ABTRACT

DITTMAR, PETER JAMES. Characterization of Diploid Watermelon Pollenizers and Utilization for Optimal Triploid Watermelon Production and Effects of Halosulfuron POST and POST-DIR on Watermelon. (Under the direction of Drs. Jonathan R. Schultheis and David W. Monks.)

Characterization study. The objective of this research was to compare several cultigens' vegetative characteristics, staminate and pistillate flower output over time, and exterior and interior fruit characteristics. In experiments conducted during 2005 and 2006, 15 pollenizer cultigens were evaluated. Based on shorter vines and internodes, pollenizers which produced a more compact plant were 'Companion', 'Sidekick', 'TP91', 'TPS92', and 'WC5108-1216'. Those cultigens with a standard vine length (longer vines and internodes) were 'Ace', 'Jenny', 'High Set 11', 'Mickylee', 'Mini Pool', 'Nun6017', 'Pinnacle', 'Summer Flavor 800' ('SF800'), 'Super Pollenizer 1' ('SP1'), and 'WH6818'. The greatest quantity of staminate flowers produced over the 5 week period was obtained with 'Sidekick' and 'SP1'; the lowest number with 'TP91' and 'TPS92'. The number of pistillate flowers produced over time followed a similar pattern according to each cultigen's production of staminate flowers. Based on fruit production and quality, pollenizers with consumption market potential include 'Mickylee', 'SF800', 'Mini Pool', 'Jenny', and 'Pinnacle'. Other pollenizers, such as 'SP1', have a white flesh and thin rind and should be used strictly as a pollenizer. Based on staminate flower production, certain cultigens may potentially be superior pollenizers and increase triploid fruit yields.

Utilization study. Studies were conducted to maximize triploid watermelon fruit yields and quality by optimizing the choice and use of pollenizers. Treatments included 'Companion', 'Super Pollenizer 1' ('SP1'), 'Summer Flavor 800' ('SF800'), and 'Mickylee' as the only pollen source (#1-4); and the various combinations of

‘Companion’, ‘SF800’, and ‘SP1’ using two pollenizer cultivars as pollen sources (#5-7). Planting arrangement was compared; ‘SF800’ in a hill (#8) versus an inter-planted field arrangement. Time of pollenizer establishment was evaluated by establishing ‘SP1’three weeks after planting (#9) with the establishment of ‘SP1’ at time of triploid plant transplanting. A triploid planting with no pollenizer (#10) was included to determine if pollen movement occurred outside of the treatment area. Pollen movement was minimal among plots. For individual pollenizer treatments, ‘Companion’, ‘SP1’, and ‘Mickylee’ produced similar total yields. The lowest yields were obtained with the ‘SF800’ treatment. ‘Companion’ produced more large fruit than the individual pollenizer treatments. Combining the pollenizers generally did not enhance triploid yields or quality. Inter-planting of pollenizers resulted in better yields than if hill planted. The late planting of ‘SP1’ resulted in a high percentage of severe hollow heart. The selection of pollenizer, planting arrangement, and time of pollenizer establishment are all important considerations to optimizing triploid yield and quality.

Halosulfuron study. Studies were conducted to determine the influence of halosulfuron postemergence-direct and postemergence on growth and yield of ‘Precious Petite’ and ‘Tri-X-313’ triploid watermelon. Treatments included a nontreated check, 39 g ai/ha halosulfuron applied to 25% distal or proximal region, and over the top. Two additional treatments were applied to ‘Precious Petite’ only: 50% distal or proximal. Watermelon treated with halosulfuron had chlorosis, shortened internodes and increased stem splitting. Halosulfuron POST over the top of watermelon caused the greatest injury. Halosulfuron directed to 25 or 50% (distal or proximal) of the plant caused less injury than halosulfuron applied over the top. Stem splitting was greatest with proximal application. Internode shortening was greatest with distal applications. However, ‘Tri-X-313’ in the 25% distal treatment produced similar total and marketable fruit weight as the nontreated check at Clinton. Fruit number did not differ among treatments for either cultivar. In ‘Precious Petite’, differences were found in the marketable fruit weight at Kinston. Plants in the nontreated check and 25% distal end treatment had greater marketable fruit weight than the 50% proximal and over the top treatments. Limiting halosulfuron to no more than 25% of the watermelon plant will likely improve crop tolerance.

