6</sup> M, or Zeatin 10 <sup>-5</sup> to 10 <sup>-7</sup> M / Continuous dips<br><u>Purpose</u> : Senescence inhibitor – increase vase life of 6 rose cultivars<br><u>Effect</u> : Zeatin worked better than Zeatin Riboside or 2iP on 6 cultivars and improved vase life by 1.6 to 3.9 days. Zeatin at 10 <sup>-7</sup> M worked roughly the same as 10 <sup>-6</sup> M and better than 10 <sup>-5</sup> M.   | (Lucaszewska et al. 1995)           |
| <i>Rosa</i><br>(Rose)                                   | <u>Cytokinin</u> : Zeatin, 2iP and their ribosides (10 <sup>-5</sup> to 10 <sup>-7</sup> M) / Vase solution<br><u>Purpose</u> : Senescence inhibitor – Can BA increase flower life?<br><u>Effect</u> : 2iP, Zeatin and their ribosides all increased vase life. 2iP & Zeatin 10 <sup>-7</sup> M were best. Zeatin 10 <sup>-5</sup> M had no effect.  | (Lucaszewska et al. 1994)           |
| <i>Rosa</i><br>(Rose)                                   | <u>Cytokinin</u> : BA 10 to 50 ppm / Continuous dip<br><u>Purpose</u> : Senescence inhibitor – increase vase life<br><u>Effect</u> : BA 10 ppm improved vase life by 2 days. BA 50 ppm was worse than water alone. BA + Preservative was better than water alone, but the same as preservative alone. No synergistic effect.   | (Lukaszewska 1986)                  |
| <i>Rosa</i><br>(Rose)                                   | <u>Cytokinin</u> : Zeatin, Zeatin Riboside, 2iP, 2iPA at 10 <sup>-7</sup> - 10 <sup>-5</sup> M (0.2 to 22 ppm) / Continuous dip<br><u>Purpose</u> : Senescence inhibitor – increase vase life<br><u>Effect</u> : Zeatin 10 <sup>-7</sup> M was best at increasing vase life by almost 3 days over control. 2iP was least effective   | (Lucaszewska et al. 1995)           |
| <i>Sandersonia aurantiaca</i><br>(Chinese lantern lily) | <u>Cytokinin</u> : BA 200 ppm / pre-plant bulb soak for 2hr<br><u>Purpose</u> : Flower enhancer – Can BA improve the cut flower?<br><u>Effect</u> : BA increased floret numbers per stem without affecting stem length and was the best of the PGRs trialed.   | (Davies et al. 1998)                |
| <i>Solidago canadensis</i><br>(Goldenrod)               | <u>Cytokinin</u> : BA (TOG-L-101) 10 to 90 µM (2.25 to 20 ppm), BA+STS (200 µM) / BA applied as pulse or Foliar spray, STS as 19h pulse treatment<br><u>Purpose</u> : Senescence inhibitor – Can BA reduce leaf yellowing and increase flower life? Is BA an effective replacement for STS?<br><u>Effect</u> : BA 10 ppm formulated as product TOG-L-101 decreased leaf yellowing and increased flower vase life as much as STS. BA + STS was slightly better than BA alone or STS alone. BA pulse similar to BA spray. Author states that BA can replace STS for this crop. | (Philosoph-Hadas et al. 1996)       |
| <i>Solidago x luteus</i><br>(Goldenrod)                 | <u>Cytokinin</u> : BA 4*10 <sup>-4</sup> M (), BA 4*10 <sup>-4</sup> M + GA3 10 <sup>-4</sup> M, KI 4*10 <sup>-4</sup> M ()<br><u>Purpose</u> : Does cytokinin affect floral development?<br><u>Effect</u> : BA+GA decreased time to flower but caused floral deformations. KI decreased time to flower  | (Florez-Roncancio and Periera 1998) |
| <i>Strelitzia</i><br>(Bird-of-paradise)                 | <u>Cytokinin</u> : BA / Stem dip<br><u>Purpose</u> : Senescence inhibitor – Delay flower senescence<br><u>Effect</u> : No effect   | (Jaroenkit and Paull 2003)          |

| Table A2 Continued                              |  |                              |
|---|--|------------------------------|
| Plant   | Notes  | Reference                    |
| <i>Strelitzia reginae</i><br>(Bird-of-paradise) | <u>Cytokinin</u> : BA 100 to 200 ppm / 10sec-1min Dip or spray applied to cut stems. Stems then packed and simulated shipped 2 to 12 days at various temperatures. Stems unpacked and vase life determined.<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life?<br><u>Effect</u> : No effect   | (Paull and Chantrachit 2001) |
| <i>Themeda australis</i><br>(Kangaroo grass)    | <u>Cytokinin</u> : Kinetin $10^{-4}$ M (21.5 ppm) + Ga <sub>3</sub> 100 ppm / Application method not described. Presume it is a liquid solution added to the paper disc that the seeds were germinated on<br><u>Purpose</u> : Germination Promoter / Dormancy release – Does Kinetin+GA increase germination percentage?<br><u>Effect</u> : Kinetin+GA doubled the germination %. Results were equivalent to GA alone. | (Hagon 1976)                 |
| <i>Tulipa</i><br>(Tulip)                        | <u>Cytokinin</u> : CPPU / rates and application method unknown<br><u>Purpose</u> : Growth enhancer<br><u>Effect</u> : CPPU caused thicker stems due to enhanced cell division  | (Arima et al. 1995)          |
| <i>Tulipa</i><br>(Tulip)                        | <u>Cytokinin</u> : Thidiazuron 10 to 100 $\mu$ M / 24hr pulse after cutting<br><u>Purpose</u> : Senescence inhibitor<br><u>Effect</u> : Thidiazuron 100 $\mu$ M delayed leaf yellowing and stem elongation in the cut flowers but did not increase vase life of the flower.  | (Ferrante et al. 2003)       |
| <i>Viola x williamsii</i><br>(Violet)           | <u>Cytokinin</u> : BA $10^{-3}$ M / Flower + stem pulse dip for 2 min<br><u>Purpose</u> : Senescence inhibitor – increase vase life<br><u>Effect</u> : BA increased vase life by 4d.   | (Heide and Oydvin 1969)      |
| <i>Viscum album</i><br>(Mistletoe)              | <u>Cytokinin</u> : BA 100 ppm / Foliar spray<br><u>Purpose</u> : Senescence inhibitor – Can BA control berry or leaf abscission?<br><u>Effect</u> : BA is effective at delaying abscission   | (Smith 1963a)                |
| <i>Viscum album</i><br>(Mistletoe)              | <u>Cytokinin</u> : BA 0.25 oz in 19.5gal (94 ppm) / Dip berries into solution<br><u>Purpose</u> : Senescence inhibitor – Can BA increase storage life?<br><u>Effect</u> : BA delayed senescence of leaves and berries  | (Smith 1963b)                |
| <i>Zantedeschia aethiopica</i><br>(Calla Lily)  | <u>Cytokinin</u> : BA 0.1 mM (22.5 ppm) 24hr Pulse or 1 mM (225 ppm) Leaf Dip for several seconds<br><u>Purpose</u> : Senescence inhibitor – increase vase life<br><u>Effect</u> : BA pulse increased vase life by 2d. BA was not as good as GA. BA dip decreased vase life by 12d.  | (Skutnik et al. 2001)        |
| <i>Zingiber spectabilis</i><br>(Beehive ginger) | <u>Cytokinin</u> : BA 100 to 200 ppm / 10sec-1min Dip or spray applied to cut stems. Stems then packed and simulated shipped 2 to 12 days at various temperatures. Stems unpacked and vase life determined.<br><u>Purpose</u> : Senescence inhibitor – Can BA increase vase life?<br><u>Effect</u> : No effect (a slight but insignificant drop in vase life)  | (Paull and Chantrachit 2001) |

### A1.3 Effects of Cytokinins on Woody Ornamental Crops

Table A3. Research efforts for exogenous cytokinins on woody plants.

| Plant  | Notes   | Reference               |
|--|---|-------------------------|
| <i>Abies balsamea</i><br>(Balsam fir<br>Christmas trees) | <u>Cytokinin</u> : BA 600 ppm / Foliar spray 1 to 2 times per week for 2 to 8 weeks at various times during shoot elongation.<br><u>Purpose</u> : Branching agent – Can BA induce branching and replace shearing?<br><u>Effect</u> : BA inhibited shoot elongation, increased lateral bud formation, induced lammas growth, and caused some phytotoxicity in current year needles. After overwintering the BA induced buds elongated resulting in a denser crown. BA worked best when nutrient status of the plant was ideal  | (Little 1984)           |
| <i>Abies balsamea</i><br>(Balsam fir)                    | <u>Cytokinin</u> : BA 125 to 1000 ppm / Branches dipped into solution 1 to 3 times at weekly intervals at various times during the summer.<br><u>Purpose</u> : Branching agent – Does BA increase branching?<br><u>Effect</u> : BA 1000 ppm applied once when branches were at 70% of final length was best at increasing lateral bud number, and branch diameter and decreasing lateral whorl and shoot elongation. Some phytotoxicity was present but disappeared by next season. Multiple applications resulted in severe phytotoxicity as did applications in new growth. | (Little 1985)           |
| <i>Abies fraseri</i><br>(Fraser fir)                     | <u>Cytokinin</u> : BA 50 to 100 ppm / Foliar sprays every two weeks for 20 weeks onto seedlings starting 18WAP<br><u>Purpose</u> : Growth enhancer – Can BA increase seedling growth?<br><u>Effect</u> : 100 ppm increased height by 19%, shoot weight by 57% but decreased root weight by 27% and caused purple needles. BA rates from 125 to 1000 ppm reduced internode and needle elongation, caused drooping leaders, and shriveled needles.  | (Bryan and Seiler 1991) |
| <i>Abies fraseri</i><br>(Fraser fir)                     | <u>Cytokinin</u> : BA 444 $\mu$ M (100 ppm) / Foliar spray monthly starting 5 weeks after germination.<br><u>Purpose</u> : Growth enhancer – Can BA increase seedling growth in artificial growth scenarios?<br><u>Effect</u> : BA increased growth in un-chilled plants, but they were still not as tall as chilled plants. They did however have larger dry weights and root color diameters, but fewer lateral branches and buds.  | (Cazell and Siler 1992) |
| <i>Acanthopanax sieboldianus</i><br>(5-leaf Aralia)      | <u>Cytokinin</u> : BA (1 to 100 ppm) / Continuous dip of dormant cut stems<br><u>Purpose</u> : Propagation – Can CKs increase the number of bud breaks and softwood stem growth from dormant cut stems<br><u>Effect</u> : BA 100 ppm delayed bud break but increased the % of buds that broke. GA worked better though. BA increased shoot length too.  | (Yang and Read 1997)    |

Table A3 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>              |
|--|---|-------------------------------|
| <i>Aralia elata</i><br>(Japanese angelica tree)              | <u>Cytokinin</u> : BA 50 to 200 ppm / 1 to 3 Sprays onto cuttings, stumps, and trunks of trees<br><u>Purpose</u> : Branching agent – Propagation - Can BA cause buds on stem cuttings, stumps, or trunks to sprout to increase propagation material?<br><u>Effect</u> : 50 ppm was best at causing all plant tissues to sprout. Only 1 spray was necessary. The second and third sprays had no additional effect.   | (Sugiura and Azuma 2005)      |
| <i>Astilbe taquetii</i>                                      | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Significant phytotoxicity  | (Lieth and Dodge 2004)        |
| <i>Berberis thunbergii</i><br>(Japanese barberry)            | <u>Cytokinin</u> : Kinetin 100 to 500 ppm with or without GA<br><u>Purpose</u> : Growth inhibitor – Can BA affect growth habit?<br><u>Effect</u> : No effect  | (McCarthy and Bünemann 1981b) |
| <i>Buxus sempervirens</i> ,<br><i>B. sinica</i><br>(Boxwood) | <u>Cytokinin</u> : BA+GA (Promalin) 1500 ppm / Foliar spray applied once or twice with or without pruning at various stages of growth.<br><u>Purpose</u> : Branching agent – Remove Dormancy – Can Promalin stimulate branching and growth during summer dormancy?<br><u>Effect</u> : Promalin + Pruning applied 10 weeks after the end of spring growth was best at increasing lateral shoots. Defoliation helped even more but resulted in unmarketable plants. | (Musselwhite et al. 2004)     |
| <i>Camellia japonica</i> ,<br><i>C. reticulata</i>           | <u>Cytokinin</u> : Kinetin 1 ppm + NAA 3 ppm pH balanced to pH 7.6 / Scions dipped into solution prior to grafting<br><u>Purpose</u> : Propagation / Can Kinetin+NAA improve grafting success?<br><u>Effect</u> : Treated grafts healed almost twice as fast as untreated grafts.   | (Stanley 1976)                |
| <i>Camellia sinensis</i><br>(Tea)                            | <u>Cytokinin</u> : Kinetin 20 to 80 ppm / Applied to shoots. Method and timing not listed. (Abstract only)<br><u>Purpose</u> : Dormancy Release – Does Kinetin release tea buds from dormancy?<br><u>Effect</u> : Kinetin 80 ppm released shoots from dormancy but was inhibited by auxin.  | (Kulasegaram 1969)            |
| <i>Camellia x williamsii</i>                                 | <u>Cytokinin</u> : BA 10 to 100 ppm / Foliar spray every 3 days from 2 to 32 times<br><u>Purpose</u> : Branching agent – Can BA substitute for a hand pinch in nursery grown crops<br><u>Effect</u> : No effect on branching or flowering at these rates  | (Richards and Wilkinson 1984) |

Table A3 Continued

| <b>Plant</b>   | <b>Notes</b>  | <b>Reference</b>               |
|--|---|--------------------------------|
| <i>Carica papaya</i><br>(Papaya)                                       | <u>Cytokinin</u> : BA+GA 500 ppm each / 3 applications at one week intervals to 1yr old plants. Applied via spraying, lanolin paste, injection, or a combination of all three<br><u>Purpose</u> : Branching agent – Can cytokinins increasing branching?<br><u>Effect</u> : Foliar sprays doubled branching over controls followed by injection, then lanolin. The combination reduced branching.     | (Giampan et al. 2005)          |
| <i>Carica papaya</i><br>(Papaya)                                       | <u>Cytokinin</u> : Kinetin 65 to 130 ppm, BA 250 to 500 ppm / Monthly foliar spray applications<br><u>Purpose</u> : Branching agent – Can cytokinins improve branching?<br><u>Effect</u> : Kinetin increased branching  | (Morales-Payan and Stall 2003) |
| <i>Castanea dentata</i><br>(Chestnut)                                  | <u>Cytokinin</u> : BA (1 to 100 ppm) / Continuous dip of dormant cut stems<br><u>Purpose</u> : Propagation – Can CKs increase the number of bud breaks and softwood stem growth from dormant cut stems<br><u>Effect</u> : BA 100 ppm delayed bud break but increased the % of buds that broke. GA worked better though.   | (Yang and Read 1997)           |
| <i>Chamaecyparis lawsoniana</i><br>(Port Orford cedar Christmas trees) | <u>Cytokinin</u> : BA 500 to 1000 ppm / Foliar spray applied 4 times at 2 week intervals<br><u>Purpose</u> : Growth inhibition – Branching agent – Can BA be used in tabletop Christmas tree production?<br><u>Effect</u> : BA at all doses caused severe phytotoxicity and did not increase lateral bud formation.   | (Duck et al. 2004)             |
| <i>Chrysobalanus icaco</i><br>(Coco plum)                              | <u>Cytokinin</u> : 2iP, BA, BA+GA (Promalin) / Single Foliar sprays onto unpinched plants.<br><u>Purpose</u> : Branching agent – Can cytokinins replace pinching as a method for increasing branching?<br><u>Effect</u> : BA 400 ppm, 2iP 400 ppm, Promalin 450 ppm all promoted branching better than pinching. Promalin was the best.   | (Rudniki and Rejman 1982)      |
| <i>Cornus alba</i><br>(Siberian dogwood)                               | <u>Cytokinin</u> : Kinetin (270 ppm) with or without GA <sub>3</sub> 90 ppm /<br><u>Purpose</u> : Branching agent – Can Kinetin increase branching?<br><u>Effect</u> : Kinetin+GA increased branching more than either chemical alone.  | (Loach and N. 1975)            |
| <i>Cotoneaster dammeri</i><br>(Bearberry cotoneaster)                  | <u>Cytokinin</u> : BA + Kinetin (Early Harvest PGR – also contains GA and auxin) 1.5 to 3.0ml in 1125ml water . (1.17 ppm BA + 1.17 ppm Kinetin) / 45ml soil drenches every two weeks from June to September in Georgia<br><u>Purpose</u> : Stress tolerance – Can a Kinetin based biostimulant reduce summer heat stress and keep crop quality high?<br><u>Effect</u> : No effect on growth indices  | (Ruter 2000)                   |
| <i>Cotoneaster salicifolius</i><br>(Willowleaf cotoneaster)            | <u>Cytokinin</u> : BA + Kinetin (Early Harvest PGR – also contains GA and auxin) 1.5 to 3.0 ml in 1125 ml water. (1.17 ppm BA + 1.17 ppm Kinetin) / 45ml soil drenches every two weeks from June to September in Georgia<br><u>Purpose</u> : Stress tolerance – Can a Kinetin based biostimulant reduce summer heat stress and keep crop quality high?<br><u>Effect</u> : No effect on growth indices | (Ruter 2000)                   |

Table A3 Continued

| <b>Plant</b>                                     | <b>Notes</b>   | <b>Reference</b>              |
|--|--|-------------------------------|
| <i>Elaeagnus angustifolia</i><br>(Tea Olive)     | <u>Cytokinin</u> : Kinetin 50 ppm / Applied to seeds<br><u>Purpose</u> : Germination promoter?<br><u>Effect</u> : Kinetin was effective at inducing germination on seeds with the endocarp removed but not when it was present.  | (Hamilton and Carpenter 1976) |
| <i>Forsythia x intermedia</i>                    | <u>Cytokinin</u> : BA (200 ppm), Promalin (1000 ppm) / Single foliar spray or 3 foliar sprays onto 6 to 10cm rooted cuttings<br><u>Purpose</u> : Branching agent – Can BA be used as a PGR in nursery crops?<br><u>Effect</u> : BA had no effect at this rate. Promalin increased width and promoted a more horizontal growth habit. Plants sprayed 3x had a greater response.                                     | (Grzesik and Rudnicki 1985)   |
| <i>Forsythia x intermedia</i>                    | <u>Cytokinin</u> : BA (200 ppm), Promalin (1000 ppm) / Single foliar spray or 3 foliar sprays onto 6 to 10cm rooted cuttings<br><u>Purpose</u> : Branching agent – Can BA be used as a PGR in nursery crops?<br><u>Effect</u> : BA and Promalin stimulated branching by 25% but this was not as good as CCC (35%). Promalin sprayed once promoted blooming by 4d. Promalin sprayed 3 times delayed blooming by 4d. | (Grzesik and Rudnicki 1985)   |
| <i>Hibiscus moscheutos</i><br>(Rose mallow)      | <u>Cytokinin</u> : BA+GA (Fascination) 125 to 500 ppm / 2 foliar spray applications at day 0 and day 21<br><u>Purpose</u> : Branching agent<br><u>Effect</u> : Did not increase branching or cause phytotoxicity   | (Lieth and Dodge 2004)        |
| <i>Hydrangea</i>                                 | <u>Cytokinin</u> : BA 1000 ppm (Verdan) – Single foliar spray when sepals started to develop.<br><u>Purpose</u> : Senescence inhibitor - Can BA decrease senescence?<br><u>Effect</u> : No effect on senescence but flowering was delayed.   | (Shanks and Link 1964)        |
| <i>Ilex</i><br>(Burfordii – Dwarf Burford Holly) | <u>Cytokinin</u> : PBA (SD8339) 200 to 1200 ppm / Two foliar sprays to sheared plants.<br><u>Purpose</u> : Branching agent – Will PBA increase branching?<br><u>Effect</u> : PBA had inconsistent results. All rates except 800 ppm increased branching.   | (Sanderson and Martin 1974)   |
| <i>Ilex</i><br>(Burfordii – Dwarf Burford Holly) | <u>Cytokinin</u> : PBA (Accel) 200 to 1200 ppm / single foliar spray 1 week prior to pinching.<br><u>Purpose</u> : Branching agent – Will PBA increase branching?<br><u>Effect</u> : PBA was not effective at increasing branching. 1200 ppm PBA reduced branching   | (Sanderson and Martin 1974)   |
| <i>Ilex</i><br>(Helleri & Rotundifolia)          | <u>Cytokinin</u> : BA 200 to 400 ppm / Foliar spray<br><u>Purpose</u> : Branching agent – Can BA replace the need to pinch in order to produce highly branched plants?<br><u>Effect</u> : BA 400 ppm was best at increasing branching by 30 to 40%. Author does not state if this is good enough to replace pinching.  | (Wright 1975)                 |

Table A3 Continued

| <b>Plant</b>                                  | <b>Notes</b>  | <b>Reference</b>            |
|---|---|-----------------------------|
| <i>Ilex crenata</i><br>(Japanese holly)       | <u>Cytokinin</u> : BA 600 ppm with or without GA <sub>3</sub> 400ppm / Two foliar sprays – one week apart starting 11 weeks after cuttings stuck.<br><u>Purpose</u> : Branching agent – Can BA stimulate a fall flush of growth in summer rooted cuttings?<br><u>Effect</u> : No results were described about BA affecting summer rooted plants. BA slightly increased branching in winter rooted cultivars and decreased their height. | (Gilliam and Wright 1977)   |
| <i>Ilex crenata</i><br>(Japanese holly)       | <u>Cytokinin</u> : BA 125 to 1000 ppm / Single foliar spray application at various times<br><u>Purpose</u> : Branching agent – Can BA reduce the need for pruning?<br><u>Effect</u> : BA 1000 ppm greatly increased bud break over pruning  | (Keever and Foster 1990)    |
| <i>Ilex crenata</i><br>(Japanese holly)       | <u>Cytokinin</u> : PBA (SD8339) 200 to 1200 ppm / Two foliar sprays to sheared plants.<br><u>Purpose</u> : Branching agent – Will PBA increase branching?<br><u>Effect</u> : PBA up to 800 ppm increased branching. 1200 ppm decreased branching and caused very short shoots.  | (Sanderson and Martin 1974) |
| <i>Ilex crenata</i><br>(Japanese holly)       | <u>Cytokinin</u> : BA (100 to 500 ppm) / 2 Foliar sprays in summer<br><u>Purpose</u> : Branching agent – Can BA be used instead of shearing in Ilex production?<br><u>Effect</u> : BA 500 ppm greatly increased the number of shoots formed and also reduced shoot length and leaf size. The experiment did not compare the results to pruned plants  | (Wright 1976)               |
| <i>Ilex glabra</i><br>(Inkberry holly)        | <u>Cytokinin</u> : BA 1750 to 3500 ppm / Three Foliar sprays one week apart at various times during plant development.<br><u>Purpose</u> : Branching agent – What is the best time to apply BA?<br><u>Effect</u> : The best time to apply BA is when the leaves start to harden off (DS3) as applications during DS1 or DS2 cause a lot of phytotoxicity.   | (Oates et al. 2005b)        |
| <i>Ilex opaca</i><br>(American holly)         | <u>Cytokinin</u> : BA 10 to 1000 ppm / Applied to both male and female cultivars.<br><u>Purpose</u> : Flower enhancer – Can exogenous BA affect the sex of flowers that form?<br><u>Effect</u> : Inconsistent effects.  | (Milbocker 1967)            |
| <i>Ilex paraguariensis</i><br>(Yerba mate)    | <u>Cytokinin</u> : BA 2.2 to 13.2 mM (495 to 2973 ppm) / Single foliar spray at the beginning of summer flush<br><u>Purpose</u> : Branching agent – Can CKs reduce the need for pruning?<br><u>Effect</u> : BA 8.8 mM was 8x better than all other treatments including pruning at stimulating lateral branching.   | (Sansberro et al. 2006)     |
| <i>Ilex verticillata</i><br>(Deciduous Holly) | <u>Cytokinin</u> : Thidiazuron (Dropp) 100 to 800 ppm / Single foliar spray<br><u>Purpose</u> : Defoliant – Does Thidiazuron cause defoliation of leaves without affecting berries<br><u>Effect</u> : Thidiazuron was effective but results not published. Harvade treatments worked better.  | (Banko and Stefani 1999)    |

Table A3 Continued

| <b>Plant</b>                                     | <b>Notes</b>   | <b>Reference</b>              |
|--|--|-------------------------------|
| <i>Ilex vomitoria</i><br>(Yaupon Holly)          | <u>Cytokinin</u> : BA 125 to 1000 ppm / Single foliar spray application at various times<br><u>Purpose</u> : Branching agent – Can BA reduce the need for pruning?<br><u>Effect</u> : BA 1000 ppm greatly increased bud break over pruning   | (Keever and Foster 1990)      |
| <i>Lonicera xylosteum</i><br>(Dwarf honeysuckle) | <u>Cytokinin</u> : Kinetin 100 to 500 ppm with or without GA<br><u>Purpose</u> : Growth inhibitor – Can BA affect growth habit?<br><u>Effect</u> : No effect   | (McCarthy and Bünemann 1981b) |
| <i>Nandina domestica</i><br>(Heavenly bamboo)    | <u>Cytokinin</u> : Thidiazuron (Dropp 50WP) 2500 to 4000 ppm / Single foliar spray OR substrate drench<br><u>Purpose</u> : Branching agent – Height control – How does Thidiazuron affect shoot formation, plant size, and phytotoxicity?<br><u>Effect</u> : Foliar sprays of Thidiazuron 4000 ppm increased branching. Substrate drenches of 2500 ppm caused severe phytotoxicity   | (Keever and Findley 2002)     |
| <i>Nandina domestica</i><br>(Heavenly bamboo)    | <u>Cytokinin</u> : BA 1000 to 2500 ppm or BA+GA (Promalin) 2000 to 5000 / Single foliar spray application at various times<br><u>Purpose</u> : Branching agent – Can BA reduce the need for pruning?<br><u>Effect</u> : BA 2500 ppm or Promalin 5000 ppm in January were equivalent to pruning, but BA 2500 in April was the best treatment to induce lateral branching and increased the number of cuttings available for propagation.        | (Keever and Foster 1990)      |
| <i>Nandina domestica</i><br>(Heavenly bamboo)    | <u>Cytokinin</u> : BA 1250 to 5000 ppm / 1 to 5 weekly foliar sprays<br><u>Purpose</u> : Branching agent – Can BA increase branching?<br><u>Effect</u> : 5000 ppm applied 5 times greatly increased shoot count. The effects of BA lasted about 6 weeks. BA dose had no effect if there were fewer than 3 applications. Phytotoxicity was initially severe but disappeared in 90d.   | (Keever and Morrison 2003)    |
| <i>Nandina domestica</i><br>(Heavenly bamboo)    | <u>Cytokinin</u> : BA 2500 to 5000 ppm / Two Foliar sprays one week apart at various times during plant development.<br><u>Purpose</u> : Branching agent – What is the best time to apply BA?<br><u>Effect</u> : Nandina showed no phytotoxicity at any development stage or BA rate.  | (Oates et al. 2005b)          |
| <i>Photinia x fraseri</i><br>(Fraser's Photinia) | <u>Cytokinin</u> : BA 500 to 2500 ppm or BA+GA (Promalin) 2000 to 5000 ppm / Single foliar spray application at various times<br><u>Purpose</u> : Branching agent – Can BA reduce the need for pruning?<br><u>Effect</u> : BA 1000 ppm in March greatly increased bud break over pruning. BA in January was better than pruning in January but BA 2500 ppm or Promalin 5000 ppm in April vastly increased lateral bud break over pruned plants | (Keever and Foster 1990)      |

Table A3 Continued

| <b>Plant</b>  | <b>Notes</b>  | <b>Reference</b>              |
|---|---|-------------------------------|
| <i>Photinia x fraseri</i> (Fraser's Photinia)                               | <u>Cytokinin</u> : BA 750 to 1000 ppm (ProShear), BA+GA 250 ppm (Promalin) and other BA/GA mixes / Single Foliar spray in May.<br><u>Purpose</u> : Branching agent – Does BA affect plant size and lateral branching?<br><u>Effect</u> : ProShear reduced height, but Promalin increased it. Neither affected branching   | (Owings and Newman 1993)      |
| <i>Photinia x fraseri</i> (Fraser's Photinia)                               | <u>Cytokinin</u> : PBA (500 to 1000 ppm) with or without Hand Pinch or Off-Shoot-O 4.2% / 3 foliar spray applications of PBA<br><u>Purpose</u> : Branching agent – Will PBA increase branching?<br><u>Effect</u> : PBA 1000 ppm + Off-Shoot-O increased branching by 6x over control. Hand Pinch plus PBA 1000 ppm was about 3.5x control. PBA alone was a little better than hand pinch. | (Ryan 1974)                   |
| <i>Picea abies</i> (Norway spruce)  | <u>Cytokinin</u> : Kinetin 100 to 500 ppm with or without GA<br><u>Purpose</u> : Growth inhibitor – Can BA affect growth habit?<br><u>Effect</u> : Kinetin retarded shoot growth and led to a reduction in shoot number   | (McCarthy and Bünemann 1981a) |
| <i>Picea glauca</i> var <i>densa</i> , (Black Hills spruce Christmas trees) | <u>Cytokinin</u> : BA 500 to 1000 ppm / Foliar spray applied 4 times at 2 week intervals<br><u>Purpose</u> : Growth inhibition – Branching agent – Can BA be used in tabletop Christmas tree production?<br><u>Effect</u> : BA at all doses caused severe phytotoxicity and deformities but it also increased lateral bud formation.  | (Duck et al. 2004)            |
| <i>Picea glehnii</i> (Sakhalin spruce)                                      | <u>Cytokinin</u> : BA 0.01 to 10 ppm<br><u>Purpose</u> : Propagation - Can BA promote seed germination?<br><u>Effect</u> : BA 1 ppm and 10 ppm strongly inhibited germination which could be partially de-inhibited with GA 50 ppm or ethrel 100 ppm  | (Shibakusa 1980)              |
| <i>Picea omorika</i> , (Serbian spruce Christmas trees)                     | <u>Cytokinin</u> : BA 500 to 1000 ppm / Foliar spray applied 4 times at 2 week intervals<br><u>Purpose</u> : Growth inhibition – Branching agent – Can BA be used in tabletop Christmas tree production?<br><u>Effect</u> : BA 500 ppm caused some phytotoxicity that disappeared later that year but it also increased lateral bud formation.  | (Duck et al. 2004)            |
| <i>Picea pungens</i> (Colorado Blue spruce Christmas trees)                 | <u>Cytokinin</u> : BA 500 to 1000 ppm / Foliar spray applied 4 times at 2 week intervals<br><u>Purpose</u> : Growth inhibition – Branching agent – Can BA be used in tabletop Christmas tree production?<br><u>Effect</u> : BA at all doses caused severe phytotoxicity and did not increase lateral bud formation.   | (Duck et al. 2004)            |
| <i>Picea pungens</i> (Colorado Blue spruce Christmas trees)                 | <u>Cytokinin</u> : BA 1000 ppm / Whole tree single foliar spray application 6 weeks after bud break<br><u>Purpose</u> : Branching agent – Does BA increase branching?<br><u>Effect</u> : No effect on lateral bud promotion. Some lammas shoots formed.   | (Mazzola and Costante 1987)   |

Table A3 Continued

| <b>Plant</b>  | <b>Notes</b>   | <b>Reference</b>             |
|---|--|------------------------------|
| <i>Picea pungens</i><br>(Colorado Blue spruce)      | <u>Cytokinin</u> : BA 0.01 to 1.0 mM (2.25 to 225 ppm) / scions dipped prior to grafting.<br><u>Purpose</u> : Propagation – Can BA improve graft success?<br><u>Effect</u> : BA at 0.1 mM (22.5 ppm) increased graft success by 13% as did NAA.  | (Beeson and Proebsting 1989) |
| <i>Picea pungens</i><br>(Colorado Blue spruce)      | <u>Cytokinin</u> : BA 100 to 1000 µM (22.5 to 225 ppm) / Single foliar spray at one of 5 developmental stages<br><u>Purpose</u> : Branching agent – Does BA promote branching?<br><u>Effect</u> : BA at 1000 mM is best applied at bud break or on pruned summer hardwood to stimulate new bud formation. The new buds do not grow into branches though. This rate also causes red coloration on the stems.  | (Mulgrew and Williams 1985)  |
| <i>Pinus banksiana</i><br>(Jack Pine)               | <u>Cytokinin</u> : BA 50 to 400 ppm / Single Foliar spray 90DAS<br><u>Purpose</u> : Growth inhibitor – Can BA improve the production of windbreak trees (shorter, thicker, with good roots)?<br><u>Effect</u> : BA 400 ppm reduced height and improved height/caliper ratio the most – even more than Uniconazole and paclobutrazol, but the plants had very poor root growth and were deformed. BA was rejected as appropriate for this use.  | (Schnurr et al. 1996)        |
| <i>Pinus densiflora</i><br>(Japanese Red Pine)      | <u>Cytokinin</u> : BA 2000 ppm / Lanolin paste applied to either the terminal bud or applied to a girdled branch. Paste applied at various times in cone bud differentiation in late summer and fall.<br><u>Purpose</u> : Flower enhancer – Yield enhancer – Can BA cause more female strobili to form and thus cause plants in seed orchards to produce more seed?<br><u>Effect</u> : Both terminal and girdling treatments were highly effective in increasing femaleness. Seed yield was decreased and the seed had a slightly lower germination rate than controls. Timing was important and the best time was in mid-september. | (Wakushima 2004)             |
| <i>Pinus mugo</i> var. <i>mughus</i><br>(Mugo Pine) | <u>Cytokinin</u> : BA 225 to 900 ppm / 6 Foliar sprays at 5 day intervals starting in May as new flush of growth was starting AND again (6 times every 5d) after the cold treatment ended.<br><u>Purpose</u> : Branching agent – Propagation - Can BA increase fascicular bud development for increased cuttings?<br><u>Effect</u> : BA 450 ppm applied 6 times greatly increased bud development and resulted in dense bushy plants the following year.   | (Stiff and Boe 1985)         |
| <i>Pinus nigra</i><br>(Austrian Pine)               | <u>Cytokinin</u> : BA 0.2 – 0.6 g/l (2000 to 6000 ppm) / 1 to 2 Foliar sprays 30 to 90 days after sowing seed<br><u>Purpose</u> : Branching agent – Growth enhancer – Can BA increase branching and growth rate of seedling pines?<br><u>Effect</u> : BA at any combination reduced height and branching.  | (Boe 1990)                   |