CHARACTERIZATION OF DIPLOID WATERMELON POLLENIZERS AND UTILIZATION FOR OPTIMAL TRIPLOID WATERMELON PRODUCTION AND EFFECTS OF HALOSULFURON POST AND POST-DIR ON WATERMELON

by

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DEDICATION

For:

Murnice and Betty Dittmar,

Who want their family to excel

in agriculture and academics

BIOGRAPHY

Peter James Dittmar was born in April 1, 1982, to James and Karen Dittmar. He was the seventh generation to grow up on his family's farm outside of Elizabeth, Illinois. Peter's family raised beef, hogs, sheep, and grain crops. Peter's interest in horticulture began in the family's large garden. Peter was active in 4-H, FFA, and his church. Peter graduated from River Ridge High School in May 2000.

In 2002, Peter received his Associate of Applied Science-Ornamental Horticulture degree from Kishwaukee College, Malta, Illinois. Afterwards, Peter continued his education at Southern Illinois University- Carbondale and received his Bachelor of Science Degree- Plant & Soil Science in 2004. At SIU, Peter had the privilege of working with Drs. Alan Walters and Bradley Taylor as an Undergraduate Research Assistant. They played an integral role in introducing Peter to fruit and vegetable research. Peter completed his undergraduate research on sweetpotato plant spacing on clay soils of southern Illinois. Peter met Dr. Jonathan Schultheis at the national ASHS meeting in Providence, Rhode Island. Peter's Master research is on the characterization and utilization of watermelon pollenizers in triploid (seedless) watermelon production. He also is doing research on application of halosulfuron as a topical treatment in watermelons. After graduating with his Master Degree, Peter will pursue his Doctor of Philosophy at North Carolina State University under the direction of Dr. David Monks. He will work with vegetables grown on black polyethylene mulch, examining application of herbicides through irrigation systems

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Table of Contents

Chapter 1

Chapter 2

Chapter 3

Appendix A.

Appendix B.

Appendix C.

List of Tables

CHARACTERIZATION OF VEGETATIVE, FLORAL, AND FRUIT GROWTH AND DEVELOPMENT OF WATERMELON POLLENIZERS

UTILIZATION OF COMMERCIALLY AVAILABLE POLLENIZERS FOR OPTIMIZING TRIPLOID WATERMELON PRODUCTION

EFFECTS OF POST AND POST-DIRECTED HALOSULFURON ON WATERMELON (*CITRULLUS LANATUS*)

ADDITIONAL TABLES AND FIGURES FOR CHAPTER 1

ADDITIONAL TABLES FOR CHAPTER 2

ADDITIONAL TABLES FOR CHAPTER 3

List of Figures

CHARACTERIZATION OF VEGETATIVE, FLORAL, AND FRUIT GROWTH AND DEVELOPMENT OF WATERMELON POLLENIZERS

UTILIZATION OF COMMERCIALLY AVAILABLE POLLENIZERS FOR OPTIMIZING TRIPLOID WATERMELON PRODUCTION

EFFECTS OF REDUCING HALOSULFURON POST CONTACT TO WATERMELON FOLIAGE ON CROP TOLERANCE

ADDITIONAL TABLES AND FIGURES FOR CHAPTER 1

Chapter 1

Characterization of the Vegetative, Floral, and Fruit Growth and Development of Watermelon Pollenizers

(In the format appropriate for submission to HortTechnology)

Characterization of the Vegetative, Floral, and Fruit Growth and Development of Watermelon Pollenizers