Table A3 Continued

| <b>Plant</b>                               | <b>Notes</b>   | <b>Reference</b>            |
|--|--|-----------------------------|
| <i>Pinus palustris</i><br>(Long leaf pine) | <p><u>Cytokinin</u>: BA 2000 to 5000 ppm, PBA, Kinetin, 6-CP, Cytex (5%-10% solutions) / 0.1ml applied to the terminal bud biweekly starting in May for 7 months</p> <p><u>Purpose</u>: Growth enhancer – Can cytokinins stimulate long leaf pine to grow out of the grass stage faster?</p> <p><u>Effect</u>: BA was very phytotoxic. BA, PBA, Kinetin and 6-CP caused too many buds to form. Cytex, Cytex + GA, BA+GA all promoted height growth. The best was Cytex 5% + 1000 ppm GA3 + 1000 ppm DPX 3778 + 0.05% Aromax C/12 in 3 biweekly sprays during early summer.</p>   | (Hare 1984)}                |
| <i>Pinus ponderosa</i><br>(Ponderosa pine) | <p><u>Cytokinin</u>: BA 10 to 1000 ppm</p> <p><u>Purpose</u>: Branching agent – Plant propagation – Can BA increase production of dwarf shoots for use in propagation?</p> <p><u>Effect</u>: Spring applications more effective than fall application. BA 1000 ppm along with terminal bud removal resulted in a large increase in fascicular buds formed.</p>   | (Cohen and Shanks 1975)     |
| <i>Pinus strobus</i><br>(White Pine)       | <p><u>Cytokinin</u>: BA 750 ppm / Single foliar spray on the terminal leader only in June along with various nitrogen rates.</p> <p><u>Purpose</u>: Branching agent – What level of nutrition is optimal in plants induced to branch with BA?</p> <p><u>Effect</u>: N status influenced BA induced branching. 300 ppm is considered ideal.</p>   | (Hinesley and Wright 1988)  |
| <i>Pinus sylvestris</i><br>(Scots pine)    | <p><u>Cytokinin</u>: BA 0.2 – 0.6 g/l (2000 to 6000 ppm) / 1 to 2 Foliar sprays 30 to 90 days after sowing seed</p> <p><u>Purpose</u>: Branching agent – Growth enhancer – Can BA increase branching and growth rate of seedling pines?</p> <p><u>Effect</u>: BA 2000 ppm 90DAS sprayed one time increased branching but plants were lightly shorter</p>   | (Boe 1990)                  |
| <i>Pinus sylvestris</i><br>(Scots pine)    | <p><u>Cytokinin</u>: BA 200 ppm, BA+TIBA (200+50 ppm), BA+Alar (200+500 ppm), BA+TIBA+Alar (200+50+500 ppm) / Foliar sprays applied to stems every 4 to 5 days for 30days with 100ml solutions under various lighting and temperature regimes.</p> <p><u>Purpose</u>: Branching agent – Propagation – Can BA increase the formation of fascicular branches that can then be used as propagation material?</p> <p><u>Effect</u>: BA mixed with other PGRs greatly increased fascicular branch development. The best was BA+TIBA+Alar resulted in 2.5x more shoots. BA also partially reduced the inhibiting effect of GA on fascicular branching. The author provides a method for rooting these shoots with a high % take.</p> | (Whitehill and Schwab 1975) |

Table A3 Continued

| <b>Plant</b>  | <b>Notes</b>   | <b>Reference</b>          |
|---|--|---------------------------|
| <i>Pinus thunbergii</i><br>(Japanese Black Pine)    | <p><u>Cytokinin</u>: BA 2000 ppm / Lanolin paste applied to either the terminal bud or applied to a girdled branch. Paste applied at various times in conebud differentiation in late summer and fall.</p> <p><u>Purpose</u>: Flower enhancer – Yield enhancer – Can BA cause more female strobili to form and thus cause plants in seed orchards to produce more seed?</p> <p><u>Effect</u>: Both terminal and girdling treatments were highly effective in increasing femaleness. Seed yield was greatly increased and the seed had a 20% lower germination rate than controls that the difference in yield more than makes up for the drop in germination. Timing was important and the best time was in mid-september.</p> | (Wakushima 2004)          |
| <i>Pinus thunbergii</i><br>(Japanese Black Pine)    | <p><u>Cytokinin</u>: 9-BA 0.1% / Vasoline paste applied to cut roots</p> <p><u>Purpose</u>: Branching agent – Does 9-BA stimulate root branching?</p> <p><u>Effect</u>: 9-BA greatly increased the number of new roots growing from the cut points.</p>  | (Yamaji and Tomioka 1980) |
| <i>Pittosporum tobira</i><br>(Japanese pittosporum) | <p><u>Cytokinin</u>: 2iP, BA, BA+GA (Promalin) / Single Foliar sprays onto unpinched plants.</p> <p><u>Purpose</u>: Branching agent – Can cytokinins replace pinching as a method for increasing branching?</p> <p><u>Effect</u>: BA 200 ppm, 2iP 100 ppm, Promalin 1800 ppm all promoted branching but not as well as pinching. Pinching was only slightly better.</p>  | (Rudniki and Rejman 1982) |
| <i>Plumeria</i><br>(Frangipani)                     | <p><u>Cytokinin</u>: PBA (Accel) 250 to 1000 ppm / 2ml solutions placed into balloon placed over cut branch.</p> <p><u>Purpose</u>: Branching agent – Can PBA increase branching in Plumeria trees to reduce the need to prune?</p> <p><u>Effect</u>: PBA 100 ppm was best at increasing branching.</p>  | (Kwon and Criley 1991)    |
| <i>Populus</i> hybrids<br>(Poplar)                  | <p><u>Cytokinin</u>: BA 1 mM (225 ppm) / 10<math>\mu</math>L droplet applied daily to a lateral bud</p> <p><u>Purpose</u>: Branching agent – What is the role of cytokinin in sylleptic branching in hybrid poplar?</p> <p><u>Effect</u>: BA increased sylleptic branching by a significant amount.</p>  | (Cline and Dong-II 2002)  |
| <i>Prunus persica</i><br>(Peach)                    | <p><u>Cytokinin</u>: BA 100 to 200 ppm / Drops placed onto dormant buds of cut branches held in a vase on peaches with various chilling requirements applied at various times during dormancy</p> <p><u>Purpose</u>: Dormancy release – Can BA substitute for some of the chilling requirement?</p> <p><u>Effect</u>: Applications of 200 ppm were best. The best time to apply was in January. The shortest and longest chilling requirement cultivars were least responsive, while mid-requirement cultivars responded best.</p>   | (Weinberger 1969)         |

Table A3 Continued

| Plant   | Notes   | Reference                   |
|---|---|-----------------------------|
| <i>Prunus x keio-zakura</i><br>(Flowering Cherry)             | <u>Cytokinin</u> : BA 300 ppm / Single Foliar spray in summer at various times<br><u>Purpose</u> : Flower Enhancer – Can BA increase the number of flower buds per branch for stems cut in October.<br><u>Effect</u> : BA spray in mid-august increased number of flower buds more than 2x on stems cut in October. All buds opened normally. BA was better than ringing.   | (Yamasaki 2003)             |
| <i>Pseudotsuga menziesii</i><br>(Douglas fir Christmas trees) | <u>Cytokinin</u> : BA 1000 ppm / Whole tree single foliar spray application 6 weeks after bud break<br><u>Purpose</u> : Branching agent – Does BA increase branching?<br><u>Effect</u> : BA increased lateral bud formation by 50% but also increased lammas shoots.  | (Mazzola and Costante 1987) |
| <i>Pseudotsuga menziesii</i><br>(Douglass fir)                | <u>Cytokinin</u> : BA 0.5 mM (112 ppm) / Foliar spray applied midway through the spring flush daily for 1 to 2 weeks.<br><u>Purpose</u> : Branching agent – Does BA promote a second flush of growth later in the year?<br><u>Effect</u> : BA daily for 1 week greatly promoted lateral bud growth in the second flush but only slightly increased terminal bud growth. More buds grew and they remained short. Needles at the shoot tips were twisted. Timing was critical as sprays earlier than mid-flush had no effect. | (Cline et al. 2006)         |
| <i>Pyrus calleryana</i><br>(Callery Pear)                     | <u>Cytokinin</u> : BA+GA (Promalin) 750 to 1500 ppm / Single foliar spray in June to 1yr old plants.<br><u>Purpose</u> : Branching agent – Does Promalin improve branching?<br><u>Effect</u> : Promalin 1500 ppm greatly increased branching without reducing height.   | (Jacyna et al. 1994)        |
| <i>Pyrus calleryana</i><br>(Callery Pear)                     | <u>Cytokinin</u> : BA 150 to 600 ppm, Promalin 300 to 1200 ppm / Single foliar sprays in fall<br><u>Purpose</u> : Branching agent – Can CKs improve crotch angles and lateral shoot counts?<br><u>Effect</u> : Promalin 1200 ppm was slightly better than BA 600 ppm at increasing shoots and crotch angles significantly. Mean lateral shoot length was reduced by all treatments  | (Keever et al. 1993)        |
| <i>Quercus alba</i><br>(White oak)                            | <u>Cytokinin</u> : BA (1 to 100 ppm) / Continuous dip of dormant cut stems<br><u>Purpose</u> : Propagation – Can CKs increase the number of bud breaks and softwood stem growth from dormant cut stems<br><u>Effect</u> : BA 100 ppm delayed bud break but increased the % of buds that broke.  | (Yang and Read 1997)        |
| <i>Quercus robur</i><br>(English oak)                         | <u>Cytokinin</u> : BA 44.3µM (10 ppm), BA+IBA (10 ppm+10 ppm), GA+BA (10 ppm+10 ppm), GA+BA+IBA (10 ppm+10 ppm+10 ppm) / 24 soak of 4yr old dormant seedlings prior to transplant into pots<br><u>Purpose</u> : Stress tolerance – Can BA improve plant growth after transplanting?<br><u>Effect</u> : BA caused small bushy plants with many more branches and leaves than control plants. The effect f BA on reducing transplant shock was not determined.  | (Smith and Schwab 1980)     |

Table A3 Continued

| <b>Plant</b>                                    | <b>Notes</b>   | <b>Reference</b>              |
|---|--|-------------------------------|
| <i>Rhapheolepis indica</i><br>(Indian Hawthorn) | <u>Cytokinin</u> : BA 1750 to 5000 ppm / 3 Foliar sprays in spring at 1 to 3 week intervals<br><u>Purpose</u> : Branching agent – Can BA replace the need for manual pruning.<br><u>Effect</u> : BA 2500 to 5000 ppm applied 3 times at a 1 or 2wk interval maximized rooting. Cultivar Olivia was much more sensitive to phytotoxicity than Eleanor Taber. Phytotoxicity was severe but transitory and made plants unmarketable in the year of application. | (Oates et al. 2005a)          |
| <i>Rhaphiolepis</i><br>(Indian Hawthorn)        | <u>Cytokinin</u> : BA 1750 to 3500 ppm / Three Foliar sprays one week apart at various times during plant development.<br><u>Purpose</u> : Branching agent – What is the best time to apply BA?<br><u>Effect</u> : The best time to apply BA is after bud break when there are expanding shoots with immature foliage (DS2). This maximizes lateral shoot formation and minimizes phytotoxicity  | (Oates et al. 2005b)          |
| <i>Rhaphiolepis indica</i><br>(Indian Hawthorn) | <u>Cytokinin</u> : BA or BA+GA (Promalin) / Single foliar spray application at various times. Rates not listed.<br><u>Purpose</u> : Branching agent – Can BA reduce the need for pruning?<br><u>Effect</u> : BA did not induce bud break   | (Keever and Foster 1990)      |
| <i>Rhaphiolepis indica</i><br>(Indian Hawthorn) | <u>Cytokinin</u> : BA (BAP-10) 1250 ppm-5000 ppm / 2 to 4 Weekly foliar spray applications.<br><u>Purpose</u> : Branching agent – Can multiple applications of BA improve branching in commercial production? Can BA replace pruning?<br><u>Effect</u> : All rates effective at increasing branching but rates above 2500 ppm caused phytotoxicity. So 1250 ppm is the recommended rate. Author states that BA can replace pruning.                          | (Oates and Keever 2003)       |
| <i>Rhaphiolepis indica</i><br>(Indian Hawthorn) | <u>Cytokinin</u> : BA 1250 to 5000 ppm / 2 to 4 Foliar sprays 1 week apart<br><u>Purpose</u> : Branching agent – Can BA induce branching?<br><u>Effect</u> : 2500 ppm BA increased branching the most but 1250 ppm worked well too. Rates above 2500 ppm caused phytotoxicity. Treated plants required little or no pruning. The best timing was to apply when plants were not flushing.   | (Oates et al. 2004)           |
| <i>Rhododendron</i>                             | <u>Cytokinin</u> : BA 100 ppm / Foliar spray 2 to 32 times<br><u>Purpose</u> : Branching agent – Can BA substitute for a hand pinch in nursery grown crops<br><u>Effect</u> : No effect on branching or flowering at these rates   | (Richards and Wilkinson 1984) |
| <i>Rhododendron</i><br>(Azalea – Exbury)        | <u>Cytokinin</u> : PBA (500 to 1000 ppm) with or without Hand Pinch or Off-Shoot-O 4.2% / 3 foliar spray applications of PBA<br><u>Purpose</u> : Branching agent – Will PBA increase branching?<br><u>Effect</u> : PBA 1000 ppm + hand pinch increased branching by 1.8x over control which was better than hand pinching. All other combinations were not as good as a hand pinch.  | (Ryan 1974)                   |

Table A3 Continued

| <b>Plant</b>                             | <b>Notes</b>   | <b>Reference</b>            |
|--|--|-----------------------------|
| <i>Rhododendron</i><br>(Azalea)          | Kinetin 100 ppm, GA+Kinetin 100 ppm+100 ppm / applied every 4 days to the flower bud<br>GA+Kinetin reduced average time of bud formation to flower by 48 days without a cold treatment   | (Furuta and Straiton 1965)  |
| <i>Rhododendron</i><br>(Azalea)          | <u>Cytokinin</u> : PBA (200 ppm) + GA (200 to 100 ppm) / Six foliar sprays during the winter<br><u>Purpose</u> : Break Dormancy – Flower enhancer – Can PBA+GA cause azalea buds to break dormancy early without a cold treatment?<br><u>Effect</u> : GA <sub>4/7</sub> + PBA caused plants to break dormancy earliest (20 to 26 days earlier) and increased flower size.                                | (Nell and Larson 1974)      |
| <i>Rhododendron</i><br>(Azalea)          | <u>Cytokinin</u> : PBA (SD8339) 200 to 1200 ppm / Two foliar sprays to sheared plants.<br><u>Purpose</u> : Branching agent – Will PBA increase branching?<br><u>Effect</u> : PBA had inconsistent results. 200 and 800 ppm increased branching but 400 and 1200 ppm decreased branching.   | (Sanderson and Martin 1974) |
| <i>Rhododendron</i><br>(Azalea)          | <u>Cytokinin</u> : PBA (Accel) 200 to 1200 ppm / single foliar spray 1 week prior to pinching.<br><u>Purpose</u> : Branching agent – Will PBA increase branching?<br><u>Effect</u> : PBA was not effective at increasing branching   | (Sanderson and Martin 1975) |
| <i>Rhododendron</i><br>(Azalea)          | <u>Cytokinin</u> : PBA 0.08% (800 ppm) / Single foliar spray at shearing time in mid winter<br><u>Purpose</u> : Branching agent – Can PBA substitute for a manual pinch?<br><u>Effect</u> : PBA had no effect  | (Shu et al. 1981)           |
| <i>Rhododendron</i><br>(Azalea, Florist) | <u>Cytokinin</u> : BA 1000 to 2000 ppm or BA+GA (Promalin) 1000 to 1816 ppm / Single foliar spray the day after plants were pruned.<br><u>Purpose</u> : Branching agent – Will BA or BA+GA increase lateral branching?<br><u>Effect</u> : BA alone had severe phytotoxicity and death. Promalin was better. Neither promoter branching.  | (Bell et al. 1997)          |
| <i>Rhododendron</i><br>(Azalea, Formosa) | <u>Cytokinin</u> : BA 2000 to 2500 ppm or BA+GA (Promalin) 2000 to 5000 ppm / Single foliar spray application at various times<br><u>Purpose</u> : Branching agent – Can BA reduce the need for pruning?<br><u>Effect</u> : BA 2000 ppm in April increased branching but not as much as pruning. Promalin 5000 ppm in April was better than pruning. BA or Promalin in January had no effect.            | (Keever and Foster 1990)    |
| <i>Rhododendron</i><br>(Azalea, Vireya)  | <u>Cytokinin</u> : BA, PBA, Thidiazuron all at 200 ppm / Single foliar spray<br><u>Purpose</u> : Branching agent – Do CKs increase branching?<br><u>Effect</u> : PBA was best and stimulated 96.4% of buds to break vs 63% for control. Thidiazuron was a close second. BA was equivalent to a pinch with 88% buds breaking. Author suggests trying higher rates of BA. Thidiazuron whorls were shorter. | (Criley 2000)               |

Table A3 Continued

| <b>Plant</b>                                  | <b>Notes</b>   | <b>Reference</b>              |
|---|--|-------------------------------|
| <i>Ribes</i><br>(Black Currant)               | <u>Cytokinin</u> : Kinetin 2 ppm / Applied in late fall or early winter, or mid winter, or late winter<br><u>Purpose</u> : Dormancy Release – Does Kinetin release currant buds from dormancy?<br><u>Effect</u> : Kinetin applied in fall accelerated flower development and the start of flowering but when applied in winter it had no effect.   | (Lenz and Karnatz 1969)       |
| <i>Salix alba</i><br>(White willow)           | <u>Cytokinin</u> : BA (200 ppm), Promalin (1000 ppm) / Single foliar spray or 3 foliar sprays onto 6 to 10cm rooted cuttings<br><u>Purpose</u> : Growth inhibitor – Can BA be used to affect height and habit?<br><u>Effect</u> : Promalin & BA caused plants to grow almost 2x taller. Plants sprayed 3x had a greater response.  | (Grzesik and Rudnicki 1985)   |
| <i>Salix purpurea</i><br>(Purple willow)      | <u>Cytokinin</u> : Kinetin 100 to 500 ppm with or without GA<br><u>Purpose</u> : Growth inhibitor – Can BA affect growth habit?<br><u>Effect</u> : Kinetin 500 ppm increased the number of shoots formed   | (McCarthy and Bünemann 1981b) |
| <i>Sophora microphylla</i><br>(Kowhai)        | <u>Cytokinin</u> : BA 50 to 150 $\mu$ M (11 to 34 ppm) / 5ml of solution applied to the base of a stem via a absorbent wick in mid summer<br><u>Purpose</u> : Branching agent – Can BA increase branching?<br><u>Effect</u> : BA increased branch angles and decreased node angles. 11ppm BA increased branch number by 28%. Plants became more divaricating.<br><u>Notes</u> : Author implies that plants with lower endogenous cytokinin levels react more strongly to exogenous applications. | (Carswell et al. 1996)        |
| <i>Sophora prostrata</i><br>(Kowhai)          | <u>Cytokinin</u> : BA 50 to 150 $\mu$ M (11 to 34 ppm) / 5ml of solution applied to the base of a stem via a absorbent wick in mid summer<br><u>Purpose</u> : Branching agent – Can BA increase branching?<br><u>Effect</u> : BA increased branch angles and decreased node angles. 11ppm BA increased branch number. The response was highly variable.<br><u>Notes</u> : Author implies that plants with lower endogenous cytokinin levels react more strongly to exogenous applications        | (Carswell et al. 1996)        |
| <i>Spiraea japonica</i><br>(Japanese spiraea) | <u>Cytokinin</u> : BA (200 ppm), Promalin (1000 ppm) / Single foliar spray or 3 foliar sprays onto 6 to 10cm rooted cuttings<br><u>Purpose</u> : Branching agent – Can BA be used as a PGR in nursery crops?<br><u>Effect</u> : BA applied 3 times increased branching 15% which was not as good as Ethrel. Promalin reduced branching at all application methods as did BA applied only once.   | (Grzesik and Rudnicki 1985)   |

Table A3 Continued

| <b>Plant</b>  | <b>Notes</b>  | <b>Reference</b>              |
|---|---|-------------------------------|
| <i>Spiraea japonica</i> (Japanese spiraea)          | <p><u>Cytokinin</u>: BA + Kinetin (Early Harvest PGR – also contains GA and auxin) 1.5 to 3.0ml in 1125ml water . (1.17 ppm BA + 1.17 ppm Kinetin) / 45ml soil drenches every two weeks from June to September in Georgia</p> <p><u>Purpose</u>: Stress tolerance – Can a Kinetin based biostimulant reduce summer heat stress and keep crop quality high?</p> <p><u>Effect</u>: The low 1.5ml rate increased plant quality by 18%. The 3.0ml rate caused a reduction in growth index and quality by 30% compared to control. There was an even larger drop in root coverage.</p> | (Ruter 2000)                  |
| <i>Spiraea x vanhoutteii</i> (Van Houtte's spiraea) | <p><u>Cytokinin</u>: BA 1 to 100 ppm, Thidiazuron 1 to 50 ppm / Continuous dip of cut stems OR BA added at various times</p> <p><u>Purpose</u>: Propagation – Can CKs increase the number of bud breaks and softwood stem growth from dormant cut stems</p> <p><u>Effect</u>: BA and Thidiazuron delayed bud break but increased the overall % of buds that broke. BA added earlier worked better than BA added later.</p>  | (Yang and Read 1991)          |
| <i>Syringia</i> spp. (Lilac)                        | <p><u>Cytokinin</u>: Kinetin &amp; BA rates and application method not listed</p> <p><u>Purpose</u>: Dormancy release – Can cytokinins replace stratification of Lilac seeds?</p> <p><u>Effect</u>: No effect on stratification. BA inhibited germination of seeds that were not dormant.</p>   | (Junttila 1970)               |
| <i>Ternstroemia gymnanthera</i> (Japanese cleyara)  | <p><u>Cytokinin</u>: BA or BA+GA (Promalin) / Single foliar spray application at various times. Rates not listed</p> <p><u>Purpose</u>: Branching agent – Can BA reduce the need for pruning?</p> <p><u>Effect</u>: BA did not induce bud break</p>   | (Keever and Foster 1990)      |
| <i>Thuja occidentalis</i> (Arborvitae)              | <p><u>Cytokinin</u>: BA + Kinetin (Early Harvest PGR – also contains GA and auxin) 1.5 to 3.0ml in 1125ml water. (1.17 ppm BA + 1.17 ppm Kinetin) / 45ml soil drenches every two weeks from June to September in Georgia</p> <p><u>Purpose</u>: Stress tolerance – Can a Kinetin based biostimulant reduce summer heat stress and keep crop quality high?</p> <p><u>Effect</u>: No effect on growth indices.</p>  | (Ruter 2000)                  |
| <i>Tsuga canadensis</i> (Canadian hemlock)          | <p><u>Cytokinin</u>: Kinetin 100 to 500 ppm with or without GA</p> <p><u>Purpose</u>: Growth inhibitor – Can BA affect growth habit?</p> <p><u>Effect</u>: Kinetin retarded shoot growth and led to a reduction in shoot number</p>   | (McCarthy and Bünemann 1981a) |
| <i>Viburnum odoratissimum</i> (Sweet Viburnum)      | <p><u>Cytokinin</u>: BA 1 to 900 ppm, BA+GA (Promalin) 250 to 1000 ppm / 7 spray applications at 3 day intervals OR 1 to 3 sprays at 3 days intervals</p> <p><u>Purpose</u>: Branching agent – Can BA increase branching?</p> <p><u>Effect</u>: BA 300 ppm and above caused severe phytotoxicity and increased later bud breaks but the buds did not grow. More than 3 applications of BA at 3 days intervals caused phytotoxicity whereas 1 to 2 applications did not. Promalin 1000 ppm was effective in greatly increasing branching but not dry weight.</p>                   | (Schoene and Yeager 2005)     |

Table A3 Continued

| <b>Plant</b>                                       | <b>Notes</b>   | <b>Reference</b>              |
|--|--|-------------------------------|
| <i>Viburnum opulus</i><br>(American cranberrybush) | <u>Cytokinin</u> : Kinetin 100 to 500 ppm with or without GA<br><u>Purpose</u> : Growth inhibitor – Can BA affect growth habit?<br><u>Effect</u> : Kinetin increased the number of shoots formed   | (McCarthy and Bünemann 1981b) |
| <i>Weigela florida</i><br>(Weigela)                | <u>Cytokinin</u> : BA (200 ppm), Promalin (1000 ppm) / Single foliar spray or 3 foliar sprays onto 6 to 10cm rooted cuttings<br><u>Purpose</u> : Branching agent – Can BA be used as a PGR in nursery crops?<br><u>Effect</u> : BA applied three times increased branching by 36% which was better than any other PGR except GA which was 81%. Promalin was not effective.   | (Grzesik and Rudnicki 1985)   |
| <i>Weigela florida</i><br>(Weigela)                | <u>Cytokinin</u> : Kinetin (270 ppm) with or without GA <sub>3</sub> 90 ppm<br><u>Purpose</u> : Branching agent – Can Kinetin increase branching?<br><u>Effect</u> : Kinetin+GA increased branching more than either chemical alone.   | (Loach and N. 1975)           |
| <i>Weigela florida</i><br>(Weigela)                | <u>Cytokinin</u> : BA + Kinetin (Early Harvest PGR – also contains GA and IBA) 1.5 to 3.0ml in 1125ml water . (1.17 ppm BA + 1.17 ppm Kinetin) / 45ml soil drenches every two weeks from June to September in Georgia<br><u>Purpose</u> : Stress tolerance – Can a Kinetin based biostimulant reduce summer heat stress and keep crop quality high?<br><u>Effect</u> : 1.5ml rate did not effect growth index or quality but it did increase dry weight. | (Ruter 2000)                  |

### A1.4 Effects of Cytokinins on Non-ornamental Horticultural Crops

Cytokinins have been researched in other areas of horticulture such as turf management, pomology, olericulture, and weed science. Each of these specialty areas has its own goals. Olericulturists have studied cytokinins as a postharvest senescence inhibitor and to some extent as a yield enhancer. Pomologists have studied cytokinins as fruit thinner and yield enhancer. In either case, yields may be enhanced, but food quality sometimes drops. Turf management has studied cytokinins as stress resistors and growth enhancers. Weed scientists have studied cytokinins as a method of breaking dormancy of weeds in order to stimulate growth upon which to apply herbicides.

Cytokinins have proven to be effective on a wide range of fruits and vegetables as listed in the table below. The following table briefly summarizes the research efforts for non-ornamental horticultural crops. The goal of this table is to show a representation of a wide variety of crops. Some crops have extensive research behind them (i.e., apples, sweet cherry, grapes) and are summarized here with only a few entries that represent the methods used in the wider research.

Table A4: Research efforts for exogenous cytokinins on non-ornamental crops.

| Plant                                   | Notes   | Reference                 |
|---|---|---------------------------|
| <i>Abelmoschus esculentus</i><br>(Okra) | <p><u>Cytokinin</u>: Thidiazuron (Dropp 50WP) 8.8 to 1120 g ai / ha applied at 350L / ha (200 ppm-16000 ppm) / Postemergence foliar sprays to 2 to 8wk old plants</p> <p><u>Purpose</u>: Growth control – Can Thidiazuron be sprayed on okra to control weeds without harming the okra?</p> <p><u>Effect</u>: Thidiazuron severely injured the plants. 8.8g ai / ha caused &gt;20% injury. Thidiazuron also reduced the height of the plants and slightly reduced dry weight.</p> | (Hodgson and Snyder 1988) |

| Table A4 Continued                                |   |                             |
|---|---|-----------------------------|
| Plant   | Notes   | Reference                   |
| <i>Abutilon theophrasti</i><br>(Velvetleaf)       | <p><u>Cytokinin</u>: Thidiazuron (Dropp 50WP) 70 to 560 g ai / ha applied at 350L / ha (200 ppm-1600 ppm) / Postemergence foliar sprays to 2 to 5wk old plants</p> <p><u>Purpose</u>: Weed control – Can Thidiazuron be used to control velvetleaf?</p> <p><u>Effect</u>: 70g ai / ha reduced growth by 95% and injured 84% of 2wk old plants – epinasty, puckered leaves, inhibited leaf expansion, chlorosis, necrosis. Injury levels fell in older plants.</p>   | (Hodgson and Snyder 1988)   |
| <i>Actinidia deliciosa</i><br>(Kiwi)              | <p><u>Cytokinin</u>: CPPU 10 to 20 ppm with and without Promalin 5 ppm, GA<sub>3</sub> 25 ppm, 2,4-D 50 ppm / Fruit dips at various times after fruit formation</p> <p><u>Purpose</u>: Yield enhancer – Can CPPU increase fruit size and improve fruit characteristics?</p> <p><u>Effect</u>: CPPU + 2,4-D + GA<sub>3</sub> applied 25 days after anthesis resulted in the largest fruit (74% bigger than control) but caused some skin blistering, reduced fruit firmness, increased soluble solids and darker skin. The thickness of the outer pericarp increased in relation to inner pericarp. There were cultivar differences.</p> | (Cruz-Castillo et al. 1999) |
| <i>Actinidia deliciosa</i><br>(Kiwi)              | <p><u>Cytokinin</u>: CPPU 5 ppm / Applied as either a fruitlet dip or spray 21 days after flowering.</p> <p><u>Purpose</u>: Yield enhancer – Can CPPU increase fruit size and improve fruit characteristics?</p> <p><u>Effect</u>: CPPU increase fresh weight of the fruits by 33 to 43%</p>  | (Patterson 1993)            |
| <i>Actinidia deliciosa</i><br>(Kiwi)              | <p><u>Cytokinin</u>: CPPU 5 ppm / Fruitlet dip or spray 21 days after flowering</p> <p><u>Purpose</u>: Yield enhancer – Can CPPU increase fruit size?</p> <p><u>Effect</u>: Dipping fruit increased size by 40%. Spraying increased size by 30% but resulted in greener fruit at harvest.</p>   | (Patterson 1993)            |
| <i>Agaricus campestris</i><br>(Mushrooms)         | <p><u>Cytokinin</u>: BA 6 to 400 ppm / Plant immersed for 10min and stored at various temperatures</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA improve postharvest quality?</p> <p><u>Effect</u>: BA was ineffective at preventing quality grade drops.</p>  | (Halevy et al. 1965)        |
| <i>Agrostis palustris</i><br>(Creeping bentgrass) | <p><u>Cytokinin</u>: Zeatin Riboside 3.5 ppm and Seaweed based biostimulants 3.5 ppm CK level / Foliar spray applications</p> <p><u>Purpose</u>: Stress tolerance – Can CKs improve heat tolerance?</p> <p><u>Effect</u>: Both Zeatin and Seaweed products resulted in greater visual quality of turf</p>   | (Ervin et al. 2006)         |
| <i>Agrostis palustris</i><br>(Creeping bentgrass) | <p><u>Cytokinin</u>: Zeatin Riboside 0.01, 0.1, 1, 10 *10<sup>-6</sup>M (0.002, 0.02, 0.22, 2.2 ppm) / Solution injected into soil near roots the day before heat treatment began and again 14 days later.</p> <p><u>Purpose</u>: Stress tolerance – Can Zeatin improve tolerance to hot air and soil temps?</p> <p><u>Effect</u>: Zeatin Riboside was effective in reducing senescence traits caused by heat stress. 2.2 ppm worked best.</p>  | (Liu et al. 2002)           |

| Table A4 Continued                                |  |                              |
|---|--|------------------------------|
| Plant   | Notes  | Reference                    |
| <i>Agrostis palustris</i><br>(Creeping bentgrass) | <u>Cytokinin</u> : Plants genetically transformed to over express IPT.<br><u>Purpose</u> : Stress tolerance – Can CK expression reduce heat stress?<br><u>Effect</u> : Overexpressing IPT reduces summer bentgrass decline due to heat stress.   | (Xing et al. 2007)           |
| <i>Agrostis palustris</i><br>(Creeping bentgrass) | <u>Cytokinin</u> : Zeatin 25µM (5 ppm) / Single drench<br><u>Purpose</u> : Stress tolerance – Can CKs reduce heat stress?<br><u>Effect</u> : Abstract only – no results listed   | (Xu and Huang 2007)          |
| <i>Allium cepa</i><br>(Onion, Shallot)            | <u>Cytokinin</u> : BA 0.1 to 50 µM (0.022 – 11 ppm) / Bulbs placed in solutions in a greenhouse at various times after harvest<br><u>Purpose</u> : Dormancy release – Can BA induce shoot formation in dormant onion bulbs?<br><u>Effect</u> : BA alone was generally ineffective except in 1 cultivar. This indicates that higher rates need to be tested. When the basal plate was wounded, BA 2 ppm was very effective in stimulating early sprouting.  | (Miedema and Kamminga 1994)  |
| <i>Allium fistulosum</i><br>(Green onions)        | <u>Cytokinin</u> : BA (SD4901, Verdan) rate and application not listed<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA is effective at maintaining freshness   | (Wittwer and Dedolph 1962)   |
| <i>Allium fistulosum</i><br>(Green onions)        | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days  | (Zink 1961)                  |
| <i>Allium sativum</i><br>(Garlic)                 | <u>Cytokinin</u> : BA 50 to 150 ppm / Single foliar treatment, 70DAT<br><u>Purpose</u> : Yield enhancer – Can BA increase bulb production?<br><u>Effect</u> : No effect on height, or bulb production  | (Filho et al. 1998)          |
| <i>Anoda cristata</i><br>(Spurred anoda)          | <u>Cytokinin</u> : Thidiazuron (Dropp 50WP) 70 to 1120 g ai / ha applied at 350L / ha (200 ppm-16000 ppm) / Postemergence sprays to 2 to 5wk old plants<br><u>Purpose</u> : Weed control – Can Thidiazuron be used to control spurred anoda?<br><u>Effect</u> : Thidiazuron at all doses reduced height only a little.   | (Hodgson and Snyder 1988)    |
| <i>Apium graveolens</i><br>(Celery)               | <u>Cytokinin</u> : BA, BA+GA <sub>4/7</sub> all at 10 <sup>-6</sup> to 10 <sup>-4</sup> M (0.22 – 22.5 ppm) / Seeds imbibed for 96hr prior to germination under various light and temperature regimes<br><u>Purpose</u> : Break dormancy - Germination promoter / Can BA break thermodormancy and promote germination under high temperatures?<br><u>Effect</u> : BA 2.25 ppm improved germination at high temperatures. 0.22 ppm was ineffective and 22.5 ppm inhibited germination. GA was better than BA BA+GA was better than GA alone. Author implies that cytokinins modify the activity of PFr on its influence of GA on germination. | (Biddington and Thomas 1978) |

| Table A4 Continued                          |  |                             |
|---|--|-----------------------------|
| Plant                                       | Notes  | Reference                   |
| <i>Apium graveolens</i><br>(Celery)         | <p><u>Cytokinin</u>: BA 2.5 to 10 ppm / Dip cut stems during the packing process. Dipping solutions maintained at various temperatures and dipping time was varied.</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA improve postharvest characteristics of celery when plants are dipped in the field washing water or the hydrocooling baths in the packing house?</p> <p><u>Effect</u>: BA 5 or 10 ppm delayed senescence the most. BA was much less effective when the solution temperature was low (34°F) than when warm or hot (64°F-84°F). Dip times of 900 to 1800 seconds were best.</p>  | (Guzman 1963)               |
| <i>Apium graveolens</i><br>(Celery)         | <p><u>Cytokinin</u>: BA <math>5 \times 10^{-4}</math>M (110 ppm), or BA+GA<sub>4/7</sub> <math>5 \times 10^{-4}</math>M + <math>3 \times 10^{-3}</math>M or BA + ethephon <math>5 \times 10^{-4}</math>M + 1000 ppm / Seeds soaked 48hr in solutions of PGR + the organic solvent DCM</p> <p><u>Purpose</u>: Break dormancy - Germination promoter / Can BA break thermodormancy and promote germination under high temperatures?</p> <p><u>Effect</u>: GA+BA worked the best followed by GA alone, BA+ethephon, &amp; BA alone.</p>   | (Palevitch and Thomas 1974) |
| <i>Apium graveolens</i><br>(Celery)         | <p><u>Cytokinin</u>: BA 5 to 20 ppm / Cut stems momentarily dipped into solution and then cold stored.</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA improve postharvest characteristics of celery?</p> <p><u>Effect</u>: All rates of BA improved visual acceptability and slightly reduced weight loss during cold storage (40°F) significantly over control for 6 weeks. The author suggests 10 ppm BA be used. However, BA treated stems stored in warm conditions (70°F) fell in quality much faster than controls. BA treated stems respired 27% less than controls for over 22 days.</p> | (Whittwer et al. 1961)      |
| <i>Apium graveolens</i><br>(Celery)         | <p><u>Cytokinin</u>: BA (SD4901, Verdant) 10 ppm / bunches dipped after harvest or washed in solution</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA delay senescence?</p> <p><u>Effect</u>: BA increases shelf life and delays loss of color. Effects are better on golden celery than green celery.</p>  | (Wittwer and Dedolph 1962)  |
| <i>Apium graveolens</i><br>(Celery)         | <p><u>Cytokinin</u>: BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest</p> <p><u>Purpose</u>: Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?</p> <p><u>Effect</u>: BA delayed yellowing and other signs of senescence by 2 to 3 days</p>  | (Zink 1961)                 |
| <i>Asparagus officinalis</i><br>(Asparagus) | <p><u>Cytokinin</u>: BA 5 to 25 ppm / Plant immersed for 10min or bases immersed for 18hr</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA improve postharvest quality?</p> <p><u>Effect</u>: BA 25 ppm plant immersion was best at preventing de-greening. Base dip was also effective.</p>   | (Halevy et al. 1965)        |

| Table A4 Continued                                      |  |                            |
|---|--|----------------------------|
| Plant   | Notes  | Reference                  |
| <i>Asparagus officinalis</i><br>(Asparagus)             | <u>Cytokinin</u> : BA 50 to 200 ppm / One or more foliar sprays in either fall or spring to foliage or to young spears.<br><u>Purpose</u> : Yield enhancer – Can BA increase yield?<br><u>Effect</u> : BA 100 to 200 ppm enhances spear sprouting, number and thickness but only in the season it is applied.                                  | (Uesugi et al. 1995)       |
| <i>Asparagus officinalis</i><br>(Asparagus)             | <u>Cytokinin</u> : BA (SD4901, Verdant) 10 ppm / Spears dipped after harvest<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA increases shelf life and delays loss of color.  | (Wittwer and Dedolph 1962) |
| <i>Asparagus officinalis</i><br>(Asparagus)             | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days  | (Zink 1961)                |
| <i>Beta vulgaris</i><br>(Sugar beet)                    | <u>Cytokinin</u> : BA 33 to 2000 ppm / Single foliar spray onto cotyledon stage seedlings.<br><u>Purpose</u> : Branching agent – Does BA stimulate lateral branching?<br><u>Effect</u> : BA 500 to 2000 ppm induced lateral shoots. BA 300 to 900 ppm caused stunting. BA caused leaves to be dissected and caused bumps and rods on petioles. | (Saunders and Mahoe 1982)  |
| <i>Bidens pilosa</i><br>(Hairy beggartick)              | <u>Cytokinin</u> : BA 5 ppm / Seeds wetted with solution at sowing.<br><u>Purpose</u> : Germination promoter – Does BA increase germination rates?<br><u>Effect</u> : BA increased germination rates in dark sown seeds from 8% to 27% or 35% depending on light source.   | (Valio et al. 1972)        |
| <i>Brassica</i><br>(Mustard greens)                     | <u>Cytokinin</u> : BA (SD4901, Verdant) rate and application not listed<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA is effective at maintaining freshness  | (Wittwer and Dedolph 1962) |
| <i>Brassica</i><br>(Mustard Greens)                     | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days  | (Zink 1961)                |
| <i>Brassica oleracea</i> var. <i>Acephala</i><br>(Kale) | <u>Cytokinin</u> : BA+GA (Promalin) 25 to 75 ppm / Single foliar spray 2WAP<br><u>Purpose</u> : Yield enhancer – Can Promalin improve Kale yields?<br><u>Effect</u> : Promalin 50 ppm was best at increasing yield by increasing leaf size, leaf number, plant dry weight. Fresh leaf yield increased by 20%                                   | (Emongor et al. 2004)      |

| Table A4 Continued  |  |                            |
|---|--|----------------------------|
| Plant   | Notes  | Reference                  |
| <i>Brassica oleracea</i> var. <i>botrytis</i> (Cauliflower)       | <u>Cytokinin</u> : BA 10 ppm with or without 2,4-D 50 ppm / Single spray after harvest and before packing<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA+2,4-D was best at delaying leaf abscission, yellowing and de-greening. Plants remained at marketable quality for much longer than control. BA alone was second best.   | (Kaufman and Ringel 1961)  |
| <i>Brassica oleracea</i> var. <i>botrytis</i> (Cauliflower)       | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days  | (Zink 1961)                |
| <i>Brassica oleracea</i> var. <i>gemmifera</i> (Brussels Sprouts) | <u>Cytokinin</u> : BA, NC5392 1 to 10 ppm / Foliar sprays every 3 days for 3wk starting at 12WAT.<br><u>Purpose</u> : Yield enhancer / Do cytokinins increase yield?<br><u>Effect</u> : NC5392 10 ppm was better than BA at increasing lateral bud size and number however this was mostly due to malformed buds. Both increased the number of flowers and flower stalk height (under noninductive conditions). NC5392 increased the number of seed pods per plant without reducing the number of seeds per pod. BA reduced the number of seeds per pod. | (Thomas 1976)              |
| <i>Brassica oleracea</i> var. <i>gemmifera</i> (Brussels sprouts) | <u>Cytokinin</u> : BA (SD4901, Verdan) rate and application not listed<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA is effective at maintaining freshness   | (Wittwer and Dedolph 1962) |
| <i>Brassica oleracea</i> var. <i>gemmifera</i> (Brussels sprouts) | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days  | (Zink 1961)                |
| <i>Brassica oleracea</i> var. <i>italica</i> (Broccoli)           | <u>Cytokinin</u> : BA $2.21 \times 10^{-4}$ M (50 ppm) / Applied to the surface of the floret.<br><u>Purpose</u> : Senescence inhibitor / Can BA delay floret senescence?<br><u>Effect</u> : BA delayed chlorophyll loss in florets by 4 days and delayed the onset of ammonia accumulation by 2days. BA was better than silver ions. BA negated the effects of ACC on promoting senescence. BA caused some morphological effects.   | (Clarke et al. 1994)       |
| <i>Brassica oleracea</i> var. <i>italica</i> (Broccoli)           | <u>Cytokinin</u> : BA 50 ppm / Heads dipped for 60s within 5 min of harvest<br><u>Purpose</u> : Senescence inhibitor / Can BA delay soluble sugar loss in freshly harvested broccoli?<br><u>Effect</u> : BA does not reduce the 50% loss of soluble sugars that occurs in the 6h after harvest. However it does delay yellowing and the loss of protein that occurs after harvest.   | (Downs et al. 1997)        |

| Table A4 Continued   |   |                               |
|--|---|-------------------------------|
| Plant  | Notes   | Reference                     |
| <i>Brassica oleracea</i> var. <i>italica</i><br>(Broccoli) | <u>Cytokinin</u> : BA 25 ppm, Zeatin & Dihydrozeatin 100 to 400 ppm / Heads dipped for 30sec prior to storage<br><u>Purpose</u> : Senescence inhibitor / Can cytokinins delay senescence of broccoli?<br><u>Effect</u> : DHZ is better than Zeatin but neither is as good as BA in delaying senescence. Repeated dips of Zeatin were not as good as a single dip of BA. | (Fuller et al. 1977)          |
| <i>Brassica oleracea</i> var. <i>italica</i><br>(Broccoli) | <u>Cytokinin</u> : BA 5 to 20 ppm / Plant immersed for 10min or bases immersed for 18hr<br><u>Purpose</u> : Senescence inhibitor / Can BA improve postharvest quality?<br><u>Effect</u> : BA 20 ppm plant immersion was best at preventing quality grade drops. Base dip was also effective.  | (Halevy et al. 1965)          |
| <i>Brassica oleracea</i> var. <i>italica</i><br>(Broccoli) | <u>Cytokinin</u> : BA 20 ppm / Heads dipped into solution for 15sec and placed into storage.<br><u>Purpose</u> : Senescence inhibitor / Can BA delay floret senescence?<br><u>Effect</u> : BA delayed de-greening and the drop in visual rating.  | (Pressman and Palevitch 1973) |
| <i>Brassica oleracea</i> var. <i>italica</i><br>(Broccoli) | <u>Cytokinin</u> : BA, <i>trans</i> -Zeatin 10 to 50 ppm / Florets dipped for 1min prior to packaging<br><u>Purpose</u> : Senescence inhibitor / Can cytokinins delay senescence of pre-packaged florets?<br><u>Effect</u> : BA was better than tZ at delaying senescence. Florets had a 90% longer shelf life than control.  | (Rushing 1990)                |
| <i>Brassica oleracea</i> var. <i>italica</i><br>(Broccoli) | <u>Cytokinin</u> : BA (SD4901, Verdan) 1 to 10 ppm / Florets dipped after harvest<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA increases shelf life and delays loss of color.  | (Wittwer and Dedolph 1962)    |
| <i>Brassica oleracea</i> var. <i>italica</i><br>(Broccoli) | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days   | (Zink 1961)                   |
| <i>Cajanus cajan</i><br>(Pigeon pea)                       | <u>Cytokinin</u> : Kinetin 5 to 500 $\mu$ M (1ppm – 100 ppm) / Single Foliar sprays 15 weeks after germination<br><u>Purpose</u> : Branching agent & Yield enhancer – Does Kinetin alter growth habit and crop yield?<br><u>Effect</u> : Kinetin slightly increased branching and crop yield.   | (Mukherjee and Kumar 2007)    |
| <i>Capsicum annuum</i><br>(Pepper)                         | <u>Cytokinin</u> : BA 0.1 to 1.0 mM (22.5 to 225 ppm) / Single foliar spray 1 hour prior to inoculation<br><u>Purpose</u> : Disease control – Can BA reduce Botrytis (Gray Mold)?<br><u>Effect</u> : BA did not reduce Botrytis severity.   | (Elad 1993)                   |

| Table A4 Continued                                       |   |                                  |
|--|---|----------------------------------|
| Plant  | Notes   | Reference                        |
| <i>Capsicum annuum</i><br>(Pepper)                       | <p><u>Cytokinin</u>: Kinetin 0.5 to 50 ppm with or without GA<sub>3</sub> 0.1 to 10 ppm / 15 weekly foliar sprays with or without foliar fertilization</p> <p><u>Purpose</u>: Yield enhancer / Do cytokinins increase yield, fruit qualities or capsaicin content in hydroponic peppers?</p> <p><u>Effect</u>: Kinetin 5 ppm + GA 10 ppm + foliar fertilization increased per plant yield by 60%. Kinetin by itself increased yield but not as much as other treatments. Kinetin 5 ppm by itself led to the largest individual fruit size but fewer fruits. Dry weight and capsaicin content was not affected by any treatment.</p> | (Nowak 1980)                     |
| <i>Carya illinoensis</i><br>(Pecan)                      | <p><u>Cytokinin</u>: BA 125 to 375 ppm, BA+GA (Promalin) 225 to 675 ppm, with or without Alar 1000 ppm / 3 spray applications – 2 in Oct and 1 in Apr.</p> <p><u>Purpose</u>: Branching agent – Yield enhancer – Dormancy release - Can cytokinins increase branching, increase yield or release trees from winter dormancy earlier?</p> <p><u>Effect</u>: BA and Promalin promote lateral branching in 6yr old trees but not 4yr old trees equivalent to manual pinching. Nut clusters were increased by all treatments.</p>   | (Herrera et al. 1987)            |
| <i>Carya illinoensis</i><br>(Pecan)                      | <p><u>Cytokinin</u>: BA 50 to 500 µg·g<sup>-1</sup> (50 to 500 ppm) / Two foliar sprays in Sept and Oct.</p> <p><u>Purpose</u>: Yield enhancer – Can BA improve yield?</p> <p><u>Effect</u>: No effect at these rates and timing.</p>   | (Worley 1989)                    |
| <i>Chenopodium rubrum</i><br>(Red goosefoot)             | <p><u>Cytokinin</u>: Kinetin 5*10<sup>-8</sup> to 5*10<sup>-4</sup> M (0.1 to 107 ppm) with or without GA and auxin / One 3µl droplet on the plumule 4hr before start of flower induction period (Short Day).</p> <p><u>Purpose</u>: Flower enhancer – Does the combination of Kinetin, GA, and Auxin affect flowering?</p> <p><u>Effect</u>: Kinetin reduces the effect of GA on stimulating flowering.</p>  | (Ullmann et al. 1985)            |
| <i>Chicorium endivea</i><br>(Endive – Escarole, Chicory) | <p><u>Cytokinin</u>: BA 2.5 to 10 ppm / Dip cut stems during the packing process. Dipping solutions maintained at various temperatures and dipping time was varied.</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA improve postharvest characteristics of celery when plants are dipped in the field washing water or the hydrocooling baths in the packing house?</p> <p><u>Effect</u>: BA 2.5 ppm delayed senescence the most. Solution temperature did not affect its activity. Dip times of 1800 seconds were best.</p>   | (Guzman 1963)                    |
| <i>Chicorium endivea</i><br>(Endive / Escarole)          | <p><u>Cytokinin</u>: Kinetin 0.001 – 0.1 µg / Applied to shoot tips every other day for 30 days in June to plants planted at various times in May</p> <p><u>Purpose</u>: Flower enhancer – Can CKs cause endive to flower sooner?</p> <p><u>Effect</u>: Only if applied to larger plants (6 to 7 leaf stage) planted in early May. Smaller plants did not respond. Kinetin did not work as well as GA.</p>  | (Michniewicz and Kamienska 1964) |

| Table A4 Continued                              |  |                            |
|---|--|----------------------------|
| Plant   | Notes  | Reference                  |
| <i>Chicorium endivea</i><br>(Endive / Escarole) | <u>Cytokinin</u> : BA (SD4901, Verdant) rate and application not listed<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA is effective at maintaining freshness  | (Wittwer and Dedolph 1962) |
| <i>Chicorium endivea</i><br>(Endive / Escarole) | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days  | (Zink 1961)                |
| <i>Citrullus lanatus</i><br>(Watermelon)        | <u>Cytokinin</u> : BA 500 ppm, Kinetin 500 ppm, CPPU 200 ppm / Ovaries sprayed once to pollinated or unpollinated flowers.<br><u>Purpose</u> : Yield enhancer / Do cytokinins affect parthenocarpic fruit formation, fruit set, or fruit development in watermelon?<br><u>Effect</u> : CPPU caused 80 to 90% of treated ovaries to form parthenocarpic fruit set but BA and Kinetin did not. Fruit size and Brix were unaffected. CPPU & BA improved fruit set (>200%) of pollinated flowers.  | (Hayata et al. 1995a)      |
| <i>Citrullus lanatus</i><br>(Watermelon)        | <u>Cytokinin</u> : CPPU 20 to 200 ppm / applied to pollinated ovaries<br><u>Purpose</u> : Yield enhancer / Do cytokinins promote fruit set and quality?<br><u>Effect</u> : CPPU 200 ppm - Fruit set increased from 27% to 95% in pollinated flowers and from 0% to 90% in unpollinated flowers. 20 ppm increased fruit set too but fruit generated from 20 ppm CPPU stopped growing early. Fruit size, soluble solids and sugars were not affected.  | (Hayata et al. 1995b)      |
| <i>Citrullus lanatus</i><br>(Watermelon)        | <u>Cytokinin</u> : CPPU (Sitofex) 50 to 200 ppm / 0.6ml spray onto each ovary starting at 44dat and every 4 days for 5 total treatments<br><u>Purpose</u> : Yield enhancer / Parthenocarpy - Can BA replace bee pollination or artificial pollination in watermelon?<br><u>Effect</u> : CPPU 100 to 200 ppm increased yield by increasing the number of fruit per plant. It did not significantly reduce fruit weight but Brix was 10% lower in one trial but within acceptable commercial levels. The CPPU results were similar to bee pollination levels. A delay in ripening was noticed with CPPU. | (Huitron et al. 2007)      |
| <i>Citrullus lanatus</i><br>(Watermelon)        | <u>Cytokinin</u> : CPPU 100 ppm / Ovaries sprayed once. 1 ml of solution per ovary.<br><u>Purpose</u> : Yield enhancer / Do cytokinins affect parthenocarpic fruit formation, fruit set, or fruit development in watermelon?<br><u>Effect</u> : CPPU caused as many fruit to grow parthenocarpically as in an open pollinated field. The elimination of pollinator plants increased production per acre by 50%.  | (Maroto et al. 2005)       |

| Table A4 Continued                                      |   |                          |
|---|---|--------------------------|
| Plant   | Notes   | Reference                |
| <i>Citrus</i><br>(Grapefruit)                           | <u>Cytokinin</u> : BA 2000 ppm / Swabbed onto quiescent scion buds with a cotton swab in April<br><u>Purpose</u> : Branching agent – Propagation - Can BA stimulate quiescent scion buds to grow on bud grafted plants?<br><u>Effect</u> : BA 250 ppm and higher stimulated almost 53% bud sprouting but only if 95% ethanol + 1.2 to 2% DMSO was used as a solvent and only if Tween was added.      | (Nauer and Boswell 1981) |
| <i>Citrus</i><br>(Pineapple sweet orange)               | <u>Cytokinin</u> : BA 16 to 8000 ppm / Swabbed onto quiescent scion buds with a cotton swab in April<br><u>Purpose</u> : Branching agent – Propagation - Can BA stimulate quiescent scion buds to grow on bud grafted plants?<br><u>Effect</u> : BA 250 ppm and higher stimulated almost 88% bud sprouting but only if ethanol+DMSO was used as a solvent and only if Tween was added.                | (Nauer and Boswell 1981) |
| <i>Citrus aurantifolia</i><br>(Mexican lime)            | <u>Cytokinin</u> : BA 16 to 8000 ppm / Swabbed onto quiescent scion buds with a cotton swab in April<br><u>Purpose</u> : Branching agent – Propagation - Can BA stimulate quiescent scion buds to grow on bud grafted plants?<br><u>Effect</u> : BA 250 ppm and higher stimulated almost 100% bud sprouting but only if 95% ethanol + 1 to 2% DMSO was used as a solvent and only if Tween was added. | (Nauer and Boswell 1981) |
| <i>Citrus jambhiri</i><br>(Rough lemon)                 | <u>Cytokinin</u> : BA 16 to 8000 ppm / Swabbed onto quiescent scion buds with a cotton swab in April<br><u>Purpose</u> : Branching agent – Propagation - Can BA stimulate quiescent scion buds to grow on bud grafted plants?<br><u>Effect</u> : BA 250 ppm and higher stimulated almost 52% bud sprouting but only if 95% ethanol + 1 to 2% DMSO was used as a solvent and only if Tween was added.  | (Nauer and Boswell 1981) |
| <i>Citrus paradisi</i><br>(Duncan grapefruit)           | <u>Cytokinin</u> : BA 16 to 8000 ppm / Swabbed onto quiescent scion buds with a cotton swab in April<br><u>Purpose</u> : Branching agent – Propagation - Can BA stimulate quiescent scion buds to grow on bud grafted plants?<br><u>Effect</u> : BA at all rates had no effect  | (Nauer and Boswell 1981) |
| <i>Citrus reticulata</i><br>(Parson's special mandarin) | <u>Cytokinin</u> : BA 16 to 8000 ppm / Swabbed onto quiescent scion buds with a cotton swab in April<br><u>Purpose</u> : Branching agent – Propagation - Can BA stimulate quiescent scion buds to grow on bud grafted plants?<br><u>Effect</u> : BA at all rates had no effect  | (Nauer and Boswell 1981) |

| Table A4 Continued   |   |                            |
|--|---|----------------------------|
| Plant  | Notes   | Reference                  |
| <p><i>Citrus sinensis</i><br/>(Navel orange)</p> <p><i>Citrus reticulata</i><br/>(‘Satsuma’ mandarin)</p> <p><i>Citrus aurantium</i><br/>(Jeng orange)</p> | <p><u>Cytokinin</u>: BA 100 to 800 ppm with or without GA 100 ppm / 3 whole tree foliar sprays prior to and during anthesis OR sprays at the young fruit stage just after petal fall OR applied to selected fruit at the young fruit stage</p> <p><u>Purpose</u>: Yield enhancer – Can BA prevent flower drop and fruit drop?</p> <p><u>Effect</u>: BA and BA+GA applied at anthesis caused severe flower thinning and reduced fruit set. GA alone or with BA caused severe leaf drop and twig death. BA or BA+GA applied at young fruit stage promoted almost complete fruit drop. BA or BA+GA applied to selected fruit increased fruit set and decreased fruit drop.</p> | (Dayuan 1981)              |
| <p><i>Citrus unshiu</i><br/>(Satsuma mandarin)</p>   | <p><u>Cytokinin</u>: BA 20 ppm / Dipping the flower or fruitlet into solutions at various times during fruit development</p> <p><u>Purpose</u>: Yield enhancer – Can BA alter fruit characteristics?</p> <p><u>Effect</u>: Dipping the flower into BA solutions at the time of flower opening increased the fruitlet size by 22% but did not increase final fruit size. Dipping older fruitlets into solution had no effect. GA results were similar to BA.</p>   | (Guardiola et al. 1992)    |
| <p><i>Citrus unshiu</i><br/>(Satsuma mandarin)</p>   | <p><u>Cytokinin</u>: BA 100 to 200 ppm / 2 Foliar sprays 4 days apart at various times from Sep to Nov</p> <p><u>Purpose</u>: Yield enhancer – Can BA be used to trigger out of season bud sprouting for year round production?</p> <p><u>Effect</u>: BA 100 ppm triggered bud break. Late Oct and Nov sprays induced bud break but there was no subsequent growth.</p>   | (Zhu et al. 1989)          |
| <p><i>Commelina communis</i><br/>(Asiatic dayflower)</p>   | <p><u>Cytokinin</u>: Zeatin, Kinetin <math>10^{-3}</math> to <math>10^{-1}</math> mol <math>\cdot</math> m<math>^{-3}</math> (0.22 ppm -22 ppm) / leaf strips incubated in cytokinin solutions</p> <p><u>Purpose</u>: Physiological control – Do cytokinins control stomata opening in Commelina?</p> <p><u>Effect</u>: Kinetin reduced the ability of stomata to react to light and CO<math>_2</math>, but Kinetin did not reverse the ABA stimulated closure of stomata.</p>  | (Blackman and Davies 1983) |
| <p><i>Coriandrum sativum</i><br/>(Coriander / Cilantro)</p>  | <p><u>Cytokinin</u>: BA 250 ppm / 1 to 2 foliar sprays onto field grown plants 15 days apart starting at the 5 to leaf stage</p> <p><u>Purpose</u>: Yield enhancer – Can CKs increase flower sex conversion to hermaphroditic flowers?</p> <p><u>Effect</u>: BA applied 2 times delayed flowering, reduced flowering and increased the % of bisexual flowers. GA increased maleness and increased flowering. BA+GA was similar to control.</p>  | (Amrutavalli 1980)         |
| <p><i>Cucumis melo</i><br/>(Muskmelon. Cantaloupe)</p>   | <p><u>Cytokinin</u>: BA 1000 ppm-20000 ppm / Applied to open pollinated flowers in propylene glycol droplets or in lanolin paste</p> <p><u>Purpose</u>: Yield enhancer / Do cytokinins promote fruit set?</p> <p><u>Effect</u>: Fruit set and seed set per pollination increased greatly (300 to 800%) but one cultivar had misshapen fruit.</p>  | (Jones 1965)               |

| Table A4 Continued                         |  |                            |
|--|--|----------------------------|
| Plant                                      | Notes  | Reference                  |
| <i>Cucumis sativus</i><br>(Cucumber)       | <u>Cytokinin</u> : BA $4.4 \times 10^{-9}$ M to $4.4 \times 10^{-7}$ M (1ppb - 100ppb) /<br>Seeds germinated in cytokinin solutions on filter paper<br><u>Purpose</u> : Growth promoter / inhibitor – How does cytokinin effect root growth during seed germination?<br><u>Effect</u> : 10ppb BA promoted root growth. 50ppb had no effect on root growth.                       | (Blokhin 1987)             |
| <i>Cucurbita pepo</i><br>(Summer squash)   | <u>Cytokinin</u> : BA (SD4901, Verdant) rate and application not listed<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : Not effective   | (Wittwer and Dedolph 1962) |
| <i>Curcubita maxima</i><br>(Pumpkin)       | <u>Cytokinin</u> : BA $4.4 \times 10^{-9}$ M to $4.4 \times 10^{-7}$ M (1ppb - 100ppb) /<br>Seeds germinated in cytokinin solutions on filter paper<br><u>Purpose</u> : Growth promoter / inhibitor – How does cytokinin effect root growth during seed germination?<br><u>Effect</u> : 1 to 10ppb BA promoted root growth. 100ppb had no effect on root growth or inhibited it. | (Blokhin 1987)             |
| <i>Cynara</i><br>(Artichoke)               | <u>Cytokinin</u> : BA+GA <sub>4/7</sub> 20 ppm+20 ppm / Two foliar sprays at various maturity stages<br><u>Purpose</u> : Flower promotion – Can BA+GA promote an earlier harvest?<br><u>Effect</u> : BA+GA advanced the production window but not as much as GA alone.   | (Schrader 1994)            |
| <i>Cynara</i><br>(Artichoke)               | <u>Cytokinin</u> : Cytokinin (unspecified) / Application method unspecified<br><u>Purpose</u> : Stress resistance – Can CKs cause artichokes to produce more evenly in hot growing conditions?<br><u>Effect</u> : BA reduced early bolting under heat stress.  | (Schrader 2005)            |
| <i>Cynara</i><br>(Artichoke)               | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA was not effective.  | (Zink 1961)                |
| <i>Cynodon dactylon</i><br>(Bermuda grass) | <u>Cytokinin</u> : BA 10 to 30 ppm applied every 3 months for a year<br><u>Purpose</u> : Growth enhancer – Can BA affect growth of bermuda grass?<br><u>Effect</u> : BA enhanced growth, color and density especially during summer months   | (Morales-Payan 2004)       |
| <i>Cynodon dactylon</i><br>(Bermuda grass) | <u>Cytokinin</u> : BA 12.4 mg · m <sup>2</sup> / Foliar spray 2 times over 2 weeks prior to chilling<br><u>Purpose</u> : Stress tolerance – Can BA improve tolerance to cold temps.<br><u>Effect</u> : BA did not effect any of the characteristics that measured chilling tolerance.  | (White and Schmidt 1989)   |
| <i>Cynodon dactylon</i><br>(Bermuda grass) | <u>Cytokinin</u> : BA 62g · ha <sup>-1</sup> (110 ppm) / Foliar sprays every 2 weeks from August to October<br><u>Purpose</u> : Growth enhancer – Can BA improve fall performance and post dormancy recovery of bermuda grass?<br><u>Effect</u> : BA promoted better fall color retention (but not as good as Fe or N) but did not affect spring recovery.                       | (White and Schmidt 1990)   |

| Table A4 Continued                            |  |                            |
|---|--|----------------------------|
| Plant   | Notes  | Reference                  |
| <i>Cyperus rotundus</i><br>(Purple Nutsedge)  | <p><u>Cytokinin</u>: BA+GA (Promalin) 25 to 300 ppm / Post emergence spray 1 to 6 weeks after emergence with a second spray 1 week later.</p> <p><u>Purpose</u>: Growth enhancer – Can Promalin alter nutsedge tuber or shoot growth?</p> <p><u>Effect</u>: Promalin 100 ppm increased shoot number when applied early (1 WAE) and greatly reduced tuber formation when applied late (3 to 6 WAE). Also Promalin followed by Glyphosate was as effective as 2 applications of glyphosate alone.</p>  | (Edenfield et al. 1999)    |
| <i>Cyperus rotundus</i><br>(Purple Nutsedge)  | <p><u>Cytokinin</u>: BA, PBA 50 to 100 ppm / Soil drench pre-plant or post-plant followed by a second application of BA</p> <p><u>Purpose</u>: Dormancy release – Can CKs be used to trigger tubers to sprout so they can be controlled with herbicides?</p> <p><u>Effect</u>: BA and PBA at 50 ppm or 100 ppm were effective in inducing sprouting. BA lasts less than 1wk in the soil.</p>   | (Teo and Nishimoto 1973)   |
| <i>Cyperus rotundus</i><br>(Purple Nutsedge)  | <p><u>Cytokinin</u>: BA 50 to 300 ppm / 6hr soaks before placing in Petri dishes</p> <p><u>Purpose</u>: Dormancy release – Can BA be used to trigger tubers to sprout so they can be controlled with herbicides?</p> <p><u>Effect</u>: BA 300 ppm induced the most shoots to sprout. ABA inhibited BA in this regard.</p>  | (Teo et al. 1973)          |
| <i>Daucus carota</i><br>(Carrot)              | <p><u>Cytokinin</u>: BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest</p> <p><u>Purpose</u>: Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of carrot tops?</p> <p><u>Effect</u>: BA delayed yellowing and other signs of senescence by 2 to 3 days</p>   | (Zink 1961)                |
| <i>Diospyros kaki</i><br>(Japanese Persimmon) | <p><u>Cytokinin</u>: CPPU 10 ppm / Branches wrapped tightly with a wire strap 'strapping' and fruitlet dipped into solution 10 days after full bloom.</p> <p><u>Purpose</u>: Yield enhancer – Can CKs and 'strapping' improve fruit size?</p> <p><u>Effect</u>: CPPU alone increased fruit size 8% and CPPU + strapping increased fruit size by 8.5%.</p>  | (Hamada and Hasegawa 2008) |
| <i>Diospyros kaki</i><br>(Japanese Persimmon) | <p><u>Cytokinin</u>: 4PU 10 to 100 ppm, Thidiazuron 10 to 100 ppm, BA 100 to 1000 ppm / Flower or fruit sprays at various times</p> <p><u>Purpose</u>: Yield enhancer – Can CKs improve fruit size or quality?</p> <p><u>Effect</u>: 4PU 100 ppm fruit dips were best at increasing fruit size (15mm wider and 78g heavier). Thidiazuron at 100 ppm was third best. BA had no effect at the rates tested. Fruit grew wider but not taller and had pronounced sutures. 4PU &amp; Thidiazuron delayed ripening. Sprays at full bloom also increased weight but by not as much.</p> | (Itai et al. 1995)         |

| Table A4 Continued                                  |   |                             |
|---|---|-----------------------------|
| Plant   | Notes   | Reference                   |
| <i>Diospyros kaki</i><br>(Japanese Persimmon)       | <u>Cytokinin</u> : Kinetin 500 ppm / Foliar sprays 5 times at 1 week interval starting in July.<br><u>Purpose</u> : Growth inhibition – Can Kinetin reduce growth rates?<br><u>Effect</u> : No significant effects on height. Leaf dry weight reduced slightly.   | (Park et al. 1997)          |
| <i>Elytrigia repens</i><br>(Quackgrass)             | <u>Cytokinin</u> : Zeatin 10 to 100 ppm, BA $10^{-8}$ to $10^{-5}$ M (.002 to 2 ppm) / Applied via solution or weekly lanolin paste applications to rhizome segments<br><u>Purpose</u> : Dormancy release – Can CKs release plants from dormancy and thus act as an herbicide?<br><u>Effect</u> : Zeatin 100 ppm generally promoted sprouting only on rhizomes with a terminal bud.   | (Taylor et al. 1994)        |
| <i>Fragaria</i><br><i>×ananassa</i><br>(Strawberry) | <u>Cytokinin</u> : Biostimulants with cytokinins in them – Burst, Cytex, Triggrr / All applied as per their respective directions<br><u>Purpose</u> : Yield enhancer – Can a biostimulant increase yield?<br><u>Effect</u> : No significant effect of any of the biostimulants on yield or marketable characteristics.  | (Albregts et al. 1988)      |
| <i>Fragaria</i><br><i>×ananassa</i><br>(Strawberry) | <u>Cytokinin</u> : BA 50 ppm, BA+GA <sub>3</sub> 50 ppm each / Foliar spray 4 to 5 times at weekly intervals at various times in spring.<br><u>Purpose</u> : Branching agent – Can BA influence axillary bud growth of in short day or day-neutral strawberries.<br><u>Effect</u> : BA+GA increased runner formation similar to GA alone. BA alone had no effect on the DN cultivar but increased runner or lateral crown formation on Short Day cultivars. Short Day cultivars had reduced flowering with BA or BA+GA.   | (Braun and Kender 1985)     |
| <i>Fragaria</i><br><i>×ananassa</i><br>(Strawberry) | <u>Cytokinin</u> : BA 300 to 1800, with various combination mixes of GA <sub>3</sub> 100 to 1800 ppm, GA <sub>4+7</sub> (Promalin) 500 to 1800 ppm / One or two foliar sprays at various times of the year.<br><u>Purpose</u> : Branching agent – Propagation - Can BA increase runner production (and daughter plants) of day neutral strawberries. Are there any synergistic affects of GA+BA?<br><u>Effect</u> : The best rates were BA 1200 ppm +GA <sub>3</sub> 300 ppm applied once for increasing runner production. Carryover was limited and beneficial – daughter plants had somewhat higher yield, and larger fruit. Single applications work better than multiple applications. | (Dale et al. 1996)          |
| <i>Fragaria</i><br><i>×ananassa</i><br>(Strawberry) | <u>Cytokinin</u> : BA 0.1ppm, 1.0 ppm or BA+ABA 0.1 to 1.0 ppm + 10 to 100 ppm / Detached fruits cultured in vitro with BA or BA+ABA in the media<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA 1ppm delayed time to fruit maturity by 5 days   | (Kano 1981)                 |
| <i>Fragaria</i><br><i>×ananassa</i><br>(Strawberry) | <u>Cytokinin</u> : BA 10 to 40 ppm in various combinations with NAA, and GA / Foliar sprays at full bloom and 14 days later.<br><u>Purpose</u> : Yield enhancer – Can BA reduce the number of deformed fruits in early production?<br><u>Effect</u> : BA+GA+NAA at various rates either had no positive effects. Yield was unchanged or reduced AND Fruit deformation was unchanged or increased.   | (Lopez-Galarza et al. 1993) |