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Abstract

Triploid (seedless) watermelon, *Citrullus lanatus* (Thunb.) Matsum. and Nak., pollen is nonviable and diploid (pollenizer) watermelon cultigens are required in production for fruit set on triploid watermelon plants. The objective of this research was to determine vegetative characteristics, staminate and pistillate flower output over time, and to measure certain exterior and interior fruit characteristics of several commercially available or soon to be released cultigens. The experiments were conducted during the 2005 and 2006 growing season at the Central Crops Research Station, Clayton, North Carolina. Both years, 13 pollenizer cultigens were included with two being added in 2006. Two triploid cultivars, 'Petite Perfection' and 'Tri-X-313', were also included. Vegetative growth was measured using vine and internode length, and staminate and pistillate flower development were quantified over a five week period beginning 5 weeks after transplanting (WAT). Fruit quality and quantity were determined by taking individual fruit weight, length width measures as well as soluble solids and rind thickness. Based on vegetative growth, pollenizer cultigens could be placed into two distinct groups. Pollenizers which produced a compact or dwarf plant were ‘Companion’, ‘Sidekick’, ‘TP91’, ‘TPS92’, and ‘WC5108-1216’. Those cultigens having a standard vine length were ‘Ace’, ‘Jenny’, ‘High Set11’, ‘Mickylee’, ‘Mini Pool’, ‘Nun6017’, ‘Pinnacle’, Summer Flavor 800’ (‘SF800’), ‘Super Pollenizer 1’ (‘SP1’), and ‘WH6818’. The cultigens with a more compact growth habit had shorter internodes and vines compared to the cultigens with standard vine lengths. The cultigens that had the most consistent and greatest quantity of staminate flower production through the entire length of the season were ‘Sidekick’ and ‘SP1’. The lowest number of staminate flowers through the experiment was produced with ‘TP91’ and ‘TPS9’. The number of pistillate flowers produced over time followed a similar pattern as did the staminate flowers on a given cultigen. Based on fruit quality characteristics and production, pollenizers currently being marketed for consumption or those with some consumption market potential include ‘Mickylee’, ‘SF80’, ‘Mini Pool’, ‘Jenny’, and ‘Pinnacle’, while the other cultigens evaluated in this study should be used strictly as a pollenizer. Arrangement of pollenizer in a commercial planting of triploid watermelons is an important consideration depending on plant vegetative development. Based on staminate flower production, certain cultigens are potentially superior pollenizers and may lead to improved triploid quality and production. Pollenizer selection should also be based on the characteristics of the fruit it produces, whether to distinguish easily from triploid fruit or sold for consumption.

Introduction

The United States’ total watermelon (*Citrullus lanatus* (Thunb.) Matsum. and Nak.) production was 38 million pounds in 2005 and North Carolina produced 1 million pounds, ranking 7th nationally in total production (USDA- National Agricultural Statistics Service, 2006). Triploid (seedless) watermelons were introduced to the United States in 1951 (Kihara, 1951). By 1990, projections were for 50% of United States watermelon production to be triploid watermelons (Karst, 1990). In 2005, three quarters of the United States watermelon production was devoted to triploid watermelons (USDA Economic Research Service, 2005).

Obtaining a triploid plant is costly and has practical application in only crops with high market value (Fehr, 1987). In a consumer survey at a farmers' market in 1990, consumers indicated they were willing to pay 50% more for a triploid watermelon compared to a diploid watermelon (Marr and Gast, 1991). Developing a triploid hybrid starts with obtaining a tetraploid parental line. A tetraploid is obtained by treating the growing point of a diploid watermelon with 0.2 or 0.4 percent colchicine (Kihara, 1951). The colchicine is used for metaphase arrest (Hadlaczky et al., 1983). Dinitroaniline herbicides may be used instead of colchicine because of their higher affinity to binding the plant tubulins during metaphase (Ramulu et al., 1991). The tetraploid plant is used as a female parent ($2n=4x=44$) and a diploid plant is used as the male parent ($2n=2x=22$). The resulting progeny is a triploid ($2n=3x=33$) (Kihara, 1951). The irregularity in chromosome pairing causes the pollen in the triploid plants to be nonviable (Fehr, 1987). In triploid watermelon production, diploid watermelons (pollenizers) are included as a viable pollen source for pollination and fruit set (Kihara, 1951; Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi, 1997). To supply sufficient pollen for maximum triploid fruit yield, plants should be planted in a ratio of 1 pollenizer plant for every 2 to 4 triploid plants (Fiacchino and Walters, 2000; Maynard and Elmstrom, 1992; NeSmith and Duval; 2001; Robinson and Decker-Walter, 1997).