| Table A4 Continued                                  |  |                           |
|---|--|---------------------------|
| Plant   | Notes  | Reference                 |
| <i>Fragaria</i><br><i>×ananassa</i><br>(Strawberry) | <p><u>Cytokinin</u>: BA 50 to 400 ppm / 1, 2, 4, or 8 weekly foliar sprays</p> <p><u>Purpose</u>: Branching agent – Propagation - Yield enhancer – Can BA increase runner formation or increase yield</p> <p><u>Effect</u>: BA 400 ppm applied once early in the season is best for increasing runners and thus increasing daughter plants. Multiple applications reduce runnering. BA increases fruit numbers but decreases individual fruit weight. BA 100 ppm applied once resulted in the largest yield. There were 50% more berries but they were 12% smaller. Foliar spray applications led to increased nutrient levels in the leaves</p>                                 | (Pritts et al. 1986)      |
| <i>Glycine max</i><br>(Soybean)                     | <p><u>Cytokinin</u>: BA <math>4.4 \times 10^{-9}</math>M to <math>4.4 \times 10^{-7}</math>M (1ppb - 100ppb) / Seeds germinated in cytokinin solutions on filter paper</p> <p><u>Purpose</u>: Growth promoter / inhibitor – How does cytokinin effect root growth during seed germination?</p> <p><u>Effect</u>: All rates of BA inhibited root growth or had no effect. However root branching was improved</p>   | (Blokhin 1987)            |
| <i>Glycine max</i><br>(Soybean)                     | <p><u>Cytokinin</u>: Thidiazuron (Dropp 50WP) 8.8 to 1120 g ai / ha applied at 350L / ha (200 ppm-16000 ppm) / Postemergence sprays to 2 to 8wk old plants</p> <p><u>Purpose</u>: Growth control – Can Thidiazuron be sprayed on soy to control weeds without harming it?</p> <p><u>Effect</u>: Thidiazuron 280g ai / ha and higher caused some phytotoxicity, reduced height by 17 to 34% but did not reduce dry weight or leaf area. Injury symptoms disappeared after 10 weeks. Harvest yields and final dry weight was not affected. Thus Thidiazuron may be used to control velvetleaf in soy without impacting yield.</p>  | (Hodgson and Snyder 1988) |
| <i>Glycine max</i><br>(Soybean)                     | <p><u>Cytokinin</u>: BA <math>10^{-3}</math>M to <math>10^{-6}</math>M (225.25 ppm to 0.225 ppm) / Absorption of 50ml of solution via cotton wick inserted through stem for 2 weeks during anthesis. Greenhouse and field trials conducted.</p> <p><u>Purpose</u>: Yield enhancer – Can BA increase seed production?</p> <p><u>Effect</u>: Greenhouse: <math>10^{-3}</math>M BA killed the plants. <math>5 \times 10^{-8}</math> moles to <math>5 \times 10^{-7}</math> moles of total BA absorbed was best at increasing pod set, seed set, and overall yield (&gt;50% increase). Some phytotoxicity noted. Field: No BA rate significantly increased yield.</p>                | (Nagel et al. 2001)       |
| <i>Gossypium hirsutum</i><br>(Cotton)               | <p><u>Cytokinin</u>: Thidiazuron (Dropp 50WP) 8.8 to 1120 g ai / ha applied at 350L / ha (200 ppm-16000 ppm) / Postemergence sprays to 2 to 8wk old plants</p> <p><u>Purpose</u>: Growth control – Can Thidiazuron be sprayed on cotton to control weeds without harming the cotton?</p> <p><u>Effect</u>: Thidiazuron 5 g ai / ha caused 20% injury to 2wk old plants. 20 g ai / ha caused 20% injury to 8 wk old plants. But rates under 70g ai / ha also promoted height growth of 2 wk old seedlings. 1120g ai / ha reduced the height growth less than 20%. Thidiazuron did not affect height of 8 wk old seedlings. Thidiazuron also reduced dry weight of the plants.</p> | (Hodgson and Snyder 1988) |

| Table A4 Continued                                |   |                              |
|---|---|------------------------------|
| Plant   | Notes   | Reference                    |
| <i>Gossypium hirsutum</i> (Cotton)                | <p><u>Cytokinin</u>: BA 5 <math>\mu</math>M (1ppm) / Foliar spray onto plants 24hr prior to beginning of drought</p> <p><u>Purpose</u>: Stress tolerance / Can BA reduce the effect of drought on cotton production?</p> <p><u>Effect</u>: BA alleviated the effects of drought and increased the lint production per plant. ABA increased lint mass even more.</p>   | (Pandey et al. 2003/4)       |
| <i>Hibiscus rosa-sinensis</i> (Tropical hibiscus) | <p><u>Cytokinin</u>: Thidiazuron (Dropp 50WP) 8.8 to 1120 g ai / ha applied at 350L / ha (200 ppm-16000 ppm) / Postemergence sprays to 2 to 8wk old plants</p> <p><u>Purpose</u>: Growth control – Can Thidiazuron be sprayed on hibiscus to control weeds without harming it?</p> <p><u>Effect</u>: Thidiazuron severely injured the plants. 8.8g ai / ha caused &gt;20% injury on 2wk old plants and 26g ai/ha injured 8wk old plants. Thidiazuron also reduced the height of the youngest plants and slightly reduced dry weight.</p>  | (Hodgson and Snyder 1988)    |
| <i>Hordeum vulgare</i> (Barley)                   | <p><u>Cytokinin</u>: BA <math>5 \times 10^{-5}</math>M (11ppm) / Daily sprays on either leaves, ears, or whole plant for 7 days.</p> <p><u>Purpose</u>: Yield enhancer – Determine which treatment method works best.</p> <p><u>Effect</u>: Spraying leaves had no effect. Spraying whole plant increased yield by 11% and spraying ears increased yield by 20%.</p>  | (Hosseini and Poustini 2008) |
| <i>Hordeum vulgare</i> (Barley)                   | <p><u>Cytokinin</u>: Kinetin, Zeatin <math>10^{-6}</math>M to <math>10^{-4}</math>M (0.2 – 22 ppm) / Tissues <i>in-vitro</i> with cytokinins in the agar 16h after inoculation.</p> <p><u>Purpose</u>: Disease resistance – Can inhibit powdery mildew development and stimulate the hypersensitive response?</p> <p><u>Effect</u>: Kinetin is involved with both the development of the fungus and the plant HR. Kinetin 22 ppm accelerated cell death via the HR by 83% and increased the number of cells that died. Zeatin had no effect. Kinetin 2 ppm-22 ppm also inhibited haustoria and hyphae development and caused malformed haustoria.</p> | (Liu and Bushnell 1986)      |
| <i>Ipomoea batatas</i> (Sweetpotato)              | <p><u>Cytokinin</u>: BA+GA (Promalin) 5 to 50 ppm / roots immersed for 10 minutes prior to placing into forcing beds.</p> <p><u>Purpose</u>: Branching agent – Propagation – Can BA increase the number of slips produced from roots in forcing beds?</p> <p><u>Effect</u>: Promalin did not reduce time to emergence but did lead to earlier slip harvest. Number of slips was not increased and transplanting was not affected.</p>   | (Hall 1994)                  |

| Table A4 Continued  |   |                            |
|---|---|----------------------------|
| Plant   | Notes   | Reference                  |
| <i>Ipomoea nil</i> syn. <i>Pharbitis nil</i> (Japanese Morning Glory) | <u>Cytokinin</u> : BA 10 <sup>-5</sup> to 10 <sup>-3</sup> M (2 to 225 ppm) / Applied by brush to the cotyledons 3x per day for 1 to 5 days<br><u>Purpose</u> : Flower enhancer – Can CKs promote flowering in a Short Day plant held in non-inductive conditions?<br><u>Effect</u> : BA 225 ppm applied for 2 or more days induced flowering in noninductive conditions. BA applied for 5 days maximized flower production. BA reduced internode length and thus overall stem length. BA applied to the shoot tip did not induce flowering. BA took about 9 days to stimulate flowering. | (Ogawa and King 1980)      |
| <i>Juglans regia</i> (Walnut)   | <u>Cytokinin</u> : BA+GA (Promalin) rate and application method unspecified<br><u>Purpose</u> : Branching agent – Can Promalin aid in scaffold branch production and thus speed up commercial production<br><u>Effect</u> : Promalin was not effective in improving branch angles.  | (Beede 2005)               |
| <i>Lactuca sativa</i> (Leaf lettuce)                                  | <u>Cytokinin</u> : BA 5 to 25 ppm / Plant immersed for 10min or bases immersed for 18hr<br><u>Purpose</u> : Senescence inhibitor / Can BA improve postharvest quality?<br><u>Effect</u> : BA was ineffective at preventing quality grade drops.   | (Halevy et al. 1965)       |
| <i>Lactuca sativa</i> (Leaf lettuce)                                  | <u>Cytokinin</u> : BA (SD4901, Verdan) rate not listed / Pre or post harvest treatments.<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : Not effective   | (Wittwer and Dedolph 1962) |
| <i>Lactuca sativa</i> (Lettuce – Iceburg)                             | <u>Cytokinin</u> : BA 1.0 mM (225 ppm) / Single foliar spray 1 hour prior to inoculation<br><u>Purpose</u> : Disease control – Can BA reduce Sclerotinia sclerotium (white rot)?<br><u>Effect</u> : BA did not reduce Sclerotinia severity.   | (Elad 1993)                |
| <i>Lactuca sativa</i> (Lettuce)                                       | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days   | (Zink 1961)                |
| <i>Lactuca sativa</i> (Romaine lettuce)                               | <u>Cytokinin</u> : 2iP 0.1ppm + GA <sub>3</sub> 10 ppm / Single foliar spray 2 days before harvest and held in cold storage for 3 weeks<br><u>Purpose</u> : Senescence inhibitor / Can 2iP improve postharvest characteristics of Romaine lettuce?<br><u>Effect</u> : 2iP + GA <sub>3</sub> reduced leaf yellowing and reduced the number of leaves that had to be trimmed but did not reduce leaf decay. 10 ppm GA <sub>3</sub> was better than 1ppm GA <sub>3</sub> but only when mixed with 2iP. The type of packaging affected the results too.                                       | (Aharoni et al. 1975)      |
| <i>Lactuca sativa</i> var. <i>capitata</i> (Head lettuce)             | <u>Cytokinin</u> : BA 5 ppm, Kinetin 5 ppm, HappyGro 5 ppm / 1 to 3 Foliar spray applications at various times during head growth.<br><u>Purpose</u> : Yield enhancer – Can BA increase head size?<br><u>Effect</u> : BA applied once, two weeks before harvest increased head weight (8%) and diameter (4%). Kinetin and HappyGro sprayed 3 times after head formation were less effective   | (Fonseca 2004)             |

| Table A4 Continued  |   |                            |
|---|---|----------------------------|
| Plant   | Notes   | Reference                  |
| <i>Lactuca sativa</i><br>var. <i>capitata</i><br>(Head lettuce) | <p><u>Cytokinin</u>: BA 10 ppm / Single foliar spray applied 2hrs before harvest followed by commercial packing, cooling and transcontinental train shipping</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA improve postharvest characteristics of head lettuce?</p> <p><u>Effect</u>: BA improved quality ratings of lettuce at delivery best on short trips but was also significant for long trips. Respiration in treated leaves was higher than untreated leaves. BA delayed yellowing much better in heads shipped at 20°C than at 3°-5°C. Only the outer leaves were affected. BA did not prevent yellowing of inner leaves and thus did not improve the marketability of trimmed heads.</p> | (Lipton and Ceponis 1962)  |
| <i>Lactuca sativa</i><br>var. <i>capitata</i><br>(Head lettuce) | <p><u>Cytokinin</u>: BA (SD4901, Verdant) rate not listed / Pre or post harvest treatments.</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA delay senescence?</p> <p><u>Effect</u>: Mixed results. Works in some experiments and not in others</p>   | (Wittwer and Dedolph 1962) |
| <i>Lagenaria leucantha</i><br>(Chinese white flowered gourd)    | <p><u>Cytokinin</u>: BA 50 ppm, DPU 50 ppm, 4-PU 50 ppm, CPPU 10 to 100 ppm / Ovaries sprayed once from 2 days before anthesis to 12 days after.</p> <p><u>Purpose</u>: Fruit enhancer / Senescence inhibitor – Can CKs cause parthenocarpy during winter when few male flowers are set?</p> <p><u>Effect</u>: CPPU 100 ppm induced 100% fruit set on unpollinated female flowers at any time near anthesis. The other CKs were not effective.</p>  | (Yu 1999)                  |
| <i>Lemna aequinoctialis</i><br>(Duckweed)                       | <p><u>Cytokinin</u>: Zeatin 1 ppm OR BA <math>10^{-7}</math> to <math>10^{-4}</math>M (.02 ppm to 22.5 ppm) / (Application method not provided)</p> <p><u>Purpose</u>: Flower enhancer – Does zeatin promote flowering of this SD plant under LDs?</p> <p><u>Effect</u>: Zeatin promotes flowering. BA .02 ppm to 22.5 ppm inhibits flowering in LD grown plants. BA 2.2 to 22.5 ppm inhibits flowering in plants grown under SDs.</p>  | (Kandeler 1986)            |
| <i>Lemna gibba</i><br>(Duckweed)                                | <p><u>Cytokinin</u>: Kinetin <math>10^{-9}</math>M to <math>10^{-6}</math> M (0.2 ppb to 0.2 ppm) / (Application method not provided)</p> <p><u>Purpose</u>: Flower enhancer – Does kinetin promote flowering of this LD plant when applied under LDs?</p> <p><u>Effect</u>: <math>10^{-9}</math> M promotes but <math>10^{-6}</math> M inhibits flowering</p>  | (Kandeler 1986)            |
| <i>Lens culinaris</i><br>(Lentils)                              | <p><u>Cytokinin</u>: Kinetin 10 to 40 ppm / Foliar spray twice at 70 and 80 days after sowing.</p> <p><u>Purpose</u>: Branching agent / Yield enhancer – Does Kinetin improve yield of Lentils?</p> <p><u>Effect</u>: Kinetin 40 ppm reduced height 25% but increased branching 25%, flowering almost 50%, and yield 38%.</p>   | (Khalil et al. 2006)       |

| Table A4 Continued  |  |                         |
|---|--|-------------------------|
| Plant   | Notes  | Reference               |
| <i>Litchi sinensis</i><br>(Litchi fruit)                                      | <p><u>Cytokinin</u>: CPPU 5 to 10 ppm / Applied to green fruits at 25 to 30mm size</p> <p><u>Purpose</u>: Senescence Delay – Can CPPU delay harvest and extend the Litchi season?</p> <p><u>Effect</u>: CPPU delayed ripening by 2 to 3 weeks thus extending the harvesting season. Fruit were 25% larger and showed less senescence in storage after harvest.</p>   | (Stern et al. 2006)     |
| <i>Luffa cylindrica</i><br>(Sponge luffa)                                     | <p><u>Cytokinin</u>: BA 50 ppm / Cotton soaked in solution applied to staminate flowers 4x per day at 3 day intervals</p> <p><u>Purpose</u>: Yield enhancer – Can BA increase flower sex conversion to hermaphroditic flowers?</p> <p><u>Effect</u>: BA converted some of the staminate flowers to pistillate flowers, hermaphroditic flowers, or shoots.</p>  | (Takahashi et al. 1980) |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> )<br>(Tomato) | <p><u>Cytokinin</u>: Kinetin <math>5 \times 10^{-5}</math> to <math>5 \times 10^{-2}</math> ppm / Roots dipped into Liqua-Gel with the hormone mixed in it at transplant</p> <p><u>Purpose</u>: Stress tolerance – Can Kinetin applied to roots at transplant time reduce transplant shock?</p> <p><u>Effect</u>: <math>5 \times 10^{-4}</math> ppm Kinetin in the gel resulted in tomatoes with increased leaf area, plant dry weight and relative growth weight. The highest rate of kinetin was not as good.</p>  | (Arteca 1982)           |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> )<br>(Tomato) | <p><u>Cytokinin</u>: Kinetin 0.0047<math>\mu</math>M to 4.7<math>\mu</math>M (0.001 to 1ppm) / Kinetin added to fertilizer tank solution of greenhouse grown plants or plants dipped (pulsed) in nutrient solution with kinetin in it for 4, 8, or 12 hr. Kinetin applied for 2 to 7 days in a row.</p> <p><u>Purpose</u>: Growth enhancer – Do cytokinins stimulate growth?</p> <p><u>Effect</u>: Kinetin increased photosynthesis and dry weight of the plants. The 1ppm rate improved growth only if it was applied for not more than 2 days. Longer exposures reduced growth. The 0.001ppm rate worked well if the exposure was 7 days. 12 hr pulses were best at increasing growth.</p> | (Dong and Arteca 1982)  |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> )<br>(Tomato) | <p><u>Cytokinin</u>: BA 0.1 to 1.0 mM (22.5 to 225 ppm) / Single foliar spray 1 hour prior to inoculation</p> <p><u>Purpose</u>: Disease control – Can BA reduce Botrytis (Gray Mold)?</p> <p><u>Effect</u>: BA 225 ppm reduced Botrytis severity on flowers and leaves by 37%. It reduces the plants sensitivity to ethylene but does not affect the plants production of ethylene</p>  | (Elad 1993)             |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> )<br>(Tomato) | <p><u>Cytokinin</u>: BA <math>10^{-9}</math> to <math>10^{-5}</math> M (0.002 - 2.25 ppm) / sprayed or dropped onto the second flower cluster as the third cluster reached anthesis</p> <p><u>Purpose</u>: Yield enhancer – Can BA improve or speed up fruit set?</p> <p><u>Effect</u>: BA 2.25 ppm accelerated fruit set by 1wk over control. The lower rates of BA delayed fruit set. BA was not as fast as ACC in this regard.</p>  | (El-adb et al. 1986)    |

| Table A4 Continued   |   |                             |
|--|---|-----------------------------|
| Plant  | Notes   | Reference                   |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> ) (Tomato) | <p><u>Cytokinin</u>: BA+GA 10 ppm each / 4Foliar sprays: 24hr before flooding, and 24, 48, 96hr later.</p> <p><u>Purpose</u>: Stress tolerance – Can BA reduce the stress caused by flooding?</p> <p><u>Effect</u>: BA+GA reduced the effects of flooding: epinasty, reduction in stem growth and reduction in dry weight gain. It increased transpiration. However, it reduced root growth during this period</p>  | (Jackson and Campbell 1979) |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> ) (Tomato) | <p><u>Cytokinin</u>: Kinetin <math>10^{-4}</math>M / Seeds soak prior to sowing</p> <p><u>Purpose</u>: Yield enhancer – Does Kinetin increase yield?</p> <p><u>Effect</u>: No effect listed</p>   | (Saxena et al. 1987)        |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> ) (Tomato) | <p><u>Cytokinin</u>: BA 5 ppm with or without GA 5 ppm and N 280 ppm / 5 Foliar sprays over 7 days onto plants grown non-aerated liquid solutions</p> <p><u>Purpose</u>: Stress tolerance – Can BA reduce the stress caused by flooding?</p> <p><u>Effect</u>: GA+BA+Nitrogen resulted in plants with the highest quality. BA contributed to thicker shoots, reduced height, reduced epinasty, reduced chlorosis, and reduced adventitious root formation. Some phytotoxicity noted with BA – cupping and anthocyanin accumulation.</p> | (Selman and Sandanam 1972)  |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> ) (Tomato) | <p><u>Cytokinin</u>: CPPU 1ppm, BA+GA<sub>4+7</sub> 1ppm each / Applied 3 times</p> <p><u>Purpose</u>: Yield enhancer – Do CKs increase yield?</p> <p><u>Effect</u>: BA+GA<sub>4+7</sub> was best at increasing fruit set, the number of fruit per truss, and the overall truss mass with no deformities.</p>   | (Tonder and Combrink 2003)  |
| <i>Lycopersicon esculentum</i> (syn <i>Solanum lycopersicum</i> ) (Tomato) | <p><u>Cytokinin</u>: Kinetin 1000 ppm / Lanolin paste applied to lateral buds every 3 days</p> <p><u>Purpose</u>: Branching agent – Does Kinetin promote lateral branching?</p> <p><u>Effect</u>: Kinetin promotes much higher branching than controls.</p>   | (Tucker 1977)               |
| <i>Malus pumila</i> (Apple)  | <p><u>Cytokinin</u>: BA+GA (Promalin) 5% (950 ppm) / single foliar spray in spring when the new terminal shoot was 6 to 10mm</p> <p><u>Purpose</u>: Branching agent – Can Promalin improve branching and break bud dormancy of apple in tropical environments?</p> <p><u>Effect</u>: Promalin 5% increased branching but not by as much as Dormex. Promalin did not break bud dormancy but Dormex did.</p>  | (Jackson 1997)              |
| <i>Malus sylvestris</i> var. <i>domestica</i> (Apple)                      | <p><u>Cytokinin</u>: BA 75 ppm / Single foliar spray at various times during a single day</p> <p><u>Purpose</u>: Fruit thinning – Does the time of day affect BA's affect?</p> <p><u>Effect</u>: BA thinned fruit but the time of day of the application was not important</p>  | (Cline and Bijl 2002)       |

| Table A4 Continued                  |   |                         |
|-------------------------------------|---|-------------------------|
| Plant                               | Notes   | Reference               |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA+GA (Promalin) 250 to 500 ppm / Single foliar sprays at two different times in July</p> <p><u>Purpose</u>: Branching agent – Can Promalin improve branching of 1yr old apple trees?</p> <p><u>Effect</u>: 500 ppm Promalin induced branching in 3 of 5 cultivars tested but reduced height of the leader. Earlier applications led to better crotch angles.</p>  | (Basak and Soczek 1986) |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA+GA (Promalin) 1000 to 2000 ppm / One or two sprays onto newly sprouted scions</p> <p><u>Purpose</u>: Branching agent – Can Promalin increase scion branching in the nursery?</p> <p><u>Effect</u>: Promalin 500 ppm applied two times increased branching the most over pruning.. BA alone was not as good as pruning.</p>  | (Cody et al. 1985)      |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: Thidiazuron (Lift) 5% (1500 ppm) / Single spray onto dormant plants 5 to 6 weeks before expected full bloom</p> <p><u>Purpose</u>: Dormancy release – Can Lift release apples from dormancy in low chill environments?</p> <p><u>Effect</u>: Lift 5% solutions promote bud break of apples in low chill environments when sprayed 5 to 6 weeks before predicted full bloom. Dormex can promote even earlier bud break but Lift does not lead to reduced yield as Dormex is perceived to.</p>   | (Costa et al. 2004)     |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA 250 to 500 ppm, BA+GA<sub>4+7</sub> 250 to 500 ppm / Single foliar spray during vegetative growth</p> <p><u>Purpose</u>: Branching agent – Can BA improve feathering?</p> <p><u>Effect</u>: BA+GA 500 ppm was better than BA alone in most cultivars in increasing branching.</p>   | (Elfving 1985)          |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA 50 to 300 ppm, with or without Daminozide 1500 ppm / foliar spray 12 days after full bloom and 3 weeks later</p> <p><u>Purpose</u>: Branching agent – Fruit thinner / Can BA applied to producing ‘Empire’ trees, stimulate lateral branching without over thinning?</p> <p><u>Effect</u>: BA 100 ppm or higher increased lateral branching and thinned fruits. Daminozide reduced the effect of BA. BA did not effect terminal growth. 2 applications of BA were the same as one on thinning but 2 applications increased spur weight and decreased bud weight and diameter.</p> | (Green and Autio 1990)  |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA, BA+GA<sub>4+7</sub> (Cytolin) / 1 to 4 weekly foliar sprays to the growing tip of the trees in December</p> <p><u>Purpose</u>: Branching agent – Can BA improve branching in spur-type apple trees?</p> <p><u>Effect</u>: Cytolin 1x at 800 ppm or 4x at 200 ppm greatly increased branching and improved crotch angles better than pinching. BA alone had no effect.</p>  | (Jarassamrit 1989)      |

| Table A4 Continued                  |   |                             |
|-------------------------------------|---|-----------------------------|
| Plant                               | Notes   | Reference                   |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA, BA+GA<sub>3</sub>, BA+GA<sub>4+7</sub> 250 to 2000 ppm / Single foliar spray in late June or in early July</p> <p><u>Purpose</u>: Branching agent – Can BA improve feathering?</p> <p><u>Effect</u>: No difference in type of GA used. 500 ppm BA+GA induced the most branches and were better than pinching. Rates above 500 ppm reduced branching.</p>   | (Juamièn et al. 1992)       |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA, BA+GA (Promalin) 137 g•ha<sup>-1</sup> to 228 g•ha<sup>-1</sup> / Foliar sprays at various amounts of water per hectare 375 to 2800L•ha<sup>-1</sup></p> <p><u>Purpose</u>: Branching agent – Does BA stimulate branching when applied at 7.5x concentrated low volume sprays?</p> <p><u>Effect</u>: Low volumes below 400L•ha<sup>-1</sup> were ineffective at inducing branching.</p>  | (Miller 1985)               |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: Thidiazuron 750µM (165 ppm) / Shoots dipped into solution before chilling begins or at various points during chilling</p> <p><u>Purpose</u>: Dormancy release – Can Thidiazuron substitute for chilling hours in low, medium and high chill requirement apples?</p> <p><u>Effect</u>: Thidiazuron promoted early bud break on all apple types when applied pre-chill. When applied post-chill, bud break occurred at lower percentages only on low chill and medium chill apples. There were positional effects.</p> | (Steffens and Stutte 1989)  |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA, Promalin, Accel / Sprays</p> <p><u>Purpose</u>: Fruit thinning – Fruit shape – Fruit size</p> <p><u>Effect</u>: BA increases fruit size. BA may be used for thinning of certain round-type apples. BA and Promalin 150 ppm stimulate lateral branching and bud initiation which increases flowering in the next year. Promalin and Accel improve the typiness of apples. Timing is important.</p>  | (Williams and Fallahi 1999) |
| <i>Malus x domestica</i><br>(Apple) | <p><u>Cytokinin</u>: BA 20 ppm / Applied to apple fruit wounds alone or with a fungal controlling bacteria <i>Cryptococcus laurentii</i></p> <p><u>Purpose</u>: Postharvest – Does BA or BA+bacteria reduce blue mold growth on stored apples?</p> <p><u>Effect</u>: BA alone was ineffective. <i>C. laurentii</i> was effective at delaying blue mold. BA + <i>C. laurentii</i> was even more effective.</p>   | (Yu et al. 2008)            |
| <i>Mangifera indica</i><br>(Mango)  | <p><u>Cytokinin</u>: BA 2*10<sup>-4</sup>M (45 ppm) / Harvested fruits held in 8L of BA solution for 6h followed by drying and shelf ripening.</p> <p><u>Purpose</u>: Postharvest / Senescence Delay – Can BA increase shelf life of Mango without affecting fruit quality?</p> <p><u>Effect</u>: BA delayed ripening by 2 days. The sugar content, acid content, and amino acid content varied slightly with BA use. No difference in color or flavor.</p>   | (Passera and Spettoli 1981) |

| Table A4 Continued                           |   |                                |
|--|---|--------------------------------|
| Plant  | Notes   | Reference                      |
| <i>Mangifera indica</i><br>(Mango)           | <p><u>Cytokinin</u>: BA 500 to 1000 ppm / Weekly Foliar sprays at various times</p> <p><u>Purpose</u>: Flower enhancer (sex) – Yield enhancer – Can BA increase the incidence of perfect flowers?</p> <p><u>Effect</u>: BA 1000 ppm applied once floral organs had differentiated increased the number of perfect flowers</p>   | (Utsunomiya et al. 1995)       |
| <i>Nasturtium officinale</i><br>(Watercress) | <p><u>Cytokinin</u>: BA (SD4901, Verdant) rate and application not listed</p> <p><u>Purpose</u>: Senescence inhibitor / Can BA delay senescence?</p> <p><u>Effect</u>: BA is effective at maintaining freshness</p>   | (Wittwer and Dedolph 1962)     |
| <i>Nicotiana tabacum</i><br>(Tobacco)        | <p><u>Cytokinin</u>: BA <math>10^{-10}</math>M to <math>10^{-3}</math>M (.022ppb - 225.25 ppm) / Seeds germinated on filter paper moistened with 5ml of the solution</p> <p><u>Purpose</u>: Germination promoter – Can BA promote germination of seed in non-inductive (dark) conditions?</p> <p><u>Effect</u>: Concentrations below <math>10^{-6}</math>M promoted germination while concentrations above this level inhibited germination. BA <math>10^{-7}</math>M was optimal. Many other growth substances promoted germination too.</p>   | (Spaulding and Steffens 1969)  |
| <i>Occimum basilicum</i><br>(Basil)          | <p><u>Cytokinin</u>: Kinetin 50 ppm / Foliar spray 3 times at 3 week intervals starting 14DAT</p> <p><u>Purpose</u>: Growth enhancer - Yield enhancer – Can Kinetin improve essential oil content and growth?</p> <p><u>Effect</u>: Kinetin increased plant height, leaf fresh and dry weight (but not as much as other treatments). Kinetin increased branching more than all other treatments. Kinetin increased the number of leaves and leaf size but not as much as GA. Kinetin increased essential oil content of leaves better than all other treatments but some essential oil components were reduced.</p> | (Mahmoud 1996)                 |
| <i>Olea europaea</i><br>(Olive)              | <p><u>Cytokinin</u>: CPPU 20 to 120 ppm / Single foliar spray applied 2wk after full bloom</p> <p><u>Purpose</u>: Yield enhancer – Can CPPU improve yield or fruit qualities?</p> <p><u>Effect</u>: CPPU 20 ppm was the best rate and increased weight (42%), pulp to pit ratio, fruit oil content and fruit drop. 60 to 120 ppm caused a slight reduction in yield.</p>  | (Antognozzi and Proietti 1995) |
| <i>Olea europaea</i><br>(Olive)              | <p><u>Cytokinin</u>: CPPU 20 to 60 ppm / Single foliar spray applied 2 to 4 weeks after full bloom</p> <p><u>Purpose</u>: Yield enhancer – Can CPPU improve yield or fruit qualities?</p> <p><u>Effect</u>: CPPU 60 ppm 2 weeks after bloom increased size 22 to 41% and weight of fruit but did not affect any other quality such as oil content, and firmness. CPPU was ineffective 4 weeks after bloom. CPPU appeared to delay fruit ripening by a small amount.</p>   | (Antognozzi et al. 1993)       |

| Table A4 Continued                               |  |                               |
|--|--|-------------------------------|
| Plant  | Notes  | Reference                     |
| <i>Olea europaea</i><br>(Olive)                  | <p><u>Cytokinin</u>: BA 25 to 100 ppm / Harvested fruit immersed for 1h prior to storage</p> <p><u>Purpose</u>: Senescence inhibitor – Postharvest – Can BA improve postharvest qualities of olives or promote the postharvest color change from green to purple?</p> <p><u>Effect</u>: BA 100 ppm delayed color degradation when olives were stored at 12°C but BA accelerated color change to red-purple in fruit stored at 24°C. BA increased ethylene production and respiration in fruit but did not affect firmness.</p> | (Tsantili et al. 2002)        |
| <i>Oryza sativa</i> var. <i>indica</i><br>(Rice) | <p><u>Cytokinin</u>: BA 10<sup>-5</sup>M () + Brassinolide 10<sup>-7</sup>M / At least 3foliar sprays given throughout development of the plant.</p> <p><u>Purpose</u>: Yield enhancer – Does BA+BR increase crop yield in pot grown rice?</p> <p><u>Effect</u>: BA+BR increases rice grain size by almost 40%.</p>  | (Krishnan et al. 1999)        |
| <i>Oryza sativa</i> var. <i>indica</i><br>(Rice) | <p><u>Cytokinin</u>: BA / Foliar spray 100 µM (22.5 ppm) at the 6 leaf stage or drench 0.01 µM (.002 ppm) at the 8 leaf stage</p> <p><u>Purpose</u>: Branching agent – Does BA induce tillering?</p> <p><u>Effect</u>: Both application methods inhibited tillering in contrast to their expectations.</p>   | (Liu et al. 2001)             |
| <i>Panax quinquefolium</i><br>(Ginseng)          | <p><u>Cytokinin</u>: Thidiazuron 62.5 or 125 ppm / Single foliar spray 3 months prior to harvest.</p> <p><u>Purpose</u>: Yield enhancer – Does Thidiazuron increase root weight?</p> <p><u>Effect</u>: Thidiazuron increased yield by 19 to 23% and induced additional adventitious buds on roots.</p>   | (Proctor et al. 1996)         |
| <i>Petroselinum crispum</i><br>(Parsley)         | <p><u>Cytokinin</u>: BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest</p> <p><u>Purpose</u>: Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?</p> <p><u>Effect</u>: BA delayed yellowing and other signs of senescence by 2 to 3 days</p>  | (Zink 1961)                   |
| <i>Phaseolus limensis</i><br>(Lima beans)        | <p><u>Cytokinin</u>: BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest</p> <p><u>Purpose</u>: Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?</p> <p><u>Effect</u>: BA was not effective.</p>  | (Zink 1961)                   |
| <i>Phaseolus vulgaris</i><br>(Bean)              | <p><u>Cytokinin</u>: BA 0.1 to 1.0 mM (22.5 to 225 ppm) / Single foliar spray 1 hour prior to inoculation</p> <p><u>Purpose</u>: Disease control – Can BA reduce Botrytis (Gray Mold)?</p> <p><u>Effect</u>: BA did not reduce Botrytis severity.</p>  | (Elad 1993)                   |
| <i>Phaseolus vulgaris</i><br>(Bean)              | <p><u>Cytokinin</u>: BA 1 µM-10 µM (0.225 to 2.25 ppm) / Foliar sprays or drenches onto water stressed plants</p> <p><u>Purpose</u>: Stress response – Can cytokinins help plants recover from drought stress more quickly?</p> <p><u>Effect</u>: 0.225 ppm slightly improved (10%) net photosynthetic rate and chlorophyll content while 2.25 ppm degraded them.</p>  | (Rulcová and Popíšilová 2001) |

| Table A4 Continued                        |  |                                   |
|---|--|-----------------------------------|
| Plant                                     | Notes  | Reference                         |
| <i>Phaseolus vulgaris</i><br>(Snap beans) | <u>Cytokinin</u> : BA (SD4901, Verdan) rate and application not listed<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : Not effective  | (Wittwer and Dedolph 1962)        |
| <i>Phaseolus vulgaris</i><br>(Snap beans) | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA was not effective.  | (Zink 1961)                       |
| <i>Piper betel</i><br>(Betel)             | <u>Cytokinin</u> : BA 5 ppm / Leaves dipped prior to packing<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence during shipping?<br><u>Effect</u> : BA delayed yellowing by about 3d.  | (Venkata-Rao and Narasimham 1977) |
| <i>Pisium sativum</i><br>(Pea)            | <u>Cytokinin</u> : Kinetin $10^{-4}$ M / Seeds soak prior to sowing<br><u>Purpose</u> : Yield enhancer – Does Kinetin increase yield?<br><u>Effect</u> : Kinetin caused taller plants increased pod weight but not as well as GA soaks. Kinetin caused a larger percentage of large fruits to be produced compared to small fruits.  | (Saxena et al. 1987)              |
| <i>Pistacia vera</i><br>(Pistachio)       | <u>Cytokinin</u> : BA 25 ppm + urea (2500 ppm N) / Two foliar sprays in June and July<br><u>Purpose</u> : Yield enhancer – Can BA reduce alternate bearing or increase yields?<br><u>Effect</u> : BA + urea foliar sprays reduced alternate bearing and increased total yield by 29%   | (Daoudi et al. 2002)              |
| <i>Pistacia vera</i><br>(Pistachio)       | <u>Cytokinin</u> : BA 50 to 100 ppm / Two sprays onto fruit at the beginning of kernel growth and 1 month later.<br><u>Purpose</u> : Disease resistance – Can BA reduce hull splitting and thus reduce infections by <i>Aspergillus</i> spp.?<br><u>Effect</u> : BA 100 ppm greatly reduced hull splitting and slipping and resulted in increased kernel crude fat % and kernel chlorophyll. BA completely prevented aflatoxin production by <i>Aspergillus</i> spp. Author recommends BA for use on Pistachios. | (Rahemi and Pakkish 2005)         |
| <i>Pisum sativum</i><br>(Pea)             | <u>Cytokinin</u> : Kinetin 30 ppm / Single foliar spray<br><u>Purpose</u> : Growth promoter – Does Kinetin induce nodule formation in legumes, and subsequent growth?<br><u>Effect</u> : Nodule number and size increased significantly. Later, fresh weight of plants, height, number and weight of peas, produced was also higher.   | (Artamonov 1975)                  |
| <i>Pisum sativum</i><br>(Pea)             | <u>Cytokinin</u> : BA $4.4 \times 10^{-9}$ M to $4.4 \times 10^{-7}$ M (1ppb - 100ppb) / Seeds germinated in cytokinin solutions on filter paper<br><u>Purpose</u> : Growth promoter / inhibitor – How does cytokinin effect root growth during seed germination?<br><u>Effect</u> : All rates of BA inhibited.  | (Blokhin 1987)                    |

| Table A4 Continued                           |  |                             |
|--|--|-----------------------------|
| Plant  | Notes  | Reference                   |
| <i>Pisum sativum</i><br>(Pea)                | <p><u>Cytokinin</u>: BA 50 ppm / Single foliar spray on 30 day old plants</p> <p><u>Purpose</u>: Stress tolerance / Can BA prevent a drop in photosynthesis under poor lighting conditions?</p> <p><u>Effect</u>: BA reduced the drop in photosynthesis, chlorophyll and Rubisco that normally occurs in low light conditions. Photosynthesis in controls dropped by 50%, BA treated plants dropped by 25%. Rubisco drop was 80% vs 20% in BA treated plants. Chlorophyll did not drop significantly in BA treated plants.</p>   | (Chernyad'ev et al. 1990)   |
| <i>Poa pratensis</i><br>(Kentucky bluegrass) | <p><u>Cytokinin</u>: BA 62g / ha / Applied as a spray 15min before harvest.</p> <p><u>Purpose</u>: Stress tolerance – Can BA reduce the affects of heat stress on shipped sod?</p> <p><u>Effect</u>: BA had no effect on reducing the heat stress.</p>   | (King et al. 1982)          |
| <i>Prunus avium</i><br>(Sour Cherry)         | <p><u>Cytokinin</u>: BA 15mg per trees / Applied to the collar of the tree in lanolin paste on a aluminum foil wrap.</p> <p><u>Purpose</u>: Growth inhibition – Can BA act as a dwarfing agent?</p> <p><u>Effect</u>: BA did not affect flowering or shoot elongation. Application to the root collar was more effective than to the mid-stem.</p>   | (Grochowska and Hodun 1997) |
| <i>Prunus avium</i><br>(Sweet Cherry)        | <p><u>Cytokinin</u>: BA+GA (Promalin) 1000 to 2000 ppm / One or two sprays onto newly sprouted scions</p> <p><u>Purpose</u>: Branching agent – Can Promalin increase scion branching in the nursery?</p> <p><u>Effect</u>: Promalin 2000 ppm increased branching the most (2.5x) followed by Pr+BA 1000+500 ppm and BA 500 ppm, crotch angle and increased branch length. Promalin also increased spur development</p>   | (Cody et al. 1985)          |
| <i>Prunus avium</i><br>(Sweet cherry)        | <p><u>Cytokinin</u>: BA+GA (Promalin) 5000 to 10,000 ppm or (Perlan) / Mixed with latex paint and painted onto buds or into the scoring cut when the buds were greening up.</p> <p><u>Purpose</u>: Branching agent – Can BA stimulate branching better if used in conjunction with scoring or notching so that pruning is not required?</p> <p><u>Effect</u>: Cytokinins applied onto scored or notched wood greatly increased the branching over painting the buds or bark.</p>   | (Elfving and Visser 2007)   |
| <i>Prunus avium</i><br>(Sweet cherry)        | <p><u>Cytokinin</u>: GA+BA (Promalin) 250 ppm / Single foliar spray at different times in the fall.</p> <p><u>Purpose</u>: Flower enhancer – Yield enhancer – Can Promalin in the fall improve flowering and yield the next spring?</p> <p><u>Effect</u>: Promalin delayed leaf senescence by 34 days in the fall and increased N concentration in the buds and increased their size. Promalin also improved shoot cold hardiness during the winter by 6°C and did not reduce bud hardiness. Flowering was advanced by 1 day and fruit set the following year was increased 36% over controls.</p> | (Guak et al. 2005)          |

| Table A4 Continued                    |  |                             |
|---------------------------------------|--|-----------------------------|
| Plant                                 | Notes  | Reference                   |
| <i>Prunus avium</i><br>(Sweet Cherry) | <p><u>Cytokinin</u>: BA (Paturyl) 0.06% (600 ppm), BA (600 ppm)+GA<sub>4+7</sub> (400 ppm), / Foliar spray. 3 applications of BA alone or with 2 additional applications of GA during the summer 1 week apart.</p> <p><u>Purpose</u>: Branching agent – Can BA improve feathering?</p> <p><u>Effect</u>: BA increased the number of laterals that formed. Separate GA treatments help the laterals to grow out.</p>  | (Hrotkó et al. 1999)        |
| <i>Prunus avium</i><br>(Sweet cherry) | <p><u>Cytokinin</u>: BA+GA in the form of Accel, Paturyl, Promalin or Paturyl + branch tipping all at 5000 ppm / Branches painted with a latex paint mixture of the chemicals in between bud swell and bud break</p> <p><u>Purpose</u>: Branching agent – Can BA stimulate feathering in nursery plants?</p> <p><u>Effect</u>: Promalin work best out of all the cytokinins at increaeasing branching. Paturyl + tipping generated the longest side shoots.</p>  | (Jacyna et al. 1994)        |
| <i>Prunus avium</i><br>(Sweet cherry) | <p><u>Cytokinin</u>: BA .02%-.08% (200 to 800 ppm) (Paturyl WSC) / Foliar spray of BA only 1 time in June followed by 2 foliar sprays of BA + GA<sub>4+7</sub> 400 ppm 1 week apart.</p> <p><u>Purpose</u>: Branching agent – Can BA stimulate feathering in nursery grown cherry trees?</p> <p><u>Effect</u>: The best combination was BA 400 ppm to stimulate branching followed by 2 applications of BA+GA 400 ppm to stimulate branch elongation. To increase spur formation the best rate is 4 to 5 weeklt applications of BA 600 ppm. No phytotoxicity observed.</p> | (Magyar and Hrotkó 2005)    |
| <i>Prunus avium</i><br>(Sweet cherry) | <p><u>Cytokinin</u>: BA 1000 ppm BA+GA 500 ppm / Foliar spray 4 times wekly onto the shoot tip in combination with deblading the new leaves at the tip.</p> <p><u>Purpose</u>: Branching agent – Can BA stimulate feathering in scions?</p> <p><u>Effect</u>: Only BA + de-blading increased lateral branching</p>   | (Neri et al. 2004)          |
| <i>Prunus divaricata</i><br>(Apricot) | <p><u>Cytokinin</u>: BA 15mg per trees / Applied to the collar of the tree in lanolin paste on a aluminum foil wrap.</p> <p><u>Purpose</u>: Growth inhibition – Can BA act as a dwarfing agent?</p> <p><u>Effect</u>: BA did not affect flowering or shoot elongation but extended the growth period into the fall. Application to the root collar was more effective than to the mid-stem.</p>  | (Grochowska and Hodun 1997) |
| <i>Prunus divaricata</i><br>(Plum)    | <p><u>Cytokinin</u>: BA 15mg per trees / Applied to the collar of the tree in lanolin paste on a aluminum foil wrap.</p> <p><u>Purpose</u>: Growth inhibition – Can BA act as a dwarfing agent?</p> <p><u>Effect</u>: BA did not affect flowering or shoot elongation but extended the growth period into the fall. Application to the root collar was more effective than to the mid-stem.</p>  | (Grochowska and Hodun 1997) |

| Table A4 Continued                        |   |                              |
|---|---|------------------------------|
| Plant                                     | Notes   | Reference                    |
| <i>Prunus dulcis</i><br>(Almond)          | <p><u>Cytokinin</u>: BA+GA (Promalin) 36 to 72 ppm with or without n-m-tolilphthalamic acid 400 ppm (Auxin) / Two foliar sprays at various times around bloom and fruit set.</p> <p><u>Purpose</u>: Yield enhancer – Can Promalin increase yield?</p> <p><u>Effect</u>: Promalin 72 ppm + Auxin Caused the largest increase in fruit set followed by Promalin 72 ppm alone (37% and 31%) and there were no significant drops in fruit dry weight, seed dry weight or seed length.</p>   | (Sotomayor and Castro 1998)  |
| <i>Prunus salicina</i><br>(Japanese Plum) | <p><u>Cytokinin</u>: Thidiazuron 50 to 200 ppm / Single canopy spray when 318 cold units had accumulated</p> <p><u>Purpose</u>: Dormancy release – Can Thidiazuron release buds from dormancy as well as Dormex?</p> <p><u>Effect</u>: Thidiazuron at any rate 50 to 200 ppm is as effective as Dormex</p>  | (Alvarado-Raya et al. 2000)  |
| <i>Punica granatum</i><br>(Pomegranate)   | <p><u>Cytokinin</u>: BA 80 to 100 ppm / Harvested fruit dipped for 2 to 5 minutes prior to cold storage</p> <p><u>Purpose</u>: Postharvest quality – Can BA improve chilling injury in stored fruits?</p> <p><u>Effect</u>: BA resulted in greater weight loss, and reduced browning compared to control but hot water treatment was superior in all regards in protecting fruit quality.</p>   | (Mirdehghan and Rahemi 2005) |
| <i>Pyrus communis</i><br>(Pear)           | <p><u>Cytokinin</u>: BA 250 to 500 ppm, BA+GA (Promalin) 250 to 2000 ppm, Promalin+BA 250+250 ppm – 1000+500 ppm / One or two sprays onto newly sprouted scions</p> <p><u>Purpose</u>: Branching agent – Can Promalin increase scion branching in the nursery?</p> <p><u>Effect</u>: Promalin 2000 ppm increased branching the most followed by Promalin 1000 + BA 500 ppm followed by BA 250 ppm. All of these were more than double that of pruning. BA alone improved crotch angle. All chemicals resulted in shorter laterals than pinching but had better branch angles.</p> | (Cody et al. 1985)           |
| <i>Pyrus communis</i><br>(Pear)           | <p><u>Cytokinin</u>: BA+GA (Promalin) 500 ppm or Promalin 250 ppm + MB25105 1000 ppm / Single foliar spray in June</p> <p><u>Purpose</u>: Branching agent – Can Promalin increase branching?</p> <p><u>Effect</u>: Promalin 250 ppm + MB25105 1000 ppm induced the most branching 3x over control.</p>  | (Sansavini et al. 1981)      |
| <i>Pyrus communis</i><br>(Pear)           | <p><u>Cytokinin</u>: BA 20 to 150 ppm / Single foliar spray at full bloom + 14d.</p> <p><u>Purpose</u>: Yield enhancer – Can BA increase fruit size of small fruited cultivars?</p> <p><u>Effect</u>: BA 100 ppm increased yield of large fruit by the most in one cultivar but caused severe thinning in another. Fruit shape and return yield were unaffected.</p>  | (Stern and Flaishman 2003)   |

| Table A4 Continued                       |  |                             |
|--|--|-----------------------------|
| Plant                                    | Notes  | Reference                   |
| <i>Raphanus sativus</i><br>(Radish tops) | <u>Cytokinin</u> : BA 5 ppm / Single foliar spray at 5gal / acre just prior to harvest<br><u>Purpose</u> : Postharvest Senescence inhibitor / Can BA delay senescence and increase shelf life of vegetables?<br><u>Effect</u> : BA delayed yellowing and other signs of senescence by 2 to 3 days  | (Zink 1961)                 |
| <i>Ribes</i><br>(Currant)                | <u>Cytokinin</u> : Kinetin 2 ppm applied in autumn, winter or early spring.<br><u>Purpose</u> : Flower enhancer – Can Kinetin alter flowering behavior of currants.<br><u>Effect</u> : Kinetin applied in the fall (Oct) caused plants to flower earlier the next spring and the flower stem was shorter.  | (Lenz and Karnatz 1969)     |
| <i>Rubus</i> spp.<br>(Blackberry)        | <u>Cytokinin</u> : BA 100 ppm with or without GA3 100 ppm / 1 to 3 foliar spray applications in July and August<br><u>Purpose</u> : Branching agent – Can BA affect primocane branching in order to increase yield?<br><u>Effect</u> : BA+GA applied 3x increased branching and dry weight. BA alone was not effective   | (Malik and Archbold 1992)   |
| <i>Sida spinosa</i><br>(Prickly sida)    | <u>Cytokinin</u> : Thidiazuron (Dropp 50WP) 70 to 1120 g ai / ha applied at 350L / ha (200 ppm-16000 ppm) / Postemergence sprays to 2 to 5wk old plants<br><u>Purpose</u> : Weed control – Can Thidiazuron be used to control prickly sida?<br><u>Effect</u> : Thidiazuron 1120 g ai / ha reduced growth by 90%. Lower rates reduced growth by smaller amounts.  | (Hodgson and Snyder 1988)   |
| <i>Simmondsia chinensis</i><br>(Jojoba)  | <u>Cytokinin</u> : BA 100 to 300 ppm, BA+GA (Promalin) 100 to 300 ppm / Single foliar spray 15 weeks after potting<br><u>Purpose</u> : Branching agent – Does BA stimulate lateral branching? Can BA replace a hand pinch?<br><u>Effect</u> : GA alone and Promalin 100 ppm were best at stimulating branching. BA 100 ppm improved branching but not by as much. All were better than hand pinching                           | (Ravetta and Palzkill 1992) |
| <i>Sinapis alba</i><br>(White mustard)   | <u>Cytokinin</u> : BA $5 \times 10^{-6}$ to $5 \times 10^{-5}$ M (1 to 5 ppm) / Cotton swab placed on apex<br><u>Purpose</u> : Flower enhancer – How do CKs affect this Long Day plant when applied under Short Days?<br><u>Effect</u> : Under Short Day, BA $5 \times 10^{-6}$ to $2.5 \times 10^{-5}$ M promoted and $5 \times 10^{-5}$ M and greater inhibited flower. BA had to be applied at night to induce the changes. | (Havelange et al. 1986)     |
| <i>Solanum melongena</i><br>(Eggplant)   | <u>Cytokinin</u> : BA 0.1 to 1.0 mM (22.5 to 225 ppm) / Single foliar spray 1 hour prior to inoculation<br><u>Purpose</u> : Disease control – Can BA reduce Botrytis (Gray Mold)?<br><u>Effect</u> : BA did not reduce Botrytis severity.  | (Elad 1993)                 |

| Table A4 Continued                   |  |                            |
|--------------------------------------|--|----------------------------|
| Plant                                | Notes  | Reference                  |
| <i>Solanum tuberosum</i><br>(Potato) | <u>Cytokinin</u> : Kinetin 30 ppm / Two foliar sprays at 42DAT and 52DAT or Single foliar spray<br><u>Purpose</u> : Growth promoter – Does Kinetin induce tuber formation in potato?<br><u>Effect</u> : Kinetin applied twice increased tuber number but reduced tuber size. Kinetin applied once increased tuber yield per unit area and weight of tubers.  | (Artamonov 1975)           |
| <i>Solanum tuberosum</i><br>(Potato) | <u>Cytokinin</u> : BA 10 to 30 ppm / Foliar spray 1 to 3 times<br><u>Purpose</u> : Growth enhancer - Yield enhancer – Can BA improve vegetative growth and tuber production?<br><u>Effect</u> : BA 10 to 20 ppm applied 2 times increased number of shoots per plant and the length of the shoots. Tuber production not affected.  | (Badizadegan et al. 1972)  |
| <i>Solanum tuberosum</i><br>(Potato) | <u>Cytokinin</u> : Kinetin 0.001 – 0.01% (10 to 100 ppm) / Single foliar spray 25DAT<br><u>Purpose</u> : Growth enhancer - Yield enhancer – Can BA improve vegetative growth and tuber production?<br><u>Effect</u> : Kinetin 100 ppm increased plant height, dry mass of plants but reduced dry mass of roots. Tuber formation was unaffected.  | (Drozdov and Volkova 1975) |
| <i>Solanum tuberosum</i><br>(Potato) | <u>Cytokinin</u> : Kinetin 10 to 100 ppm, Zeatin 10 to 100 ppm / Apical ends of the potatoes bathed in liquid solution in petri dishes.<br><u>Purpose</u> : Dormancy release – Do cytokinins cause potatoes to sprout earlier?<br><u>Effect</u> : All rates of Kinetin and Zeatin caused sprouting to occur up to 7 days sooner than control. Kinetin 50 ppm and Zeatin 100 ppm worked best.   | (Hemberg 1970)             |
| <i>Solanum tuberosum</i><br>(Potato) | <u>Cytokinin</u> : Thidiazuron (Dropp 50W) 140 to 560 g/ha / Single foliar spray when blight was first noticed<br><u>Purpose</u> : Disease resistance – Can Thidiazuron improve fungicide activity against Early Blight?<br><u>Effect</u> : Thidiazuron alone delayed progression of the disease but not as well as Mancozeb alone. Chlorothalonil + Thidiazuron was more effective than either alone in delaying disease progression and was the most effective treatment. Thidiazuron+Mancozeb was more effective than either alone. | (Pavlista 2003)            |
| <i>Spinaca oleracea</i><br>(Spinach) | <u>Cytokinin</u> : BA (SD4901, Verdan) rate and application not listed<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : BA is effective at maintaining freshness   | (Wittwer and Dedolph 1962) |
| <i>Trifolium</i><br>(Clover)         | <u>Cytokinin</u> : Kinetin or Kinetin+GA 30 ppm / Single foliar spray with or without mowing.<br><u>Purpose</u> : Growth promoter – Does Kinetin induce nodule formation in legumes, and subsequent growth?<br><u>Effect</u> : Without mowing there was no synergistic effect on nodules of Kinetin+GA. Kinetin alone and GA alone were equal in increasing yield by >15%. With mowing Kinetin+GA was better than either alone and increased yield by 20%.   | (Artamonov 1975)           |

| Table A4 Continued                    |  |                               |
|---------------------------------------|--|-------------------------------|
| Plant                                 | Notes  | Reference                     |
| <i>Triticum aestivum</i><br>(Wheat)   | <p><u>Cytokinin</u>: Thidiazuron 0.1 to 5.0 ppb, Applied on weeks 2, 3, 4, 5 after sowing. OR Thidiazuron 1ppb + Paclobutrazol 0.1ppm. Paclo applied 2, 3, 4, 5 weeks after sowing and Thidiazuron applied once at the beginning of flag leaf senescence</p> <p><u>Purpose</u>: Yield enhancer – Does Thidiazuron increase yield?</p> <p><u>Effect</u>: Thidiazuron alone reduced yield but increased tillering. Thidiazuron+Paclo increased yields by more than 10%.</p>  | (Beckett and van Staden 1992) |
| <i>Triticum aestivum</i><br>(Wheat)   | <p><u>Cytokinin</u>: BA <math>4.4 \times 10^{-9}</math>M (1ppb) / Seeds germinated in cytokinin solutions on filter paper</p> <p><u>Purpose</u>: Growth promoter / inhibitor – How does cytokinin effect root growth during seed germination?</p> <p><u>Effect</u>: 1ppb BA promoted cell division in roots. Other rates not tested</p>  | (Blokhin 1987)                |
| <i>Triticum aestivum</i> ,<br>(Wheat) | <p><u>Cytokinin</u>: BA 100 to 800 ppm with various levels of N / Single foliar spray before or after anthesis I field plots</p> <p><u>Purpose</u>: Yield enhancer – Does BA increase yield or grain protein levels?</p> <p><u>Effect</u>: BA delayed flag leaf senescence but did not improve dry matter or yield. BA increased protein content of the grains by 4 to 11%</p>   | (Caldiz et al. 1991)          |
| <i>Triticum aestivum</i> ,<br>(Wheat) | <p><u>Cytokinin</u>: Kinetin, BA, benzimidazol 5 to 100 ppm / Seeds germinated in Kinetin or BA solution in petri dishes, then transferred to cold chambers for 30 days prior to transplanting into field OR seeds soak for 24hr, re-dried and germinated later before transfer.</p> <p><u>Purpose</u>:</p> <p><u>Effect</u>: 20 ppm Kinetin better than 20 to 100 ppm BA at reducing vernalization, but BA better at increasing shoot numbers. Seeds treated for 24 hours in Kinetin or benzimidazol also showed decreased vernalization but not as much as the Petri dish solution.</p>  | (Csepely and Barabás 1979)    |
| <i>Triticum aestivum</i> ,<br>(Wheat) | <p><u>Cytokinin</u>: Kinetin <math>5 \times 10^{-4}</math>M (108 ppm), BA <math>5 \times 10^{-4}</math>M (112 ppm), BA+ABA <math>5 \times 10^{-4}</math>M / Foliar spray 3 times in the week prior to hardening OR via drench at every irrigation.</p> <p><u>Purpose</u>: Stress tolerance – Can cytokinins increase cold tolerance in acclimated or unacclimated winter wheat?</p> <p><u>Effect</u>: Kinetin or BA sprays did not improve cold tolerance. BA &amp; Kinetin added to the nutrient solution reduced the water content of the shoots but did not improve cold hardiness. BA+ABA added via irrigation improved cold tolerance only in acclimated wheat by 3 to 4°C.</p> | (Gusta et al. 1982)           |

| Table A4 Continued                                       |   |                          |
|--|---|--------------------------|
| Plant  | Notes   | Reference                |
| <i>Triticum aestivum</i> ,<br>(Wheat)                    | <p><u>Cytokinin</u>: Kinetin 2 to 50 ppm / Seeds germinated in Kinetin solution under Long Day or Short Day lighting in petri dishes, then transferred to cold chambers for various times prior to transplanting into field.</p> <p><u>Purpose</u>: Dormancy release – Flower enhancer – Can Kinetin reduce the vernalization time of winter wheat?</p> <p><u>Effect</u>: The best effect was Kinetin 50 ppm and Long Day lighting which completed the vernalization requirements in only 20 days vs 45 days for controls. Kinetin reduced tillering.</p> | (Pogna 1979)             |
| <i>Triticum aestivum</i> ,<br><i>T. durum</i><br>(Wheat) | <p><u>Cytokinin</u>: BA 100 <math>\mu</math>M (22.5 ppm) / Sprayed on shoot 5 times</p> <p><u>Purpose</u>: Growth enhancer – Can BA improve growth or tillering under various nitrogen regimes?</p> <p><u>Effect</u>: BA increased tillering in plants in which tillering was restricted because the only N source was only NO<sub>3</sub> or only NH<sub>4</sub>. BA increased tillering in these cases to match the amount in plants grown in mixed NO<sub>3</sub> and NH<sub>4</sub> sources.</p>  | (Wang and Below 1996)    |
| <i>Triticum aestivum</i> ,<br>(Wheat)                    | <p><u>Cytokinin</u>: Zeatin 50 <math>\mu</math>M (11 ppm) / 2ml injected into leaf sheath at various times during floret development</p> <p><u>Purpose</u>: Flower enhancer – Yield enhancer – Does Zeatin increase yield or effect floret development?</p> <p><u>Effect</u>: Zeatin promoted floret development most (75%) when injected at anther lobe formation and increased grain set (30 to 60%) in lower florets</p>   | (Wang et al. 2001)       |
| <i>Vaccinium angustifolium</i><br>(lowbush blueberry)    | <p><u>Cytokinin</u>: 2iP 5 to 20 mM (1015 to 4060 ppm) / Single spray to the base of stems prior to planting.</p> <p><u>Purpose</u>: Branching agent: Does 2iP trigger rhizomes to grow from seedlings?</p> <p><u>Effect</u>: 4060 ppm worked best at increasing rhizome number. 80 mM was ineffective</p>  | (Gates and Smagula 1989) |
| <i>Vaccinium angustifolium</i><br>(lowbush blueberry)    | <p><u>Cytokinin</u>: BA 10 to 100 ppm, Kinetin 10 to 100 ppm / Harvest fruits immersed in solution for 5 minutes prior to cold storage.</p> <p><u>Purpose</u>: Senescence inhibitor – Can CKs reduce respiration in blueberry fruit?</p> <p><u>Effect</u>: BA reduced respiration in blueberries 10 to 15%. Kinetin was less effective.</p>   | (Ismail 1967)            |
| <i>Vaccinium ashei</i><br>(rabbiteye blueberry)          | <p><u>Cytokinin</u>: BA 25 to 500 ppm / Single foliar spray at 10 to 20 days after corolla drop</p> <p><u>Purpose</u>: Fruit thinner – Can BA thin blueberries?</p> <p><u>Effect</u>: All concentrations of BA induced 50 to 100% fruit drop in the greenhouse. In outdoor experiments BA 75 ppm increased fruit drop by 20 to 40%. BA 25 ppm increased fruit size but did not increase fruit drop.</p>   | (Cartagena et al. 1994)  |
| <i>Vaccinium ashei</i><br>(rabbiteye blueberry)          | <p><u>Cytokinin</u>: CPPU 5 to 10 ppm with or without GA<sub>3</sub> 250 ppm / Single foliar spray at full bloom or 20 days after full bloom</p> <p><u>Purpose</u>: Yield enhancer – Can CPPU increase fruit size?</p> <p><u>Effect</u>: CPPU 10 ppm + GA applied 20 days after full bloom resulted in 9% larger fruit. CPPU 10 ppm applied at full bloom was second at 7% larger fruit. No effect on maturity or sugar concentration of the fruit.</p>   | (Merino et al. 2002)     |

| Table A4 Continued  |  |                            |
|---|--|----------------------------|
| Plant   | Notes  | Reference                  |
| <i>Vaccinium ashei</i><br>(rabbiteye<br>blueberry)  | <u>Cytokinin</u> : CPPU 10 ppm / Single foliar spray 10 to 18days after 50% bloom.<br><u>Purpose</u> : Yield enhancer – Can CPPU increase fruit size or yield?<br><u>Effect</u> : Fruit set tripled for cultivar 'Climax'. Berry size increased 22%. Ripening delayed slightly. There were variations by site and by year for the results.   | (NeSmith 2004)             |
| <i>Vicia</i><br>(Bean)  | <u>Cytokinin</u> : Kinetin 30 to 50 ppm / Single foliar spray<br><u>Purpose</u> : Growth promoter – Does Kinetin induce nodule formation in legumes, and subsequent growth?<br><u>Effect</u> : Nodule number and size increased significantly. Later, fresh weight of plants, beans, and the number of beans produced was also higher. Auxin was better at increasing nodule number and mass.  | (Artamonov 1975)           |
| <i>Vicia fabia</i><br>(Bean)  | <u>Cytokinin</u> : BA, PBA (SD8339) 10 ppm / 2 to 3 foliar sprays in March-May<br><u>Purpose</u> : Disease resistance – Can BA reduce chocolate spot disease ( <i>Botrytis fabae</i> ) in field grown beans?<br><u>Effect</u> : BA slightly prevented leaf senescence which in turn slightly delayed the onset and severity of the disease lesions in the field. PBA was less effective. BA worked well in laboratory experiments  | (Moore and Leach 1968)     |
| <i>Vitis champini</i> ,<br><i>V. berlandieri</i> ,<br><i>V. rupestris</i><br><i>V. cinerea</i><br><i>V. candicans</i><br><i>V. monticola</i><br>(Grape) | <u>Cytokinin</u> : PBA (SD 8339) 1000 ppm or Kinetin 1000 ppm / flower clusters dipped for 15secs into solution various dates before anthesis<br><u>Purpose</u> : Yield enhancer – Can CKs increase flower sex conversion to hermaphroditic flowers?<br><u>Effect</u> : <i>V. champini</i> , <i>V. berlandieri</i> , <i>V. rupestris</i> , and <i>V. cinerea</i> changed from male clones into hermaphroditic plants with PBA and set fruit. A <i>V. rupestris</i> hybrid reacted to Kinetin similarly. Others did not react at the doses and timings used.<br><u>Not es</u> : | (Moore 1970)               |
| <i>Vitis labrusca</i> &<br><i>V. labrusca</i> x <i>V. vinifera</i> cultivars<br>(Grape)   | <u>Cytokinin</u> : CPPU 5 to 15 ppm / Berry cluster sprays at the 4 to 9mm stage<br><u>Purpose</u> : Yield enhancer – Does CPPU improve berry development?<br><u>Effect</u> : CPPU 5 to 10 ppm increased berry mass, cluster mass, cluster compactness best when applied at the 4mm-7mm stage of seedless cultivars. Berry shatter and necrosis during cold storage were reduced. Seeded cultivars reacted much less.  | (Zabadal and Bukovac 2006) |
| <i>Vitis rotundifolia</i><br>(Muscadine<br>grape)   | <u>Cytokinin</u> : BA 1000 ppm Kinetin 1000 to 2000 ppm / Foliar spray every 2 weeks starting 1wk before inoculation.<br><u>Purpose</u> : Disease resistance – Can Kinetin reduce the development of Pierce's disease?<br><u>Effect</u> : Kinetin reduced the % of plants that developed the disease in moderately resistant cultivars but not susceptible cultivars. BA not tested on the resistant cultivars.  | (Hopkins 1985)             |

| Table A4 Continued                     |   |                            |
|--|---|----------------------------|
| Plant                                  | Notes   | Reference                  |
| <i>Vitis vinifera</i><br>(Table grape) | <u>Cytokinin</u> : CPPU (Prestige)<br><u>Purpose</u> : Yield enhancer – Postharvest quality<br><u>Effect</u> : CPPU enhances berry size and quality, reduces berry shatter, improves cold storage and shelf life  | (Hopkins et al. 2005)      |
| <i>Vitis vinifera</i><br>(Table grape) | <u>Cytokinin</u> : CPPU 20 to 40 ppm, with or without GA <sub>3</sub> 40 ppm / Foliar sprays at the 4mm berry size.<br><u>Purpose</u> : Yield enhancer – can CPPU increase fruit quality?<br><u>Effect</u> : GA+CPPU resulted in much larger berries than GA alone but also caused excessive rachis and pedicel lignification, delayed maturity by up to 21d, caused rounder, firmer berries, decreased postharvest berry drop, and more compact bunches. CPPU alone was not as good as GA alone. CPPU+GA does not reduce return flowering like GA alone does. Ideal rates not discussed. | (Retamales et al. 1995)    |
| <i>Zea mays</i><br>(Corn)              | <u>Cytokinin</u> : Zeatin, Kinetin 10 <sup>-3</sup> to 10 <sup>-1</sup> mol • m <sup>-3</sup> (0.22 ppm -22 ppm) / leaf strips incubated in cytokinin solutions<br><u>Purpose</u> : Physiological control – Do cytokinins control stomata opening in Corn?<br><u>Effect</u> : Kinetin or Zeatin did not open the stomata but partially overrode the ABA effect of closing them.   | (Blackman and Davies 1983) |
| <i>Zea mays</i><br>(Corn)              | <u>Cytokinin</u> : BA 4.4*10 <sup>-9</sup> M to 4.4*10 <sup>-7</sup> M (1ppb-10ppb) / Seeds germinated in cytokinin solutions on filter paper<br><u>Purpose</u> : Growth promoter / inhibitor – How does cytokinin effect root growth during seed germination?<br><u>Effect</u> : BA increased root thickness. >10ppb inhibited root growth. <10ppb stimulated root growth.   | (Blokhin 1987)             |
| <i>Zea mays</i><br>(Corn)              | <u>Cytokinin</u> : BA 10 to 100 µM (2.25 - 22.5 ppm) / Pre-treatment onto leaves 8 to 24 prior to paraquat exposure<br><u>Purpose</u> : Stress resistance / Can BA improve a plant's response to paraquat?<br><u>Effect</u> : BA was effective in increasing superoxide dismutase and peroxidase activity to prevent oxidative damage. Plants showed reduced degradation to chlorophyll, carotenoids. Pre-treatments 8hr prior to exposure worked better than 12 or 24 hr.  | (Durmus and Kadioglu 2005) |
| <i>Zea mays</i><br>(Corn)              | <u>Cytokinin</u> : Thidiazuron (Dropp 50WP) 8.8 to 1120 g ai / ha applied at 350L / ha (200 ppm-16000 ppm) / Postemergence sprays to 2 to 8wk old plants<br><u>Purpose</u> : Growth control – Can Thidiazuron be sprayed on corn to control weeds without harming it?<br><u>Effect</u> : Thidiazuron 560g ai / ha and slightly reduced height but did not injure the plant otherwise. Author hypothesized that corn yield would not be impacted by Thidiazuron and so Thidiazuron could be used to control velvetleaf in corn.  | (Hodgson and Snyder 1988)  |
| <i>Zea mays</i><br>(Corn)              | <u>Cytokinin</u> : BA 10 <sup>-5</sup> – 10 <sup>-3</sup> M (2.25 - 225 ppm), Thidiazuron 10 <sup>-5</sup> – 10 <sup>-3</sup> M (2.2 – 220 ppm) / Foliar sprays<br><u>Purpose</u> : Yield enhancer – Do cytokinins alter yield characteristics?<br><u>Effect</u> : Dry weight of kernals increased by at least 14%.   | (McNeil 1990)              |

| Table A4 Continued                       |   |                            |
|--|---|----------------------------|
| Plant                                    | Notes   | Reference                  |
| <i>Zea mays</i><br>(Sweet corn)          | <u>Cytokinin</u> : BA (SD4901, Verdant) rate and application not listed<br><u>Purpose</u> : Senescence inhibitor / Can BA delay senescence?<br><u>Effect</u> : Not effective  | (Wittwer and Dedolph 1962) |
| <i>Zoysia japonica</i><br>(Zoysia grass) | <u>Cytokinin</u> : BA 50 to 100 ppm or BA 50 ppm +GA 25 ppm / Foliar sprays<br><u>Purpose</u> : Growth enhancer – Can BA affect growth of bermuda grass?<br><u>Effect</u> : No effect   | (Borden and Campbell 1985) |
| <i>Zoysia japonica</i><br>(Zoysia grass) | <u>Cytokinin</u> : unspecified Cytokinin (brand name Per “4” Max) / 15min Pre-plant soak in 81ppm CK followed by biweekly sprays from May to Oct applying 24 to 48g CK·ha <sup>-1</sup><br><u>Purpose</u> : Branching agent – Can a biostimulator containing cytokinins improve establishment of sprigs?<br><u>Effect</u> : No effect | (Carroll et al. 1996)      |

## A2 Literature Cited

- Accati, E.G., L. Basoccu, and S. Sulis. 1979. Effect of 6-BA and other cytokinins on flower production of spray carnation. *Acta Horticulturae* 91:115-121.
- Adams, P., D.E. Nelson, S. Yamada, W. Chmara, R.G. Jensen, H.J. Bohnert, and H. Griffiths. 1991. Growth and development of *Mesembryanthemum crystallinum*. *New Phytol.* 138:171-190.
- Aharoni, N., A. Back, S. Ben-Yehoshua, and A. E. Richmond. 1975. Exogenous gibberellic acid and the cytokinin isopentyladenine retardants of senescence of Romaine lettuce *J. Amer. Soc. Hort. Sci.* 100 (1):4-6.
- Ahmad, M.R., and A.S. Murty. 1977. Note on the effect of benzyladenine on corm and cormel yield in *Gladiolus*. *Indian J. agric. Res.* 11 (4):249-250.
- Al-Juboory, K.H., M.A. Al-Khafaji, and H.H. Al-Juboory. 1997. Effects of dikegulac-sodium, BA and GA<sub>4+7</sub> to enhanced lateral branching in variegated ivies. *PGRSA quarterly* 25 (3):134-144.
- Albregts, E. E., C. M. Howard, and C. Chandler. 1988. Effects of biostimulants on fruiting of strawberry. *Proc. Fla. State Hort. Soc.* 101:370-372.
- Aldwinkle, H.S., and I.W. Selman. 1967. Some effects of supplying benzyladenine to leaves and plants inoculated with viruses. *Ann. appl. Biol.* 60 (1):49-58.
- Alvarado-Raya, H., J. Rodriguez-Alcázar, G. Calderón-Zavala, and E. Cárdenas-Soriana. 2000. Thidiazuron, flower budbreak and ovary dimensions in Japanese Plum (*Prunus salicina* L.) 'Shiro'. *Agrociencia* 34:321-327.
- Amling, J.W., G.J. Kever, J.R.J. Kessler, and D.J. Eakes. 2007. Benzyladenine (BA) promotes ramet formation in *Hemerocallis*. *J. Environ. Hort.* 25 (1):9-12.
- Amrutavalli, S.A. 1980. Interaction of gibberellic acid (GA<sub>3</sub>) and benzyladenine (BA) on flowering and sex expression in Bulgarian coriander (*Coriandrum sativum* L.). *Indian Journal of Plant Physiology* 23 (1):14-20.
- Antognozzi, E., and P. Proietti. 1995. Effects of CPPU (cytokinin) on table olive trees (cv. *Ascolana tenera*) under nonirrigated and irrigated conditions. *Acta Horticulturae* 379:159-166.
- Antognozzi, E., P. Proietti, and M. Boco. 1993. Effect of CPPU (cytokinin) on table olive cultivars. *Acta Horticulturae* 329:153-155.
- Arima, Y., K. Oshima, and K. Shudo. 1995. Evolution of a novel urea-type cytokinin: Horticultural uses of forchlorfenuron. *Acta Horticulturae* 394:75-83.
- Artamonov, V. I. 1975. Some aspects of practical use of kinetin. *Soviet Plant Physiology* 22 (6):1126-1132.