Triploid plants and pollenizers can be planted in separate rows or inter-planted in the same row (Maynard and Elmstrom, 1992). The separate row planting method extablishes one row of pollenizers and then 2 to 4 rows of triploids (Maynard and Elmstrom, 1992; Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi 1997). NeSmith and Duval (2001) reported a decrease in yield when the pollenizer 'Ferarri' was planted more than 6 m from the triploid 'Genesis' indicating that field arrangement of the pollenizer is an important consideration. Planting the pollenizer in the same row to potentially reduce the distance between pollenizer and triploid plant can be done by planting the pollenizer in-between two to three triploid plants (inter-planted), or by planting a pollenizer in every third or fourth hill that would normally be occupied by a triploid plant. Planting in the same row adds complexity to the planting and harvesting of the crop (Maynard and Elmstrom, 1992). Pollenizer fruit should have a different rind pattern from the triploid fruit so fruit can be separated and marketed properly (Kihara, 1951; Maynard and Elmstrom, 1992; Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi, 1997).

Bees are required for movement of viable pollen from the staminate flowers to the pistillate flowers of watermelon (Robison and Decker-Walters, 1997; Stanghellini et al., 1997, 1998; Walters, 2005). Diploid watermelons require 6 to 8 bee visits for fruit set (Adlerz, 1966; Stanghellini et al., 1997). In production of 'Charleston Gray', an inadequate number of bee visits lead to small fruit and misshapened fruit (Adlerz, 1966). For fruit set of triploid watermelon, the pistillate flower needs to be visited by a bee between 16 and 24 times when the pollenizer frequency is 33% (Walters, 2005).

The objectives of this research were to characterize and quantify the growth and development of diploid watermelon pollenizers, especially newly bred pollenizers developed exclusively for triploid watermelon production (dedicated pollenizers). The length of vine and internode length of the vine were measured to consider potential plant competition and suitability in the different planting arrangements with triploid plants. Determining number of flowers gives an understanding of potential pollen produced from the various pollenizers for fruit set on triploid watermelons. Counting fruit, quantifying harvestable fruit and size, measuring fruit qualities, and observing rind pattern provides information as to which pollenizers could be sold as seeded fruit as well as which rind pattern is suitable for production with specific triploid cultivars.

Materials and Methods

Treatments. In 2005, 13 cultivars of commercially available pollenizers and numbered lines were included: ‘Companion’, ‘Jenny’, ‘High Set 11’, ‘Mickylee’, ‘Mini Pool’, ‘Pinnacle’, ‘Summer Flavor 800’ (‘SF800’), ‘Super Pollenizer 1’ (‘SP1’), ‘Sidekick’, ‘TP91’, ‘TPS92’, ‘WC5108-1216’, and ‘WH6818’. In 2006, 2 additional commercially available pollenizer cultigens were evaluated: ‘Ace’ and ‘Nunhems 6017’ (‘Nun6017’). In addition, triploid watermelon cultivars were included for comparison: ‘Petite Perfection’ and ‘Tri-X-313’.

Cultural practices. Plants were sown into LE 1803 transplant trays (Landmark Plastics Corp.; Akron, OH.) on 20 April each year. The plants were grown in the greenhouse for two weeks and then moved to the cold frame for conditioning for field establishment. Seedlings were transplanted into black polyethylene mulch at the Central Crops Research Station, Clayton, NC into a Norfolk loamy sand (fine-loamy, kaolinitic, thermic typic Kandiudults) soil on 24 May 2005 and 17 May 2006. Before mulch was laid, the soil was fumigated with 1,3-dichloropropene and chloropicrin (Telone C-17: Dow AgroSciences, Calgary, Alberta, Canada) and broadcast fertilized (0N-0P-60K at 149.1 kg/ha and 16N-0P-0K at 213.0 kg/ha) according to soil test recommendations. In-row spacing was 1.3 m and between row spacing was 3.1 m. Plant spacing around the plants was maximized to facilitate measurements of individual plants. Four plants of one cultigen were in each plot. Cultigens were arranged in a randomized complete block design and replicated 5 times. Pesticides were applied basis based on North Carolina cultural recommendations (Sanders, 2004; 2005).