- Arteca, R.N. 1982. Effect of root applications of kinetin and gibberellic acid on transplanting shock in tomato plants. *HortScience* 17 (4):633-634.
- Atkins, C.A., and A. Pigeaire. 1993. Application of cytokinins to flowers to increase pod set in *Lupinus angustifolius* L. *Aust. J. Agric. Res.* 44:1799-1819.
- Badizadegan, M., E. Tafazoli, and M. Kheradnam. 1972. Effect of N<sup>6</sup>benzyladenine on vegetative growth and tuber production in potato. *Amer Potato J* 49 (3):109-116.
- Ballantyne, D.J. 1963. Note on the effect of growth substances on the bloom life of *Narcissus* cut flowers. *Canad. J. Plant Sci.* 43:225-227.
- Ballantyne, D.J. 1965. Senescence of Daffodil (*Narcissus pseudonarcissus*) cut flowers treated with benzyladenine and auxin. *Nature* 205:819.
- Ballantyne, D.J. 1966. Respiration of floral tissue of the daffodil (*Narcissus pseudonarcissus* Linn.) treated with benzyladenine and auxin. *Can. J. Bot.* 44:117-119.
- Banko, T.J., and M. Stefani. 1999. Defoliating deciduous hollies grown for the cut flower market. *Holly Society Journal* 17 (4):14-18.
- Banko, T.J., and M.A. Stefani. 1991. Chemical growth control of *Salvia farinacea* 'Victoria Blue'. *SNA Research Conference Proceedings* 41:214-215.
- Banko, T.J., and M.A. Stefani. 1997a. Growth control in container production of *Verbena* 'Homestead Purple'. *SNA Research Conference Proceedings* 42:290-291.
- Banko, T.J., and M.A. Stefani. 1997b. Growth regulators enhance branching of *Portulaca*. *SNA Research Conference Proceedings* 42:288-289.
- Basak, A., and Z. Soczek. 1986. The influence of Promalin on branching of one-year-old apple nursery trees. *Acta Horticulturae* 179:279-280.
- Beach, S.E. 2005. Shipping and nitrogen toning effects on postharvest shelf life of vegetative annuals, Floriculture, Texas A&M University.
- Beckett, R.P., and J. van Staden. 1992. The effect of thidiazuron on the yield of wheat grown with varying nutrient supply. *Plant Growth Regulation* 11:343-348.
- Beede, R.H. 2005. Uses of plant growth regulators in tree nut crops. *Proceedings of the plant growth regulation society of America* 32nd Annual Meeting:36.
- Beeson, R.C., and W.M. Proebsting. 1989. Picea graft success: Effects of environment, rootstock disbudding, growth regulators, and antitranspirants. *HortScience* 24 (2):253-254.
- Bell, M., R.A. Larson, and D.A. Bailey. 1997. Vegetative growth responses of florist azaleas to Dikegulac, GA<sub>4+7</sub>, and 6-benzylamino purine. *HortScience* 32 (4):690-697.

- Beltrano, J., D.O. Caldiz, R. Barreyro, G.S. Vallduvi, and R. Bezus. 1994. Effects of foliar applied gibberellic acid and benzyladenine upon yield components in sunflower (*Helianthus annuus* L.). *Plant Growth Regulation* 15:101-106.
- Bessler, B. 1997. The use of 6-benzylaminopurine for rapid multiplication of *Tillandsias* *HortScience* 32 (2):256-258.
- Bichara, A.E., and J. Van Staden. 1993. The effect of aminoxyacetic acid and cytokinin combinations on carnation flower longevity. *Plant Growth Regulation* 13:161-167.
- Biddington, N. L., and T. H. Thomas. 1978. Thermodormancy in celery seeds and its removal by cytokinins and gibberellins. *Physiol. Plant.* 42:401-405.
- Biran, I., B. Leshem, I. Gur, and A.H. Halevy. 1974. Further studies on the relationship between growth regulators and tuberization of *Dahlia*s. *Physiol. Plant.* 31:23-28.
- Bismuth, F., and E. Miginiac. 1984. Influence of zeatin on flowering in root forming cuttings of *Anagallis arvensis* L. *Plant & Cell Physiol.* 25 (6):1073-1076.
- Blackman, P. G., and W. J. Davies. 1983. The effects of cytokinins and ABA on stomatal behavior of maize and *Commelina*. *J. Exp. Bot.* 34 (149):1619-1626.
- Blanchard, M.G., and E.S. Runkle. 2008. Benzyladenine promotes flowering in *Doritaenopsis* and *Phalaenopsis* Orchids. *J. Plant Growth Regul.* 27:141-150.
- Blokhin, V. G. 1987. Concentration dependence of the effect of 6-benzylaminopurine on root growth in plants of different species. *Soviet Plant Physiology* 33 (6):828-833.
- Boe, A.A. 1990. Effects of application of benzyladenine to seedlings of *Pinus sylvestris* and *Pinus nigra*. *J. Environ. Hort.* 8 (4):212-214.
- Boe, A.A., R.B. Stewart, and T.J. Banko. 1972. Effects of growth regulators on root and shoot development on sedum leaf cuttings. *HortScience* 7 (4):404-405.
- Borden, P., and R.W. Campbell. 1985. Use of chemical growth regulators to increase growth of 'Meyer' zoysiagrass. *Proceedings of the plant growth regulation society of America* 12th annual meeting:38-44.
- Boyle, T.H. 1992. Modification of plant architecture in 'Crimson Giant' Easter cactus with benzyladenine. *J. Amer. Soc. Hort. Sci.* 117 (4):584-589.
- Boyle, T.H., D.J. Jacques, and D.P. Stimart. 1988. Influence of photoperiod and growth regulators on flowering of *Rhipsalidopsis gaertneri*. *J. Amer. Soc. Hort. Sci.* 113 (1):75-78.
- Braun, Joseph W., and Walter J. Kender. 1985. Correlative bud inhibition and growth habit of the strawberry as influenced by application of gibberellic acid, cytokinin, and chilling during short daylength. *J. Amer. Soc. Hort. Sci.* 110 (1):28-34.

- Bryan, J.A., and J.R. Seiler. 1991. Accelerating Fraser fir seedling growth with benzylaminopurine sprays. *HortScience* 26 (4):389-390.
- Caldiz, D.O., J. Beltrano, L.V. Fernandez, S.J. Sarandon, and C. Favorett. 1991. Effects of foliar applied benzyladenine on grain yield and grain protein in wheat (*Triticum aestivum* L.). *Plant Growth Regulation* 10:197-204.
- Carey, D.J., B.E. Whipker, I. McCall, and W. Buhler. 2007. Cytokinin based PGR affects growth of vegetative petunia. *SNA Research Conference Proceedings* 52 (8):102-104.
- Carey, D.J., B.E. Whipker, I. McCall, and W. Buhler. 2008. Benzyladenine foliar sprays increase offsets in *Sempervivum* and *Echeveria*. *SNA Research Conference Proceedings* 53:19-21.
- Carlson, W. H., and W. J. Carpenter. 1972. Drenches of plant growth regulators improve poinsettia rooting. *Michigan Florist* 491:22-23.
- Carow, B., and K. Bahnemann. 1980. Influence of silver nitrate, kinetin, and benzylaminopurine on yellowing of *Pelargonum zonale* cuttings. *Gartenbauwissenschaft* 45 (6):273-278.
- Carpenter, W. J., and G.R. Beck. 1972. Growth regulator induced branching of poinsettia stock plants. *HortScience* 7 (4):405-406.
- Carpenter, W. J., and W. H. Carlson. 1972a. Improved geranium branching with growth regulator sprays. *HortScience* 7 (3):291-292.
- Carpenter, W. J., and R.C. Rodriguez. 1971. The effect of plant growth regulating chemicals on rose shoot development from basal and axillary buds. *J. Amer. Soc. Hort. Sci.* 96 (3):389-391.
- Carpenter, W. J., R.C. Rodriguez, and W. H. Carlson. 1971. Growth regulator induced branching of non-pinched poinsettias. *HortScience* 6 (5):457-458.
- Carpenter, W.J., and W.H. Carlson. 1972b. The effect of growth regulators on *Chrysanthemum*. *J. Amer. Soc. Hort. Sci.* 97 (3):349-351.
- Carroll, M.J., P.H. Dernoeden, and J.M. Krouse. 1996. Zoysiagrass establishment from springs following application of herbicides, nitrogen, and a biostimulator. *HortScience* 31 (6):972-975.
- Carswell, F.E., J.S. Day, and K.S. Gould. 1996. Cytokinins and the regulation of plant form in three species of *Sophora*. *New Zealand Journal of Botany* 34:123-130.
- Cartagena, J.R., F.B. Matta, and J.M. Spiers. 1994. Chemical fruit thinning of *Vaccinium ashei* Reade. *J. Amer. Soc. Hort. Sci.* 119:1133-1136.
- Carter, J., B.P. Singh, and W. Whitehead. 1996. Dikegulac, but not benzyladenine enhances the quality of Boston fern. *HortScience* 31 (6):978-980.

- Cazell, B.H., and J.R. Siler. 1992. Intermittent short days and chilling, and benzylaminopurine affect the growth and morphology of Fraser fir seedlings. *J. Environ. Hort.* 10 (4):205-207.
- Çelikel, F.G., L.L. Dodge, and M.S. Reid. 2002. Efficacy of 1-MCP (1-methycyclopropene) and Promalin for extending the post-harvest life of Oriental lilies (*Lilium* × 'Mona Lisa' and 'Stargazer'). *Scientia Horticulturae* 93:149-155.
- Chandrappa, J.V., J.V.N. Gowda, M.C. Gowda, and A.P.M. Gowda. 2006. Influence of growth regulators and their combinations on growth and flower production in *Anthurium* cv. Royal Red. *Res. on Crops* 7 (1):279-281.
- Chang, S.T., W.S. Chen, C.Y. Hsu, H.C. Yu, B.S. Du, and K.L. Huang. 1999. Changes in cytokinin activities before, during and after floral initiation in *Polianthes tuberosa*. *Plant Physiol. Biochem.* 37 (9):679-684.
- Chen, W.S., H.W. Chang, W.H. Chen, and Y.S. Lin. 1997. Gibberellic acid and cytokinin affect *Phalaenopsis* flower morphology at high temperature. *HortScience* 32 (6):1069-1073.
- Chernyad'ev, I. I., A. Kondratskaya, and N. G. Doman. 1990. Effect of 6-benzylaminopurine, a cytokinin, on photosynthesis under insufficient light in pea plants. *Applied biochemistry and microbiology* 26 (1):85-88.
- Cho, I.J., Lee C.H., and Cho J.H. 2008. Effects of CPPU, TDZ, and BAP on tubercle proliferation of *Chamaecereus silvestrii* f. *variegata*. *Korean Journal of Horticultural Science and Technology* 26 (2):124-128.
- Clark, D.G., J.W. Kelly, and H.B. Pemberton. 1991. Postharvest quality characteristics of cultivars of potted rose in response to holding conditions and cytokinins. *HortScience* 26 (9):1195-1197.
- Clark, J.R., and W.P. Hackett. 1980. Assimilate translocation in juvenile-adult grafts of *Hedera helix*. *J. Amer. Soc. Hort. Sci.* 105 (5):727-729.
- Clark, J.R., and W.P. Hackett. 1981. Interaction of Ancymidol and benzyladenine in control of growth of juvenile *Hedera helix*. *Physiol. Plant.* 53:483-486.
- Clarke, S.F., P.E. Jameson, and C.G. Downs. 1994. The influence of 6-benzylaminopurine on post-harvest senescence of floral tissues of broccoli (*Brassica oleracea* var. *italica*). *Plant Growth Regulation* 14 (1):21-27.
- Cline, John A., and Mary Bijl. 2002. Diurnal spray timing does not affect the thinning of apples with carbaryl, benzyladenine, and naphthaleneacetic acid. *Canad. J. Plant Sci.* 82 (2):437-441.
- Cline, M., M. Yoders, D. Desai, C. Harrington, and W. Carlson. 2006. Hormonal control of second flushing in Douglas-fir shoots. *Tree Physiology* 26 (1369-1375).
- Cline, M.G., and K. Dong-II. 2002. A preliminary investigation of the role of auxin and cytokinin in sylleptic branching of three hybrid poplar clones exhibiting contrasting degrees of sylleptic branching. *Ann. Bot.* 90:417-421.

- Cody, C.A., F.E. Larsen, and R. Jr. Fritts. 1985. Stimulation of lateral branch development in tree fruit nursery stock with GA<sub>4+7</sub>+BA. *HortScience* 20 (4):758-759.
- Cohen, M.A., and J. Shanks. 1975. Effect of N<sup>6</sup>-BA, GA<sub>3</sub>, and removal of terminal buds on dwarf development in *Pinus ponderosa*. *J. Amer. Soc. Hort. Sci.* 100 (4):404-406.
- Costa, C., P.J. Stassen, and J. Mudzunga. 2004. Chemical rest breaking agents for the South African pome and stone fruit industry. *Acta Horticulturae* 636:295-302.
- Criley, R.A. 1980. Stimulating lateral bud break on *Dracaena*. *Plant Propagator* 26 (2):3-5.
- Criley, R.A. 1988. Propagation of tropical cut flowers: *Strelitzia*, *Alpinia*, and *Heliconia*. *Acta Horticulturae* 226:509-517.
- Criley, R.A. 2000. Growth regulators in the control of flowering in a *Vireya Rhododendron* hybrid. *Journal of the American Rhododendron Society* 65:64-69.
- Criley, R.A. 2008. Gibberellic acid induced flowering of *Paphiopedilum* (Macabre x glanduliferum). *Acta Horticulturae* 766:279-282.
- Cruz-Castillo, J.G., D.J. Wooley, and G.S. Lawes. 1999. Effects of CPPU and other plant growth regulators on fruit development in kiwifruit. *Acta Horticulturae* 498:173-178.
- Csepely, I. T. , and Z. Barabás. 1979. Acceleration of vernalization in wheat *Triticum aestivum* L. by cytokinins: Preliminary report. *Cereal Res. Comm.* 7 (1):55-59.
- Cushman, L.C., and H.B. Pemberton. 1994. Cultivar, flower stage, silver thiosulfate, and BA interactions affect performance of potted roses. *HortScience* 29 (7):805-808.
- Dai, T.J.W., and R.E. Paull. 1991. Postharvest handling of *Alstroemeria*. *HortScience* 26 (3):314.
- Dale, A., D.C. Elfving, and C.K. Chandler. 1996. Benzyladenine and gibberellic acid increase runner production in day neutral strawberries. *HortScience* 31 (7):1190-1194.
- Daoudi, H., L. Ferguson, and C. J. Lovatt. 2002. Reducing alternate bearing in pistachio with foliar applied 6-benzyladenine and low-biuret urea. *Proceedings of the plant growth regulation society of America* 29:49.
- Das, P., T. Bose, and P. Roy. 1977. Effect of growth regulators on the photoperiodic response of short and long day plants. *Orissa Journal of Horticulture* 5 (1/2):1-6.
- Davies, F.T., and B.C. Moser. 1980. Stimulation of bud and shoot development of Reiger begonia leaf cuttings with cytokinins. *J. Amer. Soc. Hort. Sci.* 105 (1):27-30.
- Davies, L.J. , P.R. Hicklenton, and J.L. Catley. 1996. Vernalization and growth regulator effects of flowering of *Gypsophila paniculata* L. cvs Bristol Fairy and Bridal Veil. *Journal of Horticultural Science* 71 (1):1-9.

- Davies, L.J., I.R. Brooking, J.L. Cately, and E.A. Halligan. 1998. Sprouting temperature and growth regulators influence cut flower quality of *Sandersonia aurantiaca*. *HortScience* 33 (7):1167-1171.
- Day, J.S., and B.R. Loveys. 1998. Propagation from cuttings of two woody ornamental Australian shrubs, *Boronia megastigma* Nees (brown boronia) and *Hypocalymma angustifolium* Endl. (white myrtle). *Australian Journal of Experimental Agriculture* 38:201-206.
- Dayuan, W. 1981. Effect of BA and GA on fruit drop of citrus. *HortScience* 16 (5):657-659.
- de Moraes, P.J., F.L. Finger, J.G. Barbosa, P.R. Cecon, and L.P. Cesa. 2005. Influence of benzyladenine on longevity of *Heliconia latispatha* Benth. *Acta Horticulturae* 683:369-373.
- de Munk, W.J., and J. Gijzenberg. 1977. Flower bud blasting in tulip plants mediated by the hormonal status of the plant. *Scientia Horticulturae* 7:255-268.
- de Munk, W.J., and P. Hoogeterp. 1975. Flower bud blasting in tulips. *Acta Horticulturae* 47:149-154.
- de Vries, D.P., and Lidwein A.M. Dubois. 1988. The effect of BAP and IBA on sprouting and adventitious root formation of 'Amanda' rose single-node softwood cuttings. *Scientia Horticulturae* 34:115-121.
- del Río, M.A., P. Navarro, and M. Mateos. 1989. Effect of pretreatment and storage conditions on cut rose flowers. *Acta Horticulturae* 246:319-325.
- Deutch, B. 1973. Bulblet formation in *Achimenes longiflora*. *Physiol. Plant.* 30:113-118.
- Dong, C.N., and R.N. Arteca. 1982. Changes in photosynthetic rates and growth following root treatments of tomato plants with phytohormones. *Photosynthesis Research* 3:45-52.
- Downs, C.G., S.D. Somerfield, and M.C. Davey. 1997. Cytokinin treatment delays senescence but not sucrose loss in harvested broccoli. *Postharvest Biology and Technology* 11:93-100.
- Drozdov, S.N., and R.I. Volkova. 1975. Effect of kinetin on potato growth and productivity. *Soviet Plant Physiology* 22 (3):527-528.
- Duck, M.W., B.M. Cregg, R.T. Fernandez, Royal D. Heins, and F.F Cardoso. 2004. Height control of *Picea* spp. and *Chamaecyparis lawsoniana* with uniconazole and 6-benzyladenine. *J. Environ. Hort.* 22 (3):165-169.
- Durmus, N., and A. Kadioglu. 2005. Reduction of paraquat toxicity in maize leaves by benzyladenine. *Acta Biologica Hungarica* 56 (1/2):97-107.
- Dvorská, L. 1979. The effect of growth regulators and temperature gradients on flowering of *Saintpaulia ionantha* Wendl. *Acta Horticulturae* 91:507-510.

- Edenfield, M.W., B.J. Brecke, D.G. Shilling, M.E. Kane, J.A. Dusky, Colvin D.L., and G.E. MacDonald. 1999. Evaluation of plant growth regulators on the phenology and growth and development of purple nutsedge (*Cyperus rotundus*) *Proceedings, Southern Weed Science Society* 52:169.
- El-adb, S.O., A.S. El-Beltagy, and M.A. Hall. 1986. Physiological studies on flowering and fruit set in tomatoes. *Acta Horticulturae* 190:389-396.
- El-Keltawi, N.E., and R. Croteau. 1987a. Influence of foliar applied cytokinins on growth and essential oil content of several members of the Lamiaceae. *Phytochemistry* 26 (4):891-895.
- El-Keltawi, N.E., and R. Croteau. 1987b. Salinity depression of growth and essential oil formation in spearmint and majoram and its reversal by foliar applied cytokinin. *Phytochemistry* 26 (5):1333-1334.
- Elad, Y. 1993. Regulators of ethylene biosynthesis or activity as a tool for reducing susceptibility of host plant tissues to infection by *Botrytis cinerea*. *Neth. J. Pl. Path.* 99:105-113.
- Elfving, D.C. 1985. Comparison of cytokinin and apical-dominance-inhibiting growth regulators for lateral branch induction in nursery and orchard apple trees. *J. Hort. Sci.* 60 (4):447-454.
- Elfving, D.C., and D.B. Visser. 2007. Improving the efficacy of cytokinin applications for stimulation of lateral branch development in young sweet cherry trees in the orchard. *HortScience* 42 (2):251-256.
- Emino, E.R., J.E. Barrett, and D.G. Clark. 2002. Mediation of ethylene damage during shipping of geranium cuttings: Application of anti-ethylene growth regulators and cytokinins. *Proceedings of the plant growth regulation society of America* 29:181-185.
- Emongor, V., F. Pule-Meulenberg, and O. Phole. 2004. Effect of Promalin on growth and development of kale (*Brassica oleracea* L. var. *acephala* DC). *Journal of Agronomy* 3 (3):208-214.
- Ervin, E.H., X. Zhang, and G. Seaver. 2006. Impact of seaweed-based cytokinins and zeatin riboside on creeping bentgrass heat tolerance. *PGRSA quarterly* 34 (2):28.
- Even-Chen, Z., R.M. Sachs, and W.P. Hackett. 1979. Control of flowering in *Bougainvillea* 'San Diego Red'. *Plant Physiol.* 64:646-651.
- Fagan, A.E., M.A. Dirr, and F.A. Pokorny. 1981. Effects of depulping, stratification and growth regulators on seed germination of *Liriope muscari*. *HortScience* 16 (2):208-209.
- Farris, and G.J. Keever. 2008. To be published. *SNA Research Conference Proceedings* 53.
- Ferrante, A., D.A. Hunter, W.P. Hackett, and M.S. Reid. 2002a. Thidiazuron—a potent inhibitor of leaf senescence in *Alstroemeria*. *Postharvest Biology and Technology* 25:333-338.

- Ferrante, A., A. Mensuali-Sodi, G. Serra, and F. Tognoni. 2002b. Effects of ethylene and cytokinins on vase life of cut *Eucalyptus parvifolia* Cambage branches. *Plant Growth Regulation* 38:119-125.
- Ferrante, A., F. Tognoni, A. Mensuali-Sodi, and G. Serra. 2003. Treatment with thidiazuron for preventing leaf yellowing in cut tulips and chrysanthemum. *Acta Horticulturae* 624:357-363.
- Filho, C.A.B., R.J. Souza, and M. Tavares. 1998. Spraying alpha-naphtalene acetic acid and benzil aminopurine on garlic leaves for control of sprouting and yield increase. *Cientifica (Jaboticabal)* 26 (1/2):213-220.
- Finch-Savage, W.E., D. Gray, and G.M. Dickson. 1991a. The combined effects of osmotic priming with plant growth regulator and fungicide soaks on the seed quality of five bedding pant species. *Seed Sci. & Technol.* 19:495-503.
- Finch-Savage, W.E., D. Gray, and G.M. Dickson. 1991b. Development of bulk priming/plant growth regulator seed treatments and their effect on the seedling establishment of four bedding plant species. *Seed Sci. & Technol.* 19:477-485.
- Finch-Savage, W.E., D. Gray, and G.M. Dickson. 1991c. Germination responses of seven bedding species to environmental conditions and gibberellic acid. *Seed Sci. & Technol.* 19:487-494.
- Findley, D.A., G.J. Keever, and C.H. Gilliam. 1994. BA-induced offset formation in *Hosta*. *SNA Research Conference Proceedings* 39:33-34.
- Florez-Roncancio, V.J., and M. de F.A.D. Periera. 1998. Influence of photoperiod on floral development in plants of *Solidago chilensis*, *Aster ericoides* cv. 'Montecasino' and *Solidago x luteus* *Agronomia Colombiana* 15 (1):82-97.
- Foley, J.T., and G.J. Keever. 1991. Growth regulators and pruning alter growth and axillary shoot development of *Dianthus*. *J. Environ. Hort.* 9 (4):191-195.
- Foley, J.T., and G.J. Keever. 1992. Chemical promotion of axillary shoot development of geranium stock plants. *J. Environ. Hort.* 10 (2):90-94.
- Foley, J.T., and G.J. Keever. 1993. Chemically induced branching of *Vinca minor*. *J. Environ. Hort.* 11 (4):149-152.
- Fonseca, J.M. 2004. Effect of cytokinins on yield of iceberg lettuce. *PGRSA quarterly* 32 (2):70.
- Fooshee, W.C., and R.J. Henny. 1986. BA-induced basal shoot production in *Spathiphyllum* 'Viscount' affected by plant age. *Proc. Fla. State Hort. Soc.* 99:240-241.
- Franco, R.E., and S.S. Han. 1997. Respiratory changes associated with growth-regulator-delayed leaf yellowing in Easter lily. *J. Amer. Soc. Hort. Sci.* 122 (1):117-121.
- Franssen, J.M., and P.G.J.M. Voskens. 1997. Competition between sprout and daughter bulbs for carbohydrates as affected by mother bulb size and cytokinins. *Acta Horticulturae* 430:63-71.

- Fukui, R., S. Kikuchi, Y. Ichida, and H. Honjo. 2005. Vase life of imported *Anthurium* flowers evaluated in Japan in relation to the effects of postimportation benzyladenine treatment. *HortScience* 40 (5):1439-1443.
- Fuller, G., J.A. Kuhnle, J.W. Corse, and B.E. Mackey. 1977. Use of natural cytokinins to extend the storage life of broccoli (*Brassica oleracea*, Italica group). *J. Amer. Soc. Hort. Sci.* 102 (4):480-484.
- Funnell, K.A., and R.D. Heins. 1998. Plant growth regulators reduce postproduction leaf yellowing of potted asiflorum lilies. *HortScience* 33 (6):1036-1037.
- Furuta, T., and T.H. Straiton. 1965. Synergism of kinetin and gibberellic acid in flowering of unchilled azalea cultivar 'Red Wing'. *American Society for Horticultural Science* 88:591-594.
- Garner, J.M., and G.J. Keever. 1995. Initial offset number affects *Hosta*'s responses to BA. *SNA Research Conference Proceedings* 40:69-70.
- Garner, J.M., G.J. Keever, D.J. Eakes, and J.R.J. Kessler. 1996. Sequential BA Applications enhance offset formation in *Hosta*. *SNA Research Conference Proceedings* 41:48-49.
- Garner, J.M., G.J. Keever, D.J. Eakes, and J.R.J. Kessler. 1997a. BA application promotes offset formation in *Hosta* cultivars. *J. Environ. Hort.* 15 (3):119-122.
- Garner, J.M., G.J. Keever, D.J. Eakes, and J.R.J. Kessler. 1997b. Benzyladenine-induced offset formation in *Hosta* dependent on cultivar. *HortScience* 32 (1):91-93.
- Garner, J.M., G.J. Keever, D.J. Eakes, and J.R.J. Kessler. 1998. Sequential BA applications enhance offset formation in *Hosta*. *HortScience* 33 (4):707-709.
- Gates, J.C., and J.M. Smagula. 1989. Initiating rhizomes of lowbush blueberry with the cytokinin 2iP. *HortScience* 24 (6):1035.
- Giampan, J.S., T.S. Cerquiera, A.P. Jacomino, J.A.M. Rezende, and F.F. Sasaki. 2005. Induction of lateral shoots of Papaya tree (*Carica papaya* L.). *Rev. Bras. Frutic., Jaboticabal* 27 (1):185-187.
- Gianfagna, T., and R. Merritt. 1998. GA<sub>4/7</sub> promotes stem growth and flowering in a genetic line of *Aquilegia x hybrida* Sims. *Plant Growth Regulation* 24:1-5.
- Gilbertson-Ferriss, T.L., and H.F. Wilkins. 1981. Response of *Freesia hybrida* corms to exogenous growth regulator applications. *HortScience* 16 (4):568-570.
- Gilliam, C.H., and R.D. Wright. 1977. Effects of nitrogen and growth regulators on growth of Japanese holly. *J. Amer. Soc. Hort. Sci.* 102 (1):46-48.
- Ginzburg, C. 1973. Hormonal regulation of cormel dormancy in *Gladiolus grandiflorus*. *Journal of Experimental Botany* 24 (80):558-566.

- Goh, C.J. 1977. Regulation of floral initiation and development in an orchid hybrid *Aranda* Deborah. *Ann. Bot.* 41:763-769.
- Goh, C.J. 1979. Hormonal regulation of flowering in a sympodial orchid hybrid *Dendrobium* Louisae. *New Phytol.* 82:375-380.
- Goh, C.J., and A.L. Yang. 1978. Effects of growth regulators and decapitation on flowering of *Dendrobium* orchid hybrids. *Plant Science Letters* 12:287-292.
- Green, Duane W., and Wesley R. Autio. 1990. Vegetative response of apple trees following benzyladenine and growth regulator sprays. *J. Amer. Soc. Hort. Sci.* 115 (3):400-404.
- Grochowska, M.J., and M. Hodun. 1997. The dwarfing effect of a single application of growth inhibitors to the root-stem connection - "the collar tissue" - of five species of fruit trees. *J. Hort. Sci.* 72 (1):83-91.
- Grønberg, H. 1987. Cytokinin fremskynder sideskud. *Gartner Tidende* 34 (87):986-987.
- Grzesik, M., M. K. Joustra, and S. Marczynski. 1990. Effects of Promalin and nutritional levels on the growth of *Skimmia reevesiana* under glass. *Gartenbauwissenschaft* 55 (3):125-126.
- Grzesik, M., and R.M. Rudnicki. 1985. The use of growth regulators in nursery production of woody ornamental plants. *Acta Horticulturae* 167:401-415.
- Guak, S., M. Beulah, D. Neilsen, H.A. Quamme, and N.E. Looney. 2005. Effects of urea and plant bioregulators (Ethephon and Promalin) on tissue nitrogen levels, cold hardiness, and cropping of sweet cherry trees. *Acta Horticulturae* 667:453-460.
- Guardiola, J.L., M.T. Barres, C. Albert, and A. Garcia Luis. 1992. Growth regulators and fruit development in Satsuma mandarin. *Current plant science and biotechnology in agriculture* 13:411-417.
- Gulzar, S., I. Tahir, I. Amin, S. Farogg, and S.M. Sultan. 2005. Effect of cytokinins on the senescence and longevity of isolated flowers of day lily (*Heemerocallis fulva*) cv. Royal Crown sprayed with cycloheximide. *Acta Horticulturae* 669:395-403.
- Gusta, L. V., D. B. Fowler, and N. J. Tyler. 1982. The effect of abscisic acid and cytokinins on the cold hardiness of winter wheat. *Can. J. Bot.* 60:301-305.
- Guzman, V. L. 1963. Concentration of N<sup>6</sup> benzyladenine, temperature, and time effects on retardation of senescence in celery and endive. *Proc. Fla. State Hort. Soc.* 75:196-201.
- Hagon, M.W. 1976. Germination and dormancy of *Themeda australis*, *Danthonia* spp., *Stipa bigeniculata* and *Bothriochloa macra*. *Aust. J. Bot.* 24:319-327.
- Halevy, A.H., D.R. Dilley, and S. H. Wittwer. 1965. Chemical regulation of leaf senescence. *Quart. Bull. Mich. agric. Exp. Stat.* 48:30-35.

- Hall, M.R. 1994. Early sweetpotato plant production increased by GA<sub>3</sub> and BA plus GA<sub>4+7</sub>. *HortScience* 29 (2):126.
- Hamada, K., and K. Hasegawa. 2008. Strapping and a synthetic cytokinin promote cell enlargement in 'Hiratanenashi' Japanese persimmon. *Plant Growth Regulation* 54:225-230.
- Hamilton, D.F., and P.L. Carpenter. 1976. Factors influencing low-temperature after-ripening in seed of *Elaeagnus umbellata* Thunb. *J. Amer. Soc. Hort. Sci.* 10 (2):171-175.
- Han, S.S. 1995. Growth regulators delay foliar chlorosis of Easter lily leaves. *J. Amer. Soc. Hort. Sci.* 120 (2):254-258.
- Han, S.S. 1997. Preventing postproduction leaf yellowing in Easter lily. *J. Amer. Soc. Hort. Sci.* 122 (6):869-872.
- Han, S.S. 2000. Growth regulators reduce leaf yellowing in Easter lily caused by close spacing and root rot. *HortScience* 35 (4):657-660.
- Han, S.S. 2001. Benzyladenine and gibberellins improve postharvest quality of cut asiatic and oriental lilies. *HortScience* 36 (4):741-745.
- Hanks, G.R., and A.R. Rees. 1977a. Growth regulator treatments to improve the yield of twin-scaled *Narcissus*. *Scientia Horticulturae* 6:237-240.
- Hanks, G.R., and A.R. Rees. 1977b. Stem elongation in tulip and *Narcissus*: The influence of floral organs and growth regulators. *New Phytol.* 78:579-591.
- Hare, R.C. 1984. Stimulation of early height growth in longleaf pine with growth regulators. *Can. J. For. Res.* 14:459-462.
- Harkema, H., M.W.C. Dekker, and M.L. Edsers. 1991. Distribution of amino-oxyacetic acid in cut carnation flowers after pretreatment. *Scientia Horticulturae* 47 (3-4):327-333.
- Harkess, R.L., and R.E. Lyons. 1994. Gibberellin- and cytokinin-induced growth and flowering responses in *Rudbeckia hirta* L. *HortScience* 29 (3):141-142.
- Havelange, A., M. Bodson, and G. Bernier. 1986. Partial floral evocation by exogenous cytokinin in the long day plant *Sinapis alba*. *Physiol. Plant.* 67:695-701.
- Hayata, Y., Y. Niimi, and N. Iwasaki. 1995a. Inducing parthenocarpic fruit of watermelon with plant bioregulators. *Acta Horticulturae* 394:235-240.
- Hayata, Y., Y. Niimi, and N. Iwasaki. 1995b. Synthetic cytokinin--1-(2-chloro-4-pyridyl)-3-phenylurea (CPPU)--promotes fruit set and induces parthenocarpy in watermelon. *J. Amer. Soc. Hort. Sci.* 120 (6):997-1000.
- Heide, O.M. 1965. Interaction of temperature, auxins, and kinins in the regeneration ability of *Begonia* leaf cuttings. *Physiol. Plant.* 18:891-920.

- Heide, O.M., and J. Oydvin. 1969. Effects of 6-benzylamino-purine on the keeping quality and respiration of glasshouse carnations. *Hort. Res.* 9:26-36.
- Heins, R.D., A.M. Armitage, and W.D. Carlson. 1981. Influence of temperature, water stress, and BA on vegetative and reproductive growth of *Schlumbergera truncata*. *HortScience* 16 (5):679-680.
- Hemberg, T. 1970. The action of some cytokinins on the rest-period and the content of acid growth-inhibiting substances in potato. *Physiol. Plant.* 23:850-858.
- Henley, R.W., and R.T. Poole. 1974. Influence of growth regulators on tropical foliage plants. *Proceedings of the Florida State Horticultural Society* 87th annual meeting:435-438.
- Henny, R.J. 1985. BA induces lateral branching of *Peperomia obtusifolia*. *HortScience* 20 (1):115-116.
- Henny, R.J. 1986. Increasing basal shoot production in a non-branching *Dieffenbachia* hybrid with BA. *HortScience* 21 (6):1386-1388.
- Henny, R.J. 1995. Thidiazuron increases basal bud and shoot development in *Spathiphyllum* 'Petite'. *PGRSA quarterly* 23 (1):13-16.
- Henny, R.J., and W.C. Fooshee. 1985. Induction of basal shoots in *Spathiphyllum* 'Tasson' following treatment with BA. *HortScience* 20 (4):715-717.
- Henny, R.J., and W.C. Fooshee. 1986. Comparison of BA, kinetin, and 2iP for inducing basal shoot production in *Spathiphyllum* 'Bennett'. *Foliage Digest* 9 (11):6-8.
- Henny, R.J., and W.C. Fooshee. 1989. BA-treatment stimulates basal shoot production in *Anthurium* X 'Southern Blush'. In *CFREC-Apopka Research Report RH-89-16*, 3.
- Henny, R.J., and W.C. Fooshee. 1990a. Thidiazuron stimulates basal bud and shoot formation in *Alocasia* X *Chantrieri* Andre. *HortScience* 25 (1):124.
- Henny, R.J., and W.C. Fooshee. 1990b. Treatment of *Syngonium* 'Maya Red' with thidiazuron in attempt to induce basal branching. In *CFREC-Apopka Research Report RH-91-1*.
- Henny, R.J., and W.C. Fooshee. 1990c. Use of Thidiazuron in attempt to stimulate basal branching of *Monstera siltepecana*. In *CFREC-Apopka Research Report RH-90-24*.
- Herrera, E., M. Cardenas, and K. Gustafson. 1987. Promotion of lateral growth of pecans (*Carya illinoensis* (Wangenh.) K. Koch) with plant regulator sprays. *Phyton* 47 (1/2):53-62.
- Hicklenton, P.R. 1991. GA<sub>3</sub> and benzylaminopurine delay leaf yellowing in cut *Alstroemeria* stems. *HortScience* 26 (9):1198-1199.
- Higaki, T., and H.P. Rasmussen. 1979. Chemical induction of adventitious shoots in *Anthurium*. *HortScience* 14 (1):64-65.

- Hinesley, L.E., and R. D. Wright. 1988. Budset and growth of Eastern White Pine following application of 6-benzylaminopurine to seedlings fertilized with different levels of nitrogen. *J. Environ. Hort.* 6 (2):33-38.
- Ho, Y.S., K.C. Sanderson, and J.C. Williams. 1985. Effect of chemicals and photoperiod on the growth and flowering of Thanksgiving cactus. *J. Amer. Soc. Hort. Sci.* 110 (5):658-662.
- Hodgson, R.H., and R.H. Snyder. 1988. Thidiazuron effects on Malvaceae, Corn, *Zea mays*; and Soybean, *Glycine max.* *Weed Technology* 1988 (2):342-349.
- Holcomb, E.J., R.G. Brumfield, L.D. Tukey, and J.M. McDowell. 1987. The effect of growth regulators and photoperiod on the growth of roses. *Bul. Plant Growth Reg. Soc. Amer.* 15 (4):12-14.
- Hoover, M.P., J.B. London, W.B. Miller, G. Legnani, and R.T. Fernandez. 1998. Benzyladenine induces branching in eleven new *Hosta* cultivars. *SNA Research Conference Proceedings* 43:303-304.
- Hopkins, D. L. 1985. Effects of plant growth regulators on development of Pierce's disease symptoms in grapevine. *Plant Disease* 69 (11):944-946.
- Hopkins, R., R. Beach, and R. Menendez. 2005. Benefits of Prestige (CPPU, Forchlorfenuron) use in California table grapes. *Proceedings of the 32nd Annual Meeting of the Plant Growth Regulation Society of America, Newport Beach, California, USA, 24-27 July, 2005 Research Triangle Park*:35.
- Hosseini, S. M., and K. Poustini. 2008. Effects of foliar application of BAP on source and sink strength in four six-rowed barley (*Hordeum vulgare* L.) cultivars. *Plant Growth Regulation* 54:231-239.
- Hrotkó, K., L. Magyar, and B. Öri. 1999. Improved feathering on one-year-old 'Germersdorfi FL 45' sweet cherry trees in the nursery. *Gartenbauwissenschaft* 64 (2):75-78.
- Huang, K.L., and W.S. Chen. 2002. BA and sucrose increase vase life of cut *Eustoma* flowers. *HortScience* 37 (3):547-549.
- Huitron, M.V., M. Diaz, F. Dianez, and F. Camacho. 2007. Effect of 2,4-D and CPPU on triploid watermelon production and quality. *HortScience* 42 (3):559-564.
- Hutchinson, M.J., D.K. Chebet, and V.E. Emongor. 2003. Effects of Accel, sucrose and silver thiosulphate on the water relations and postharvest physiology of cut tuberose flowers. *African Crop Science Journal* 11 (4):279-287.
- Iizuka, M., K. Takeuchi, J. Watanabe, and Sein-Hla Bo. 1978. Artificial induction of bubils in *Lilium* species. *HortScience* 13 (6):666-667.
- Imamura, J.S., and T. Higaki. 1988. Effect of GA<sub>3</sub> and BA on lateral shoot production on *Anthurium*. *HortScience* 23 (2):353-354.

- Imanishi, H., and D. Yue. 1986. Effects of duration of exposure to ethylene on flowering of Dutch iris. *Acta Horticulturae* 177:141-145.
- Ismail, A.A. 1967. Respiratory inhibition of mature detached blueberry fruit (*Vaccinium angustifolium* Ait.) by N<sup>6</sup>-benzyladenine, kinetin, and N-dimethylamino-succinamic acid. *Botanical Gazette* 128 (3/4):206-208.
- Itai, A., K. Tanabe, F. Tamura, S. Susaki, K. Yonemori, and A. Sugiura. 1995. Synthetic cytokinins control persimmon fruit shape, size and quality. *Journal of Horticultural Science* 70 (6):867-873.
- Jackson, E.K. 1975. Increased yield of carnation cuttings and flowers by treatment with ACCEL plant growth regulator. *HortScience* 10 (3):309.
- Jackson, J.E. 1997. Branch induction using hydrogen cyanamide and Promalin. *Acta Horticulturae* 451:679-681.
- Jackson, M.B., and D.J. Campbell. 1979. Effects of benzyladenine and gibberellic acid on the responses of tomato plants to anaerobic root environments and to ethylene. *New Phytol.* 82:331-340.
- Jacyna, T., Starbuck C.J., and M.R. Ellersiek. 1994. Increasing branching of landscape pear trees with Promalin and Dikegulac-sodium. *J. Environ. Hort.* 12 (2):90-92.
- Jaiswal, S., and S. Sawhney. 2006. Correlation of epiphyllous bud differentiation with foliar senescence in crassulacean succulent *Kalanchoe pinnata* as revealed by thidiazuron and ethrel application. *Journal of Plant Physiology* 163:717-722.
- Jarassamrit, N. 1989. Branch induction of spur type red delicious apple nursery trees. *Acta Horticulturae* 240:155-158.
- Jaroenkit, T., and R.E. Paull. 2003. Postharvest handling of *Heliconia*, red ginger, and bird-of-paradise. *HortTechnology* 13 (2):259-266.
- Jeffcoat, B. 1977. Influence of the cytokinin, 6-benzylamino-9-(tetrahydropyran-2-yl)-9H-purine, on the growth and development of some ornamental crops. *Journal of Horticultural Science* 52:143-153.
- Jones, C.M. 1965. Effects of benzyladenine on fruit set in muskmelon. *Proc. Amer. Soc. Hort. Sci.* 87:335-340.
- Juamièn, Fr., B. Czarnecki, and Mitrut T. 1992. Very similar effects of a mixture of GA<sub>3</sub> and BA (6-benzylaminopurine) and of GA<sub>4+7</sub> and BA on branching of some apple cultivars in nursery. *Acta Horticulturae* 329:35-42.
- Junttila, O. 1970. Effects of stratification, growth substances and temperature on the germination of some *Syringa* species. *Meld. Norg. LandbrHogsk.* 49 (35):1-58.

- Kamínek, M., T. Vanek, A. Kalendová-Kulasová, and J. Pilar. 1987. The effect of two cytokinins on production of stem cuttings by stock plants of *Euphorbia pulcherrima* Willd. and *Gerbera jamesonii* Hook. *Scientia Horticulturae* 33:281-289.
- Kandeler, R. 1986. Lemnaceae. In *CRC Handbook of Flowering*, ed. A. H. Halevy, 251-278. Boca Raton, FL: CRC Press.
- Kano, Y. 1981. Roles of cytokinin and abscisic acid in the maturing of strawberry fruits. *J. Japan. Soc. Hort. Sci.* 50 (1):31-36.
- Kaufman, J., and S.M. Ringel. 1961. Tests of growth regulators to retard yellowing and abscission of cauliflower. *Proc. Amer. Soc. Hort. Sci.* 78:349-352.
- Keever, G.J. 1994. BA-induced offset formation in *Hosta*. *J. Environ. Hort.* 12 (1):36-39.
- Keever, G.J., and T.J. Brass. 1998. Offset increase in *Hosta* following benzyladenine application. *J. Environ. Hort.* 16 (1):1-3.
- Keever, G.J., D.J. Eakes, and C.H. Gilliam. 1995. Offset stage of development affects *Hosta* propagation by stem cuttings. *J. Environ. Hort.* 13 (1):4-5.
- Keever, G.J., and D.A. Findley. 2002. Thidiazuron increases shoot formation in *Nandina*. *J. Environ. Hort.* 20 (1):24-28.
- Keever, G.J., and W.J. Foster. 1990. Chemically induced branching of woody landscape plants. *J. Environ. Hort.* 8 (2):78-82.
- Keever, G.J., W.J. Foster, J.W. Olive, and M.S. West. 1993. Increasing 'Bradford' pear crotch angles and lateral shoot counts with benzyladenine or Promalin sprays. *HortScience* 28 (6):678.
- Keever, G.J., and J.C. Warr. 2005. Response of *Hosta* to method and time of BA application. *PGRSA quarterly* 33 (1):4-11.
- Keever, Gary J., and Teresa J. Morrison. 2003. Multiple benzyladenine applications increase shoot formation in *Nandina*. *J. Environ. Hort.* 21 (3):144-147.
- Khademi, M., and M. Khosh-Khui. 1977. Effect of growth regulators on branching, flowering, and fruit development of ornamental pepper (*Capsicum annuum* L.). *J. Amer. Soc. Hort. Sci.* 102 (6):796-798.
- Khaimov, A., and Y. Mizrahi. 2006. Effects of day-length, radiation, flower thinning and growth regulators on flowering of the vine cacti *Hylocereus undatus* and *Selenicereus megalanthus*. *Journal of Horticultural Science & Biotechnology* 81 (3):465-470.
- Khalil, S., H.M. El-Saeid, and M. Shalaby. 2006. The role of kinetin in flower abscission and yield of lentil plant. *Journal of Applied Science Research* 2 (9):587-591.

- Khosh-Khui, M., I. Rouhani, and B. ShayBany. 1978. Axillary shoot stimulation and plant development of coleus treated with certain plant growth regulators. *Canad. J. Plant Sci.* 58:971-976.
- Kim, J.H., A.K. Lee, and J.K. Suh. 2005. Effect of certain pre-treatment substances on vase life and physiological character in *Lilium* spp. *Acta Horticulturae* 673:307-314.
- Kim, S.E., and H. Okubo. 1996. Hormonal control of growth habit in determinate Lablab bean (*Lablab purpureus*). *Scientia Horticulturae* 65:95-104.
- King, J.W., J.B. Beard, and P.E. Rieke. 1982. Factors affecting survival of Kentucky bluegrass sod under simulated shipping conditions. *J. Amer. Soc. Hort. Sci.* 107 (4):634-637.
- King, R.W., I.A. Dawson, and S.S. Speer. 1992. Control of growth and flowering in two western Australian species of *Pimelea*. *Aust. J. Bot.* 40:377-388.
- Kochankov, V.G. 1989. Effect of 6-benzylaminopurine on stem formation and flower bud initiation in *Rubeckia bicolor* plants of different ages under non-inductive conditions. *Acta Horticulturae* 251:25-33.
- Krishnan, S., K. Azhakanandam, G.A. Ebenezer, N.P. Samson, and P. Sayanandan. 1999. Brassinosteroids and benzylaminopurine increase yield in IR50 indica rice. *Current Science* 76 (2):145-147.
- Kulasegaram, S. 1969. Studies on the dormancy of tea shoots. 1. Hormonal stimulation of the growth of dormant buds. *Tea Quart.* 40:31-46.
- Kulka, R.G. 2006. Cytokinins inhibit epiphyllous plantlet development on leaves of *Bryophyllum* (*Kalanchoe*) *marnierianum*. *Journal of Experimental Botany* 57 (15):4089-4098.
- Kumar, M.U., and K.S.K. Sastry. 1974. Effect of exogenous application of growth regulators on germinating ability of developing sunflowers. *Indian Journal of Experimental Biology* 12:543-545.
- Kuraishi, S., Y. Hashimoto, and M. Shiraishi. 1981. Latent periods of cytokinin-induced stomatal opening in the sunflower leaf. *Plant & Cell Physiol.* 22 (5):911-916.
- Kwon, E., and R.A. Criley. 1991. Cytokinin and ethephon induce greater branching of pruned *Plumeria*. *Horticultural Digest* 93:6-8.
- Leclerc, M., C.D. Caldwell, and R.R. Lada. 2006. Effect of plant growth regulators on propagule formation in *Hemerocallis* spp. and *Hosta* spp. *HortScience* 41 (3):651-653.
- Leclerc, M., C.D. Caldwell, L. Mapplebeck, R.R. Lada, and J. Norrie. 2003. Enhancement of propagule formation of *Hemerocallis* and *Hosta*. *Proceedings of the plant growth regulation society of America Thirtieth Annual Meeting*:74.

- Lee, A.K., S.R. Rhee, J.K. Suh, and H.C. Cha. 2005. Development of floral organ and physiochemical changes of cut *Iris hollandica* 'Blue Magic' according to plant growth regulators and storage temperature. *Acta Horticulturae* 673:315-321.
- Leeson, T., and R. Harkess. 2006. Influence of cytokinins on lateral branching of *Iris germanica* rhizome. *SNA Research Conference Proceedings* 51:330-331.
- Lenz, F., and A. Karnatz. 1969. The effect of growth regulators on cuttings of black currants at different stages of dormancy. I. Development of the inflorescences. *Angew. Bot.* 43:261-274.
- Leonard, R.T., and T.A. Nell. 2004. Short-term pulsing improves postharvest leaf quality of cut oriental lilies. *HortTechnology* 14 (3):405-411.
- Lewnes, M.A., and B.C. Moser. 1976. Growth regulator effects on apical dominance of English ivy. *HortScience* 11 (5):484-485.
- Lieth, H., and L.L. Dodge. 2004. Efficacy and phytotoxicity of Fascination (6-benzyladenine and GA<sub>4</sub>+GA<sub>7</sub>) on a variety of ornamental plants. *Proceedings of the 32nd Annual Meeting of the Plant Growth Regulation Society of America, Newport Beach, California, USA, 24-27 July, 2005 Research Triangle Park*:52.
- Lipton, W.J., and M.J. Ceponis. 1962. Retardation of senescence and stimulation of oxygen consumption in head lettuce treated with N<sup>6</sup> benzyladenine. *Proc. Amer. Soc. Hort. Sci.* 91:379-384.
- Little, C.H.A. 1984. Promoting bud development in balsam fir Christmas trees with 6-benzylaminopurine. *Can. J. For. Res.* 14:447-451.
- Little, C.H.A. 1985. Increasing lateral shoot production in Balsam fir Christmas trees with cytokinin application. *HortScience* 20 (4):713-714.
- Liu, F.H., and N. Longnecker. 2001. Interactive effect of cytokinin and potassium on sink-source relationships in *Lupinus angustifolius*. *Plant Growth Regulation* 00:1-6.
- Liu, X., B. Huang, and G. Banowetz. 2002. Cytokinin effects on creeping bentgrass responses to heat stress: I. Shoot and root growth. *Crop Sci.* 42:457-465.
- Liu, Z., and W.R. Bushnell. 1986. Effects of cytokinins on fungus development and host response in powdery mildew of barley. *Physiological and molecular plant pathology* 29 (1):41-52.
- Liu, Z., Y. Goto, I. Nishiyama, and M. Kokubun. 2001. Effects of foliar and root-applied benzyladenine on tillering of rice plants grown in hydroponics. *Plant Prod. Sci.* 4 (3):220-226.
- Loach, K., and Whalley D. N. 1975. Use of light, carbon dioxide enrichment and growth regulators in the overwintering of hardy ornamental nursery stock cuttings. *Acta Horticulturae* 54:105-116.

- Lona, F., and A. Bocchi. 1957. Morphogenetic and organogenetic effects of kinetin on herbaceous plants in a controlled environment. *Nuovo G. bot. ital.* 64:236-246.
- Lopez-Galarza, S., J.V. Maroto, B. Pascual, and M.S. Bono. 1993. Productive response of strawberry plants (*Fragraria x ananassa* Duch.) to different plant growth regulator mixes in Spain. *Acta Horticulturae* 348:307-314.
- Lucaszewska, A.J., P. Barthe, and M.T. Le Page-Devigry. 1995. The effect of exogenous cytokinins on longevity of cut roses. *Acta Horticulturae* 405:422-426.
- Lucaszewska, A.J., J. Bianco, P. Barthe, and M.T. Le Page-Devigry. 1994. Endogenous cytokinins in rose petals and the effect of exogenously applied cytokinins on flower senescence. *Plant Growth Regulation* 14 (2):119-126.
- Lukaszewska, A. 1986. The effect of benzyladenine and ethephon on soluble protein content and invertase activity in wilting cut roses cv. Carina. *Acta Horticulturae* 181:87-92.
- Luria, G., D. Weiss, O. Ziv, and A. Borochoy. 2005. Effect of planting depth and density, leaf removal, cytokinin and gibberellic acid treatments on flowering and rhizome production in *Zantedeschia aethiopica*. *Acta Horticulturae* 673:725-730.
- Lyons, R.E., and C.L. Hale. 1987. Comparison of pinching methods on selected species of *Columnea*, *Kalanchoe*, and *Crassula*. *HortScience* 22 (1):72-74.
- MacKay, W.A., N. Sankhla, and T.D. Davis. 2002. Forchlorfenuron (CPPU): A novel agent for preventing leaf senescence and flower abscission in cut phlox flower heads. *Proceedings of the plant growth regulation society of America* 29:177-180.
- MacKay, W.A., N. Sankhla, S.M.L. Rahman, and T.D. Davis. 2003. Effect of Fascination™ on postharvest performance of cut racemes of bigbend bluebonnet. *Proceedings of the plant growth regulation society of America* Thirtieth Annual Meeting:113-115.
- MacLean, D.C., and R.R. Dedolph. 1962. Effects of N<sup>6</sup>-benzyladenine on post-harvest respiration of *Chrysanthemum morifolium* and *Dianthus caryophyllus*. *Botanical Gazette* 124 (1):20-21.
- Mae, T., and C.R. Vonk. 1974. Effect of light and growth substances on flowering of *Iris x hollandica* cv. Wedgewood. *Acta Bot. Neerl.* 23 (3):321-331.
- Maene, L.J., and P.C. Deburgh. 1982. Stimulation of axillary shoot development of *Cordyline terminalis* 'Celestine Queen' by foliar sprays of 6-benzylamino purine. *HortScience* 17 (3):344-345.
- Magyar, L., and K. Hrotkó. 2005. Effect of BA (6-benzyladenine) and GA<sub>4+7</sub> on feathering of sweet cherry cultivars in the nursery. *Acta Horticulturae* 667:417-422.
- Mahmoud, S.E.D.M. 1996. Response of growth and essential oil content of sweet basil (*Ocimum basilicum* L.) to some natural hormones. *Acta Horticulturae* 426:629-634.

- Malik, H., and D.D. Archbold. 1992. Manipulating primocane architecture in thornless blackberry with uniconazole, GA<sub>3</sub>, and BA. *HortScience* 27 (2):116-118.
- Marczynski, S., G. Klimczyk, and K. Majchrzak. 1979. Branching stimulation of budded roses with growth regulators. *Acta Horticulturae* 91:467-474.
- Maroto, J.V., A. Miguel, S. Lopez-Galarza, A.S. Bautista, B. Pascual, J. Alagarda, and J.L. Guardiola. 2005. Parthenocarpic fruit set in triploid watermelon induced by CPPU and 2,4-D applications. *Plant Growth Regulation* 45:209-213.
- Matsubara, S. 1973. Overcoming self-incompatibility by cytokinins treatment on *Lilium longiflorum*. *Bot. Mag. Tokyo* 86:43-46.
- Matsumoto, T.K. 2006. Gibberellic acid and benzyladenine promote early flowering and vegetative growth of *Miltoniopsis* orchid hybrids. *HortScience* 41 (1):131-135.
- Mazzola, M., and J. F. Costante. 1987. Efficacy of BA for the promotion of lateral bud formation on Douglas-fir and Colorado blue spruce. *HortScience* 22 (2):234-235.
- McAvoy, R.J., and B.B. Bible. 1998. Poinsettia bract necrosis is affected by scion/rootstock combinations and arrested by a benzyladenine spray. *HortScience* 33 (2):242-246.
- McCarthy, D., and G. Bünemann. 1981a. The use of growth regulators in the production of dwarf ornamental shrubs I. Dwarf conifers. *Gartenbauwissenschaft* 46 (5):193-199.
- McCarthy, D., and G. Bünemann. 1981b. Use of growth regulators in the production of dwarf ornamental shrubs II. Dwarf deciduous shrubs. *Gartenbauwissenschaft* 46 (6):253-261.
- McConnell, D.B., and R.T. Poole. 1972. Vegetative growth modification of *Scindapsus aureus* by ancymidol and PBA. *Proceedings of the Florida State Horticultural Society* 85th Annual Meeting:387-389.
- McNeil, K.J. 1990. Effect of benzylaminopurine and thidiazuron on maize kernel development. *Proceedings of the plant growth regulation society of America* (17):16-17.
- Merino, R., H. Serri, and Holzapfel J. 2002. Effect of GA<sub>3</sub> and CPPU on fruit of 'Tifblue' rabbiteye blueberry (*Vaccinium ashei* R.). *Acta Horticulturae* 574:239-243.
- Messinger, N.L., and E.J. Holcomb. 1986. The effect of chlormequat chloride, ancymidol, BAS 106, and SD8339 on selected dianthus cultivars. *HortScience* 21 (6):1397-1400.
- Meyer, P. 1974. The effects of Accel (SD-8339) on chrysanthemums. *Ohio Florists Association Bulletin* (531):8.
- Michniewicz, M., and A. Kamienska. 1964. Flower formation induced by kinetin and vitamin E treatment in cold-requiring plant (*Chichorium intybus* L.) grown under non-inductive conditions. *Naturwissenschaften* 51:295-296.

- Miedema, P., and G.C. Kamminga. 1994. Bulb dormancy in onion. II. The role of cytokinins in high-temperature imposed sprout inhibition. *Journal of Horticultural Science* 69 (1):41-45.
- Milbocker, D.C. 1967. Dioecy in the holly. *Proc. 42nd Mtg Holly Soc. Amer.* 1967:10-11.
- Milbocker, D.C. 1972. Axillary shoot stimulation in poinsettia with kinetin. *HortScience* 7 (5):483-484.
- Miller, S.S. 1985. Low-volume sprays of BA and Promalin increase branching in apple trees. *HortScience* 20 (4):730-732.
- Mirdehghan, S.H., and M. Rahemi. 2005. Effects of hot water treatment on reducing chilling injury of pomegranate (*Punica granatum*) fruit during storage. *Acta Horticulturae* 682 (2).
- Miyajima, D. 2000. Flower bud removal and cytokinin treatment stimulate capitulum formation in double-flowered zinnias. *HortScience* 35 (2):260-261.
- Moe, R. 1979. Hormonal control of flower blasting in tulips. *Acta Horticulturae* 91:221-228.
- Moe, R., and M. Berland. 1986. Effect of various corm treatments on flowering of *Liatris spicata* Willd. *Acta Horticulturae* 177:197-201.
- Moore, J. N. 1970. Cytokinin-induced sex conversion in males clones of *Vitis* species. *J. Amer. Soc. Hort. Sci.* 95 (4):387-393.
- Moore, K. G., and R. Leach. 1968. The effect of 6-benzylaminopurine (benzyladenine) on senescence and chocolate spot (*Botrytis fabae*) of winter beans (*Vicia faba*). *Ann. appl. Biol.* 61:65-76.
- Mor, Y., and A.H. Halevy. 1984. Dual effect of light on flowering and sprouting of rose shoots. *Physiol. Plant.* 61:119-124.
- Morales-Payan, J.P. 2004. Bermuda turfgrass response to benzyladenine and phosphorus fertilization. *PGRSA quarterly* 34 (2):67.
- Morales-Payan, J.P., and W.M. Stall. 2003. Plant growth regulators and nitrogen affect ratoon production in papaya (*Carica papaya*). *Proceedings of the plant growth regulation society of America Thirtieth Annual Meeting*:159.
- Mukherjee, D., and R. Kumar. 2007. Kinetin regulates plant growth and biochemical changes during maturation and senescence of leaves, flowers and pods of *Cajanus cajan* L. *Biologia Plantarum* 51 (1):80-85.
- Mulgrew, S.M., and D.J. Williams. 1985. Effect of benzyladenine on the promotion of bud development and branching of *Picea pungens*. *HortScience* 20 (3):380-381.
- Murch, S.J., S. KrishnaRaj, and P.K. Saxena. 1997. Thidiazuron-induced morphogenesis of Regal geranium (*Pelargonium domesticum*): A potential stress response. *Physiol. Plant.* 101:183-191.

- Musselwhite, S., R. Harris, J. Lattimer, and R. Wright. 2004. Effect of pruning, defoliation, and Promalin on new shoot development of boxwood. *J. Environ. Hort.* 22 (3):124-128.
- Mutui, T.M., V.E. Emongor, and M.J. Hutchinson. 2001. Effect of Accel on the vase life and post harvest quality of Alstroemeria (*Alstroemeria aurantiaca* L.) cut flowers. *African Journal of Science and Technology* 2 (1):82-88.
- Mynett, K. 1979. Growth regulators in the bud development of carnation. *Acta Horticulturae* 91:461-465.
- Mynett, K. 1985. Growing tree-like plants of *Fuchsia* by using gibberellic acid GA<sub>3</sub>. *Acta Horticulturae* 167:333-338.
- Mynett, K.J. 1977. La benzyladenine influence les plantes meres chez L oeillet en serre. *Acta Horticulturae* 71:19-21.
- Nagel, L., R. Brewster, W.E. Riedell, and R.N. Reese. 2001. Cytokinin regulation of flower and pod set in soybeans (*Glycine max* (L.) Merr.). *Ann. Bot.* 88 (1):27-31.
- Naor, V., J. Kigel, and M. Ziv. 2005. The effect of gibberellin and cytokinin on floral development in *Zantedeschia* spp. *in vivo* and *in vitro*. *Acta Horticulturae* 673:255-263.
- Napier, D.R., G. Jacobs, Can Staden J., and C. Forsyth. 1986. Cytokinins and flower development in *Leucospermum*. *J. Amer. Soc. Hort. Sci.* 111 (5):776-780.
- Nauer, E.M., and S.B. Boswell. 1981. Stimulating growth of quiescent citrus buds with 6-benzylamino purine. *HortScience* 16 (2):162-163.
- Nell, T.A., and R.A. Larson. 1974. The influence of foliar applications of GA<sub>3</sub>, GA<sub>4,7</sub> and PBA on breaking flower bud dormancy on azalea cvs Redwing and Dogwood. *J. Hort. Sci.* 49:323-328.
- Neri, D., M. Mazzoni, F. Zucconi, and G. Dradi. 2004. Feathering control in sweet cherry (*Prunus avium* L.) nursery, by deblading and cytokinin. *Acta Horticulturae* 636:119-127.
- NeSmith, D.S. 2004. Rabbiteye blueberry field trials with the growth regulator CPPU. *Small Fruits Review* 3:183-191.
- Ngamu, K. 2001. Promoting side shoot development in *Zantedeschia aethiopica* 'Green Goddess'. *Gartenbauwissenschaft* 66 (2):85-92.
- Nishijima, T., M. Hideari, K. Sasaki, and T. Okazawa. 2006. Cultivar and anatomical analysis of corolla enlargement of petunia (*Petunia hybrida* Vilm.) by cytokinin application. *Scientia Horticulturae* 111:49-55.
- Nishijima, T., and K. Shima. 2006. Change in flower morphology of *Torenia fournieri* Lind. induced by forchlorfenuron application. *Scientia Horticulturae* 109:254-261.

- Nobel, P.S. 1996. Shading, osmoticum, and hormone effects on organ development for detached cladodes of *Opuntia ficus-indica*. *Int. J. Plant Sci.* 157 (6):722-728.
- Nowak, J., and K. Mynett. 1985. The effect of growth regulators on postharvest characteristics of cut *Lilium* 'Prima' inflorescences. *Acta Horticulturae* 167:109-116.
- Nowak, T.J. 1980. Effect of gibberellin, auxin and kinetin treatments combined with foliar applied NPK on the yield of *Capsicum annuum* L. fruits and their capsaicin content. *Acta Agrobotanica* 33 (1):81-92.
- Oates, J.M., and G.J. Keever. 2003. BA-induced shoot formation in Indian hawthorn. *SNA Research Conference Proceedings* 48:283-284.
- Oates, J.M., G.J. Keever, and J.R.J. Kessler. 2004. BA-induced shoot formation in Indian hawthorn. *J. Environ. Hort.* 22 (2):71-74.
- Oates, J.M., G.J. Keever, and J.R.J. Kessler. 2005a. BA application frequency and concentration effects on two Indian hawthorn cultivars. *J. Environ. Hort.* 23 (1):37-41.
- Oates, J.M., G.J. Keever, and J.R.J. Kessler. 2005b. Developmental stage influences plant response to benzyladenine. *J. Environ. Hort.* 23 (3):149-152.
- Ogawa, Y., and R.W. King. 1980. Flowering in seedlings of *Pharbitis nil* induced by benzyladenine applied under a non-inductive daylength. *Plant & Cell Physiol.* 21 (6):1109-1116.
- Ohkawa, K. 1979. Effects of gibberellins and benzyladenine on dormancy and flowering of *Lilium speciosum*. *Scientia Horticulturae* 10:255-260.
- Ohkawa, K. 1984. Effects of benzyladenine on bud break of roses. *Scientia Horticulturae* 24 (379-383).
- Owings, A.D., and S.E. Newman. 1993. Chemical modification of *Photinia* × *fraseri* plant size and lateral branching. *J. Environ. Hort.* 11 (1):1-5.
- Pais, M.S., and H.C. Neves. 1982. Regreening of *Zantedeschia aethiopica* Spreng. spathe induced by reapplied cytokinins. *Plant Growth Regulation* 1:233-242.
- Palevitch, D., and T. H. Thomas. 1974. Thermodormancy release of celery seed by gibberellins, 6-benzylaminopurine, and ethephon applied in organic solvent to dry seeds. *Journal of Experimental Botany* 25 (88):981-986.
- Pallez, L.C., J.M. Dole, and B.E. Whipker. 2002. Production and postproduction studies with potted sunflowers. *HortTechnology* 12 (2):206-210.
- Pandey, D.M., C.L. Goswami, and B. Kumar. 2003/4. Physiological effects of plant hormones in cotton under drought. *Biologia Plantarum* 47 (4):535-540.

- Park, M.J., B.H. Kim, and S.M. Kang. 1997. Effect of kinetin and B-9 on growth and carbohydrate partitioning in one-year-old trees of persimmon (*Diospyros kaki*). *Acta Horticulturae* 436:365-373.
- Passera, C., and P. Spettoli. 1981. Effects of benzyladenine on mango fruit ripening. *Food Chemistry* 7:195-201.
- Patterson, K.J. 1993. Effects of CPPU (N-(2-chloro-4-pyridyl)-N'-phenylurea) on fruit growth, maturity, and storage quality of kiwifruit. *New Zealand Journal of Crop and Horticultural Science* 21:253-261.
- Paulin, A., and K. Muloway. 1979. Perspective in the use of growth regulators to increase the cut flowers vase life. *Acta Horticulturae* 91:135-141.
- Paull, R.E., and T. Chantrachit. 2001. Benzyladenine and the vase life of tropical ornamentals. *Postharvest Biology and Technology* 21:303-310.
- Pavlista, A.D. 2003. Thidiazuron, a cytokinin-like compound, enhances fungicidal activity against early blight in potato. *Acta Horticulturae* 619:145-152.
- Persson, B. 1993. Enhancement of seed germination in ornamental plants by growth regulators infused via acetone. *Seed Sci. & Technol.* 21:281-290.
- Petridou, M., C. Voyiatzi, and D. Voyiatzis. 2001. Methanol, ethanol and other compounds retard leaf senescence and improve the vase life and quality of cut chrysanthemum flowers. *Postharvest Biology and Technology* 23:79-83.
- Pharis, R.P. 1972. Flowering of *Chrysanthemum* under non-inductive long days by gibberellins and N<sup>6</sup>-benzyladenine. *Planta* 105:205-212.
- Philosoph-Hadas, S., R. Michaeli, Y. Reuveni, and S. Meir. 1996. Benzyladenine pulsing retards leaf yellowing and improves quality of goldenrod (*Solidago canadensis*) cut flowers. *Postharvest Biology and Technology* 9:65-73.
- Pierik, R.L.M., and H.H.M. Steegmans. 1975. Effect of auxins, cytokinins, gibberellins, abscisic acid and ethephon on regeneration and growth of bulbets on excised bulb scale segments of hyacinth. *Physiol. Plant.* 34:14-17.
- Pinto, A.C.R., T.J.D Rodrigues, and J.C. Barbosa. 2005. Benzyladenine sprays and senescent flowers removal on postproduction performance of potted *Zinnia* 'Profusion Cherry'. *Acta Horticulturae* 683:391-397.
- Plummer, J.A., and J.M. Wann. 1998. Plant growth regulators cannot be used to alter significantly the commercial harvest date of *Boronia heterophylla* F. Muell. (Rutaceae). *Aust. J. Agric. Res.* 49:99-105.
- Pogna, N. E. 1979. Interaction of kinetin and day length on vernalization of winter wheat. *Cereal Res. Comm.* 7 (3):175-181.

- Pound, W.E., and H.K. Tayama. 1984. The effect of the plant growth regulator "Accel" in increasing axillary shoots of potted chrysanthemum plants. *Ohio Florists Association Bulletin* 656:5-7.
- Preece, J.E. 1990. Growth stimulation of *Euphorbia lathyris* L. by GA<sub>4+7</sub> and BA. *J. Plant Growth Regul.* 9:85-88.
- Pressman, E., and D. Palevitch. 1973. Cytokinin-like activity of benomyl as a senescence inhibitor of broccoli heads. *HortScience* 8 (6, 1):496-497.
- Prevot, M.P. 1967. Effets de la benzyl-adenine chez *Begonia rex* Putz. *C.R. Acad. Agric. Fr* 53:1292-1297.
- Pritts, M.P., G.S. Posner, and K.A. Worden. 1986. Effects of 6-BA application on growth and development in 'Tristar', a strong day-neutral strawberry. *HortScience* 21 (6):1421-1423.
- Proctor, J.T.A., T. Slimmon, and P.K. Saxena. 1996. Modulation of root growth and organogenesis in thidiazuron-treated ginseng (*Panax quinquefolium* L.). *Plant Growth Regulation* 20:201-208.
- Puchalski, J., M. Puchalska, and M. Saniewski. 1979. Glucose-6-phosphate dehydrogenase electrophoretic forms during differentiation of benzyladenine induced bulblets of *Muscari*. *Acta Horticulturae* 91:241-245.
- Puglisi, S. 2002. Use of plant growth regulators to enhance branching of *Clematis* spp. Master of Science, Department of Horticultural Science, Virginia Polytechnic Institute and State University, Blacksburg.
- Puglisi, S., H.L. Scoggins, and J.G. Latimer. 2002. Atrimmec and Fascination enhance branching of *Clematis* spp. *Proceedings of the plant growth regulation society of America* 29:186.
- Pytlewski, C., and J. Hetman. 1985. The effect of growth regulators on development of lateral shoots in *Fosterellia penduliflora*. *Acta Horticulturae* 167:327-333.
- Quinn, J. 1977. The effects of Florel (ethephon) and Shell SD-8339 (PBA) on chrysanthemums. *Ohio Florists Association Bulletin* (569):6.
- Rahemi, M., and Z. Pakkish. 2005. Gibberellic acid and benzyladenine reduce hull splitting and aflatoxin levels in pistachio kernels. *Journal of Horticultural Science & Biotechnology* 80 (2):229-232.
- Ram, R., D. Mukherjee, and S. Manuja. 2002. Plant growth regulators affect the development of both corms and cormels in *Gladiolus*. *HortScience* 37 (2):343-344.
- Ramina, A., W.P. Hackett, and R.M. Sachs. 1979. Flowering in *Bougainvillea*. *Plant Physiol.* 64:810-813.
- Ranwala, A., and W.B. Miller. 1999. Timing of gibberellin<sub>4+7</sub> + benzyladenine sprays influences efficacy against foliar chlorosis and plant height in Easter lily. *HortScience* 34 (5):902-903.

- Ranwala, A., and W.B. Miller. 2002. Effects of gibberellin treatments on flower and leaf quality of cut hybrid lilies. *Acta Horticulturae* 570:205-210.
- Ranwala, A.P., G. Legnani, and W.B. Miller. 2003. Minimizing stem elongation during spray applications of gibberellin<sub>4+7</sub> and benzyladenine to prevent leaf chlorosis in Easter lilies. *HortScience* 38 (6):1210-1213.
- Ranwala, A.P., and W.B. Miller. 2000. Ancymidol drenches, reversed greenhouse temperatures, postgreenhouse cold storage, and hormone sprays affect postharvest leaf chlorosis in Easter lily. *J. Amer. Soc. Hort. Sci.* 125 (2):248-253.
- Ranwala, A.P., and W.B. Miller. 2005. Effects of cold storage on postharvest leaf and flower quality of potted Oriental-, Asiatic-, and LA-hybrid lily cultivars *Scientia Horticulturae* 105:383-392.
- Ranwala, A.P., and W.B. Miller. 1998. Gibberellin<sub>4+7</sub>, benzyladenine, and supplemental light improve postharvest leaf and flower quality of cold-stored 'Stargazer' hybrid lilies. *J. Amer. Soc. Hort. Sci.* 123 (4):563-568.
- Ravetta, D., and D.A. Palzkill. 1992. The effect of growth regulators and apex removal on branching and flower bud production of jojoba. *Industrial Crops and Products* 1:47-55.
- Retamales, J., F. Bangerth, T. Cooper, and R. Callejas. 1995. Effects of CPPU and GA<sub>3</sub> on fruit quality of Sultanina table grape. *Acta Horticulturae* 394:149-157.
- Richards, D. 1985. Effect of cytokinin application and environment on growth and flowering of *Boronia heterophylla* F. Meull. *Scientia Horticulturae* 27:325-334.
- Richards, D., and R.I. Wilkinson. 1984. Effect of manual pinching, potting-on and cytokinins on branching and flowering of *Camellia*, *Rhododendron*, and *Rosa*. *Scientia Horticulturae* 23:75-83.
- Rogler, C.E., and W.P. Hackett. 1975. Phase change in *Hedera helix*: Induction of mature to juvenile phase change by gibberellin A<sub>3</sub>. *Physiol. Plant.* 34:141-147.
- Roh, M.S., and Y.G. Sim. 1996. Seed germination of *Lilium x formolongi* as influenced by temperature and plant growth regulators. *Acta Horticulturae* 414:243-250.
- Roukova, L.A. 1985. Cytokinins effect on some ornamental plants. *Acta Horticulturae* 167:69-77.
- Roychowdhury, N. 1989. Effect of plant spacing and growth regulators on growth and flower yield of *Gladiolus* grown under polyethylene tunnel. *Acta Horticulturae* 246:259-263.
- Rudniki, R.M., and S. Rejman. 1982. The effect of pinching-chemicals and growth regulators on branching of *Pittosporum tobira* Ait. and *Chrysobalanus icaco* L. cultivated in containers. *Experimental work of the institute of pomology and floriculture Skierniewice, Poland* 7:155-163.

- Rulcová, J., and J. Popišilová. 2001. Effect of benzylaminopurine on rehydration of bean plants after water stress. *Biologia Plantarum* 44 (1):75-81.
- Runger, W. 1984. Effect of 6-benzyladenine at different temperatures in short day on flowering and vegetative growth of *Schlumbergera*. *Gartenbauwissenschaft* 49 (1):36-39.
- Runger, W., and H. Patzer. 1986. Influence of N<sup>6</sup>-benzyladenine on the flowering of *Rebutia vioaciflora*. *Gartenbauwissenschaft* 51 (3):108-110.
- Rushing, J.W. 1990. Cytokinins affect respiration, ethylene production, and chlorophyll retention of packaged broccoli florets. *HortScience* 25 (1):88-90.
- Ruter, J.M. 2000. Growth of five ornamental species as influenced by Early Harvest PGR. *SNA Research Conference Proceedings* 45:295-296.
- Ryan, G. F. 1974. Chemicals to increase branching of *Photinia* 'Faseri' and *Rhododendron* Exbury azaleas. *HortScience* 9 (4):534-535.
- Ryu, B.Y., and J.S. Lee. 1993. Effects of growth regulators on growth and flowering of *Aster tataricus* L. var. *minor* M. *Journal of the Korean Society for Horticultural Science* 34 (2):120-128.
- Sakai, K., Y. Katano, and H. Higuchi. 1979. Promoting flowering in *Cyclamen persicum* by benzyladenine. *Research Bulletin of the Aichi-Ken Agricultural Research Center* 11:81-87.
- Sammons, B., J.F. Rissler, and J.B. Shanks. 1981. Effects of growth regulators on diseases of begonia, chrysanthemum, poinsettia, and rose. *HortScience* 16 (5):673-674.
- Sanderson, K.C., Y.S. Ho, W.C. Martin, and R.B. Reed. 1986. Effect of photoperiod and growth regulators on growth of three Cactaceae. *HortScience* 21 (6):1381-1382.
- Sanderson, K.C., and W.C. Martin. 1974. Effect of PBA on the branching of azalea cv. Kingfisher, dwarf Burford holly and Japanese holly. *SNA Research Conference Proceedings* 19:88.
- Sanderson, K.C., and W.C. Martin. 1975. Further studies on PBA as a branching agent on ornamentals. *SNA Research Conference Proceedings* 20:93-95.
- Sanderson, K.C., W.C. Martin, and R.D. Patterson. 1987. Prepropagation dips of Acanthaceae cuttings in growth regulators to retard subsequent growth. *HortScience* 22 (2):243-244.
- Sanderson, K.C., and J.A. McGuire. 1988. Growth regulator sprays during propagation increase African violet crowns and leaves. *HortScience* 23 (6):1085.
- Saniewski, M., and W.J. De Munk. 1981. Hormonal control of shoot elongation in tulips. *Scientia Horticulturae* 15:363-372.
- Saniewski, M., and K. Mynett. 1977. The formation of parrot-like flowers in benzyladenine treated bulbs of some tulip cultivars. *Acta Horticulturae* 68:151-153.

- Saniewski, M., and J. Puchalski. 1983. The synergistic effect of benzyladenine and cyclohexamidine in *Muscari* bulblets formation. *Prace Instytutu Sadownictwa i Kwiaciarnictwa w kierniewicach, B (Rosliny Ozdobne)* 8:167-177.
- Saniewski, M., and J. Puchalski. 1997. Formation of parrot-like flowers after treatment of non-parrot tulip bulbs with benzyladenine before flower bud development. *Acta Horticulturae* 430:107-115.
- Sansavini, S., G. Cristoferi, M. Antonelli, and P. Montalti. 1981. Growth regulators in pear production. *Acta Horticulturae* 120:143-148.
- Sansberro, P., L. Mroginski, and R. Bottini. 2006. Stimulation of lateral branch formation on *Ilex paraguariensis* (Aquifoliaceae) seedlings *Australian Journal of Experimental Agriculture* 46 (707-710).
- Saunders, J., and M.D. Mahoe. 1982. Benzyladenine induces foliar adventitious shoot formation on young plants of two sugar beet (*Beta vulgaris* L.) cultivars. *Euphytica* 31:801-804.
- Saxena, O.P., G. Singh, and T. Pakeeraiah. 1987. Yield of okra, tomato, and pea as affected by seed treatments and foliar sprays. *Acta Horticulturae* 215:145-151.
- Schnurr, J.P., Z.M. Cheng, and A.A. Boe. 1996. Effects of plant growth regulators on sturdiness of jack pine seedlings. *J. Environ. Hort.* 14 (4):228-230.
- Schoene, G., and T. Yeager. 2005. Effects of benzyladenine applied alone or in combination with gibberellic acid on sweet viburnum. *SNA Research Conference Proceedings* 50:119-121.
- Schrader, W.L. 1994. Growth regulator gives earlier harvest in artichokes. *California agriculture* 48 (3):29-32.
- Schrader, W.L. 2005. Effects of plant growth regulators on heat stress in annual artichoke production. *Acta Horticulturae* 681:207-208.
- Schultz, H.C., G.J. Keever, J.R.J. Kessler, and R.R. Dute. 2000. BA Application timing affects offset formation in *Hosta*. *J. Environ. Hort.* 18 (2):63-65.
- Schultz, H.C., G.J. Keever, J.R.J. Kessler, and R.R. Dute. 2001a. Application timing affects offset formation in *Hosta*. In *Alabama Agricultural Experiment Station 2001 Ornamentals Research Report*, 23-24.
- Schultz, H.C., G.J. Keever, J.R.J. Kessler, and R.R. Dute. 2001b. BA does not reduce detrimental effects of high night temperature on offset formation in *Hosta*. In *Alabama Agricultural Experiment Station 2001 Ornamentals Research Report*, 27-28.
- Schultz, H.C., G.J. Keever, J.R.J. Kessler, and R.R. Dute. 2001c. BA does not reduce detrimental effects of high nighttime temperature on offset formation in *Hosta*. *J. Environ. Hort.* 19 (1):29-32.

- Schultz, H.C., G.J. Keever, J.R.J. Kessler, R.R. Dute, and J.W. Olive. 1998. Root mass and BA affect offset formation in *Hosta*. *SNA Research Conference Proceedings* 43:300-302.
- Schultz, H.C., G.J. Keever, J.R.J. Kessler, R.R. Dute, and J.W. Olive. 2001d. Root mass and BA affect offset formation in *Hosta*. In *Alabama Agricultural Experiment Station 2001 Ornamentals Research Report*, 22-23.
- Selman, I.W., and S. Sandanam. 1972. Growth responses of tomato plants in non-aerated water culture to foliar sprays of gibberellic acid and benzyladenine. *Ann. Bot.* 36:837-848.
- Semeniuk, P., and R.J. Griesbach. 1985. Bud applications of BA induces branching of a nonbranching poinsettia. *HortScience* 20 (1):120-121.
- Serek, M., and A.S. Anderson. 1993. AOA and BA influence on floral development and longevity of potted 'Victory Parade' miniature rose. *HortScience* 28 (10):1039-1040.
- Serek, M., and A.S. Anderson. 1995. The possibility for improvement of the longevity of intact flowers. *Acta Horticulturae* 404:48-57.
- Setyadjit, D.C. Joyce, D.E. Irving, and D.H. Simons. 2004. Effects of 6-benzylaminopurine treatments on the longevity of harvested *Grevillea* 'Sylvia' inflorescences. *Plant Growth Regulation* 43:9-14.
- Shanks, J.B., and C.B. Link. 1964. The chemical regulation of plant growth for florists. *Maryland Flor.* 108:1-16.
- Shanks, J.B., and H.G. Mityga. 1985. Effects of Promalin on greenhouse roses. *Proceedings of the plant growth regulation society of America* 12:224-230.
- Shibakusa, R. 1980. Effect of GA<sub>3</sub>, IAA, ethrel, and BA on seed germination of *Picea glehnii* Masters. *J. Jap. For. Soc.* 62:440-443.
- Shimada, Y., G. Mori, Y. Katahara, and M. Oda. 2005. The Influence of BA and NAA on adventitious bud formation in leaf cuttings of *Begonia x tuberhybrida*. *Acta Horticulturae* 673:537-541.
- Shimomura, T., and K. Fujihara. 1980. Stimulation of axillary shoot formation of cuttings of *Hylocereus trigonus* (Cactaceae) by pre-soaking in benzyladenine solution. *Scientia Horticulturae* 13:289-296.
- Shu, L.J., K.C. Sanderson, and J.C. Williams. 1981. Comparison of several chemical pinching agents on greenhouse forcing azaleas, *Rhododendron* cv. *J. Amer. Soc. Hort. Sci.* 106 (5):557-561.
- Sieminska-Michalak, E. 1989. Influence of growth regulators on branching and elongation of pot plants. *Acta Horticulturae* 251:341-343.
- Simmonds, J.A., and B.G. Cumming. 1976. Propagation of *Lilium* hybrids I. Dependence of bulblet production on time of scale removal and growth substances. *Scientia Horticulturae* 5:77-83.

- Sindagi, S.S., and K. Puttarudrappa. 1972. Sex conversion in castor (*Ricinus communis* Lin.). *Science and Culture* 39 (9):408-410.
- Siraj-Ali, Y.S., H.K. Tayama, T.L. Prince, and S.A. Carver. 1990. The relationship between maturity level and splitting in poinsettia. *HortScience* 25 (12):1616-1618.
- Skutnik, E., A. Lukaszewska, M. Serek, and J. Rabiza. 2001. Effect of growth regulators on postharvest characteristics of *Zantedeschia aethiopica*. *Postharvest Biology and Technology* 21:241-246.
- Skutnik, E., and J. Rabiza-Swider. 2005. Control of postharvest longevity of cut leaves of *Nephrolepis exaltata* (L.) Schott. *Annals of Warsaw Agricultural University, Horticulture and Landscape Architecture* 26:43-48.
- Skutnik, E., J. Rabiza-Świder, and A.J. Łukaszewska. 2006. Evaluation of several chemical agents for prolonging vase life in cut asparagus greens. *Journal of Fruit and Ornamental Plant Research* 14:233-240.
- Smeltz, K. 1995. An alternative method of *Phalaenopsis* stem propagation. *American Orchid Society Bulletin* May 1995:496-500.
- Smith, D.J., and W.W. Schwab. 1980. Cytokinin activity in oak (*Quercus robur*) with particular reference to transplanting. *Physiol. Plant.* 48:27-32.
- Smith, M.A. 1963a. Control of berry and leaf abscission and mold control in packaged mistletoe. *Plant Dis. Repr.* 47:1001-1005.
- Smith, M.A. 1963b. Science keeps mistletoe fresh longer *Agric. Mktg.* 8 (12):16.
- Sotomayor, C., and J. Castro. 1998. Improvement of fruit set in almonds using growth regulators. *Acta Horticulturae* 470:262-267.
- Spaulding, D.W., and G.L. Steffens. 1969. Elimination of light requirements for tobacco seed germination with gibberellic acid, indole-3-acetic acid and N<sup>6</sup> benzyladenine. *Tobacco New York* 169 (19):25-28.
- Stanley, A. G. 1976. The effect of 6-furfurylaminopurine (kinetin) in conjunction with Naphthaleneacetic acid on the healing of newly grafted *Camellias*. *The Camellia Review* 37 (6):34-37.
- Steffens, G. L., and G. W. Stutte. 1989. Thidiazuron substitution for chilling requirement in three apple cultivars. *J. Plant Growth Regul.* 8:301-307.
- Steinitz, B., A. Ackerman, and A. Hagiladi. 1987. Improved storability of *Pelargonium* cuttings having root primordia. *Gartenbauwissenschaft* 52 (6):266-270.
- Stern, R.A., and M.A. Flaishman. 2003. Benzyladenine effects on fruit size, fruit thinning and return yield of 'Spadona' and 'Corsica' pear. *Scientia Horticulturae* 98:499-504.

- Stern, R.A., O. Nerya, and R. Ben-Arie. 2006. The cytokinin CPPU delays maturity in litchi cv. 'Mauritius' and extends storage-life. *Journal of Horticultural Science & Biotechnology* 81 (1):158-162.
- Stiff, C.M., and A.A. Boe. 1985. Effects of foliar-applied benzylaminopurine on fascicular bud development in mugo pine. *HortScience* 20 (2):285-287.
- Sugiura, H. 2004. Effects of 6-benzylaminopurine and ethephon applications on flowering and morphology in summer-to-autumn-flowering chrysanthemum under open field conditions. *J. Pestic. Sci.* 29 (4):308-312.
- Sugiura, H., and T. Azuma. 2005. Effects of 6-benzylaminopurine applications on bud sprouting in *Aralia elata* Seem. *Journal of Pesticide Science* 30 (3):199-202.
- Suh, J.K. 1997. Stem elongation and flowering response of *Tulipa* cultivars as influenced by bulb cooling, growth regulators and light quality *Acta Horticulturae* 430:101-106.
- Svenson, S.E. 1991. Rooting and lateral shoot elongation of *Verbena* following benzylaminopurine application. *HortScience* 26 (4):391-392.
- Swart, A. 1986. Effect of a post-harvest treatment at the growers on bulb flower quality. *Acta Horticulturae* 181:435-438.
- Systema, W. 1986. Post-harvest treatment of *Freesia* with silver thiosulphate and cytokinins. *Acta Horticulturae* 181:439-442.
- Tabuchi, T., A. Uesugi, A. Furukawa, M. Mariyama, and K. Toba. 2005. Anatomical studies of the leaf yellowing process on *Lilium* 'Pollyanna' following some plant growth regulators application *Acta Horticulturae* 673:717-720.
- Takahashi, H., H. Suge, and T. Saito. 1980. Sex expression as affected by N<sup>6</sup>-benzylaminopurine in staminate inflorescence of *Luffa cylindrica*. *Plant & Cell Physiol.* 21 (4):525-536.
- Taylor, J.S., J.M. Robertson, K.N. Harker, M.K. Bhalla, E.J. Daly, and D.W. Pearce. 1994. Apical dominance in rhizomes of quackgrass, *Elytrigia repens*: the effect of auxin, cytokinins, and abscisic acid. *Can. J. Bot.* 73:307-314.
- Teo, C.K.H., L.E. Benidixen, and R.K. Nishimoto. 1973. Bud sprouting and growth of purple nutsedge altered by benzyladenine. *Weed Science* 21 (1):19-23.
- Teo, C.K.H., and R.K. Nishimoto. 1973. Cytokinin-enhanced sprouting of purple nutsedge as a basis for control. *Weed Res.* 13:118-121.
- Thimann, K.V., T. Sachs, and K.N.M. Mathur. 1971. The mechanism of apical dominance. *Physiol. Plant.* 24:68-72.

- Thomas, P.A., J.G. Latimer, D. Zhang, and S. Hartzler. 1992. Effects of plant growth regulators on lateral branching and shoot growth of *Hypericum*. *SNA Research Conference Proceedings* 37:261-262.
- Thomas, T.H. 1976. Comparison of N<sup>6</sup>-benzyladenine and N-4-pyridyl-N'-phenylurea effects on lateral bud growth, flowering and seed production of brussels sprouts (*Brassica oleracea* var. *gemmifera*). *Physiol. Plant.* 38 (1):1976.
- Tjosvold, S.A., M.J. Wu, and M.S. Reid. 1995a. Reduction of post-production quality loss in potted miniature roses. *Acta Horticulturae* 405:408-414.
- Tjosvold, S.A., M.J. Wu, and M.S. Reid. 1995b. Reduction of postproduction quality loss in potted miniature roses. *HortScience* 29 (4):293-294.
- Toky, K.L., S. Sawhney, and K.K. Nanda. 1969. Chemical control of flowering. *Indian Journal of Plant Physiology* 12 (1/2):48-57.
- Tonder, C.S.M., and N.J.J. Combrink. 2003. The effect of plant growth regulators on the production of out-of-season greenhouse tomatoes (*Lycopersicon esculentum*). *South African Journal of Plant and Soil* 20 (4):165.
- Tonecki, J. 1979. Effect of the growth substances on plant growth and shoot apex differentiation in Gladiolus (*Gladiolus hortorum* cv. *Acca Laurentia*). *Acta Horticulturae* 91:201-203.
- Tonecki, J. 1986. Effect of short photoperiod and growth regulators on growth, flowering and tuberization of *Begonia x tuberhybrida*. *Acta Horticulturae* 177:147-156.
- Tsantili, E., K. Rekoumi, P.A. Roussos, and C. Pontikis. 2002. Effects of postharvest treatment with N<sup>6</sup>-benzyladenine on green olive fruit. *Journal of Horticultural Science & Biotechnology* 77 (3):294-299.
- Tse, A.T.Y., A. Ramina, W.P. Hackett, and R.M. Sachs. 1974. Enhanced inflorescence development in *Bougainvillea* "San Diego Red" by removal of young leaves and cytokinin treatments. *Plant Physiol.* 54:404-407.
- Tucker, D.J. 1977. Hormonal regulation of lateral bud outgrowth in the tomato. *Plant Science Letters* 8:105-111.
- Uesugi, T., M. Koshioka, T. Nishijima, and H. Yamakazi. 1995. Stimulation of asparagus spear sprouting with benzyladenine. *Acta Horticulturae* 394:241-249.
- Ullmann, J., J. Krekule, L. Pavlová, Z. Josefusová, J. Opatrná, F. Seidlová, and D. Soucková. 1985. Effect of two- or three-component PGR solution on the flowering of short-day plant *Chenopodium rubrum*. *Biologia Plantarum* 27 (4-5):398-401.
- Upfold, S. J., and J. Van Staden. 1990. Cytokinins in cut carnation flowers. VII. The effect of zeatin and dihydrozeatin derivatives on flower longevity. *Plant Growth Regulation* 9:77-81.

- Uppar, D.S., and G.N. Kulkarni. 1989. Effect of nitrogen and growth regulators on seed yield and quality in sunflower. *Seed Research* 17 (2):113-117.
- Utsunomiya, N., K. Sogawa, and K. Sasaki. 1995. Sex expression of cv. Irwin mango flowers affected by temperature, soil water stress and plant bioregulators. *Acta Horticulturae* 394:183-190.
- Valio, I.F.M., S.L. Kirszenzaft, and R.F. Rocha. 1972. Germination of achenes of *Bidens pilosa* L. I. Effect of light of different wavelengths. *New Phytol.* 71:677-682.
- van Bragt, J., and H. van Gelder. 1979. Effects of gibberellic acid 6-benzylaminopurine, a-naphthaleneacetic acid and ethephon on growth and flowering of tulip bulbs cv. 'Apeldoorn' and their bulblets. *Acta Horticulturae* 91:161-165.
- van Doorn, W.G., J. Hibma, and J. de Wit. 1992. Effect of exogenous hormones on leaf yellowing in cut flowering branches of *Alstroemeria pelegrina* L. . *Plant Growth Regulation* 11:59-62.
- van Staden, J., and J.I. Joughin. 1988. Cytokinins in cut carnation flowers . IV Effects of benzyladenine on flower longevity and the role of different longevity treatments on its transport following application to the petals. *Plant Growth Regulation* 7:117-128.
- van Staden, J., S.J. Upfold, and A.D. Bayley. 1990. Cytokinins in cut carnation flowers . IX. Transport and metabolism of iso-pentenyladenine and the effect of its derivatives on flower longevity. *Plant Growth Regulation* 9:255-261.
- Venkata-Rao, M., and B. Narasimham. 1977. Prolonging storage life of betel leaves. *Indian Journal of Horticulture* 34 (2):175-182.
- Viswanath, D.P., K.M. Appaiah, S.R. Rao, and K.S.K. Sastry. 1971. Effect of pre-treatment of leaves of *Coleus blumei*, Benth. with cytokinins on amino-acid induced abscission of debladed petioles. *Current Science* 40:19-20.
- Vlahos, J.C. 1985a. Effects of BA and GA<sub>3</sub> on sprouting of *Achimenes* rhizomes. *Acta Horticulturae* 167:211-223.
- Vlahos, J.C. 1985b. Effects of GA<sub>3</sub> and BA on two cultivars of *Achimenes longiflora* under two levels of irradiance. *Acta Horticulturae* 167:225-235.
- Vonk, C. R., and S.A. Ribot. 1982. Assimilate distribution and the role of abscisic acid and zeatin in relation to flower-bud blasting, induced by lack of light, in *Iris* cv. Ideal. *Plant Growth Regulation* 1:93-105.
- Wakushima, S. 2004. Promotion of female strobili flowering and seed production in two Japanese pine species by 6-benzylaminopurine (BAP) paste application in a field seed orchard. *J. Plant Growth Regul.* 23 (2):135-145.
- Wallerstein, I. 1986. *Banksia ashbyi*. In *CRC Handbook of Flowering*, ed. A. H. Halevy, 87-93. Boca Raton, Fl: CRC Press.

- Wang, J., and V.R. Walter. 2006. Effect of vernalization and plant growth regulators on flowering of *Ornithogalum* 'Chesapeake Snowflake' *Agricultural Science & Technology - Hunan* 7 (1):23-28.
- Wang, X.T., and F.E. Below. 1996. Cytokinins in enhanced growth and tillering of wheat induced by mixed nitrogen source. *Crop Sci.* 36 (1):121-126.
- Wang, Y.T. 1987. Effect of warm medium, light intensity, BA, and parent leaf on propagation of golden pothos. *HortScience* 22 (4):597-599.
- Wang, Y.T. 1988. Branching Agents. *Greenhouse Manager*, August 1988, 7:136-141.
- Wang, Y.T., and C.A. Boogher. 1987. Effect of stock plant shading, developmental stage and cytokinin on growth and lateral branching of *Syngonium podophyllum* 'White Butterfly'. *Scientia Horticulturae* 33:137-145.
- Wang, Yin-Tung. 1996. Cytokinin and light intensity regulate flowering of Easter lily. *HortScience* 31 (6):976-977.
- Wang, Z., W. Cao, T. Dai, and Q. Zhou. 2001. Effects of exogenous hormones on floret development and grain set in wheat. *Plant Growth Regulation* 35:225-231.
- Warr, J.C., and G.J. Keever. 2004. Response of *Hosta* to BA crown drenches applied at division and establishment. *J. Environ. Hort.* 22 (3):129-132.
- Weinberger, J.H. 1969. The stimulation of dormant peach buds by a cytokinin. *HortScience* 4:125-126.
- Wesenberg, B.G. 1963. Influence of production environment on the longevity of flowers on potted chrysanthemums (*Chrysanthemum morifolium* Ramat.) *Diss. Abstr.* 24:20.
- Whipker, B.E., and J.L. Gibson. 2007. Lateral branching agents. Paper read at Southeast Greenhouse Conference, June 2007, at Greenville, SC.
- Whipker, B.W., B.A. Krug, and I. McCall. 2005. Pre-plant tuber soaks of 6-benzyladenine ineffective for chemical de-eyeing of *Caladium*. *PGRSA quarterly* 33 (1):16-20.
- White, J.W., C. Allen, M. Easley, and P. Strock. 1978. Effects of growth regulants on *Opuntia basilaris*. *HortScience* 13 (2):181-182.
- White, R.H., and R.E. Schmidt. 1989. Bermudagrass response to chilling temperatures as influenced by iron and benzyladenine. *Crop Sci.* 29:768-773.
- White, R.H., and R.E. Schmidt. 1990. Fall performance and post-dormancy growth of 'Midiron' bermudagrass in response to nitrogen, iron, and benzyladenine. *J. Amer. Soc. Hort. Sci.* 115 (1):57-61.

- Whitehill, S.J., and W.W. Schwab. 1975. Vegetative propagation of *Pinus sylvestris*. *Physiol. Plant.* 35:66-71.
- Whitman, C.M., R.D. Heins, R. Moe, and K.A. Funnell. 2001. GA<sub>4+7</sub> plus benzyladenine reduce foliar chlorosis of *Lilium longiflorum*. *Scientia Horticulturae* 89:143-154.
- Whittwer, S. H., Dedolph R. R., V. Tuli, and D. Gilbert. 1961. Respiration and storage deterioration in celery (*Apium graveolens* L.) as affected by post-harvest treatments with N<sup>6</sup>-benzylaminopurine. *J. Amer. Soc. Hort. Sci.* 80:408-416.
- Wijeratnam, R.S.W, D. Sivakumar, and M. Abeysekere. 1995. Post harvest treatments and refrigerated storage studies on *Dracaena marginata*. *Acta Horticulturae* 405:415-421.
- Williams, K.M., and E. Fallahi. 1999. The effects of exogenous bioregulators and environment on regular cropping of apples. *HortTechnology* 9 (3):323-327.
- Wilson, M.R., and T.A. Nell. 1983. Foliar applications of BA increase branching of 'Welkeri' *Dieffenbachia*. *HortScience* 18 (4):447-448.
- Wilton, M.T., G.J. Keever, and D.J. Eakes. 1994. Offset stage of development affects *Hosta* propagation by division. *SNA Research Conference Proceedings* 39:269.
- Witaszek, W. 1989. Light and growth regulators in the cuttings production of poinsettia *Euphorbia pulcherrima* mother plants. *Acta Horticulturae* 251:315-317.
- Wittwer, S. H., and R. R. Dedolph. 1962. "Youth" hormone keeps vegetables fresh longer. *American Vegetable Grower*, 10 (3):15, 54-55.
- Wong, A., K. Birushingh, P. Chien, and W. Eisinger. 1989. Regulation of carnation (*Dianthus caryophyllus*) flower development. *Acta Horticulturae* 261:35-49.
- Worley, R.E. 1989. Pecans show little response to low rates of GA and BA. *HortScience* 24 (1):151.
- Wright, R. D. 1975. Benzyladenine-induced growth of holly axillary buds. *SNA Research Conference Proceedings* 20:100-101.
- Wright, R. D. 1976. 6-Benzylaminopurine promotes axillary shoots in *Ilex crenata* Thunb. *HortScience* 11 (1):43-44.
- Xing, J., Y. Xu, J. Tian, T. Gianfagna, and B. Huang. 2007. Effects of CPPU (N-(2-chloro-4-pyridyl)-N'-phenylurea) on fruit growth, maturity, and storage quality of kiwifruit. *Proceedings of the sixteenth annual Rutgers turfgrass symposium*:18.
- Xu, Y., and B. Huang. 2007. Effects of an ethylene inhibitor and cytokinin on heat-induced leaf senescence in creeping bentgrass. *Proceedings of the sixteenth annual Rutgers turfgrass symposium*:53.

- Yamaguchi, T. 1987. Stimulating effects of some chemical and physical treatments on the growth of carnation. *Acta Horticulturae* 216:281-288.
- Yamaji, K., and K. Tomioka. 1980. Effect of 9-benzyl adenine on the promotion of rooting in Kuromatsu, Japanese black pine. *J. Jap. For. Soc.* 62:425-428.
- Yamasaki, N. 2003. Effects of ringing and BA foliage treatment on cut flower quality of *Prunus* x Keio-zakura Ohwi. *Acta Horticulturae* 624:255-257.
- Yang, G., and P.E. Read. 1991. Influence of plant growth regulators and season on growth responses of forced woody stems. *Acta Horticulturae* 300:173-176.
- Yang, G., and P.E. Read. 1997. Plant growth regulators in the forcing solution influenced bud break and shoot elongation of dormant woody plant species. *PGRSA quarterly* 25 (3):145-152.
- Yonemura, K. 1979. Studies on the control of flowering in Christmas cactus. *Aichi-ken Nogyo Sogo Shikenjo tokubetsu hokoku*:1-35.
- Yonemura, K., and H. Higuchi. 1978. The control of flowering in Christmas cactus V. *Res. Bull. Aichi Agric. Res. Centr.* 10:30-35.
- Yoon, M.J., K.B. Park, and C.H. Pak. 2002. Effects of growth regulators and temperature on the growth of pseudobulbs in *Bletilla striata*. *Korean Journal of Horticultural Science and Technology* 20 (2):120-123.
- Youssef, A.A., and I.M. Talaat. 1998. Physiological effect of brassinosteroid and kinetin on the growth and chemical constituents of lavender plant. *Annals Agric. Sci., Ain Shams Univ.* 43 (1):261-272.
- Yu, J.Q. 1999. Parthenocarpy induced by N-(2-chloro-4-pyridyl)-N'-phenylurea (CPPU) prevents flower abortion in chinese white-flowered gourd (*Lagenaria leucantha*). *Environmental and Experimental Botany* 42:121-128.
- Yu, T., L. Wang, Y. Yin, F. Feng, and X. Zheng. 2008. Suppression of postharvest blue mould of apple fruit by *Cryptococcus laurentii* and N<sup>6</sup>-benzyladenine. *J. Sci. Food Agric.* 88:1266-1271.
- Yue, D., Y. Komi, and H. Imanishi. 1988. Effects of ethylene exposure on flowering of Dutch iris 'Blue Magic' grown in the open. *J. Japan. Soc. Hort. Sci.* 57 (3):481-486.
- Zabadal, T.J., and M.J. Bukovac. 2006. Effect of CPPU on fruit development of selected seedless and seeded grape cultivars. *HortScience* 41 (1):154-157.
- Zhang, X., J.W. White, and D.J. Beattie. 1990. The effects of photoperiod, PPF, Promalin, STS and water on flowering of asiatic lily hybrids. *Acta Horticulturae* 266:243-249.
- Zhao-wu, G., and X. Lang-tao. 2002. A study of 6-BA and GA<sub>3</sub> stimulating the regeneration of *Viola tricolor*. *Journal of Hunan Agricultural University (Natural Sciences)* 28 (6):499-501.

- Zhu, X.R., K. Matsumoto, and M. Shiraishi. 1989. Acceleration effect of 6-benzylamino purine (BA) spray on the sprouting of axillary buds in satsuma (*Citrus unshiu* Marc.) trees. *Journal of the Japanese Society for Horticultural Science* 57 (4):578-584.
- Zieslen, N., E. Khayat, S. Yogev, and J. Shoub. 1985. Promotion of cuttings of *Gerbera jamesonii* by cytokinin. *Acta Horticulturae* 226:425-429.
- Zieslin, N., Y. Mor, E. Khayat, and M. Levy. 1985. The use of cytokinins for promotion of flower production in roses. *Acta Horticulturae* 167:433-434.
- Zimmer, K., and K. Junker. 1986. *Salvia splendens*. In *CRC Handbook of Flowering*, ed. A. H. Halevy, 265-273. Boca Raton, FL: CRC Press.
- Zink, F.W. 1961. N<sup>6</sup>-benzyladenine, a senescence inhibitor for green vegetables. *Agricultural and Food Chemistry* 9 (4):304-307.