Vegetative development. Vegetative characteristics of the pollenizers were characterized by measuring the lengths of vine and internode. Vine and internode lengths were measured at 4 and 5 weeks after transplanting (WAT). The longest vine on each plant was measured with a tape measure to the nearest 0.5 cm from the crown of the plant to the tip of the vine. The internode measurement to the nearest 0.5 cm was taken from the internode between the third and fourth fully expanded leaves from the tip of the longest vine. Fruit set had occurred by 5 WAT on many of the plants and moving the vines for measurement after this time increased the risk of the fruit being detached from the vines.

Flower production. Pistillate and staminate flowers were counted weekly from 3 to 9 WAT. This time period was used since this is when triploid fruit set occurred. Flowers were counted between 0730 and 1200 on individual plants. Flowers open only on the day of counting were included in the final count. Flowers in which floral anthesis occurred the previous or subsequent days were not included in the count.

Fruit development. The number of fruit set was counted during the same time period as the flowers. Fruit set was determined to be when the petals had dried and fallen off the fruit. Fruit set was measured to determine the association of staminate and pistillate flower performance with the set and development of the fruit. When fruit were mature they were harvested, weighed, and counted. Rind thickness, soluble sugars, and flesh color were included to determine if the fruits produced by a cultigen were a viable option for the seeded watermelon market. Rind thickness was measured on 5 cut fruit from each plot and measured from the outside of the melon to where the interior of the fruit started to turn pink or cream in color. Rind measurements were taken on both sides of the fruit at the equatorial position of the fruit. Soluble solids were measured with a hand held refractometer (Q-A supplies, LLC, model number NT-032ATC; Norfolk, Va). Flesh color was evaluated on a scale of 1 to 10 in 2005 and 1 to 4 in 2006; 1 was white, 7/3 (2005/2006) was ‘Crimson Sweet’ red, and 10/4 was dark red.

Results and Discussion

Vegetative development. The vine lengths of watermelon cultigens over both years fit into two distinct vegetative categories. The two groups began to separate at 4 WAT; however, the distinction was more apparent 5 WAT when the vines had more growth. A dwarf cultivar of watermelon has shorter internodes caused by fewer cells in the internode compared to a normal watermelon vine (Liu and Loy, 1972). The dwarf cultigens included in these studies were ‘Companion’, ‘Sidekick’, ‘TP91’, ‘TPS92’, and ‘WC5108-1216’. In 2005, five WAT, the vine lengths of the dwarf cultigens ranged from 75.2 to 103.8 cm, while in 2006 ‘Sidekick’ was generally longest at 77.2 cm (Table 1). Five WAT, in 2005, the shortest vine length for those cultigens with a standard vine length was ‘High Set 11’ (172 cm), while in 2006, ‘Jenny’ (104.7 cm) was one of the cultigens with standard vine length that had the shortest standard vine lengths. Other cultigens with short vine length in the standard vine length type watermelon category were ‘Jenny’, ‘Ace’, and ‘High Set 11’. For both years, the cultigens with standard vine length with the longest vines were ‘Mickylee’ (293 and 184 cm) and ‘Mini Pool’ (297 or 194 cm) in 2005 and 2006, respectively. The triploid watermelon cultigens, ‘Petite Perfection’ and ‘Tri-X-313’, had similar vine lengths compared with pollenizers that had the standard vine type.

The dwarf vine type cultigens had shorter internodes than the cultigens with a standard vine type. In 2005, ‘TPS92’ consistently had one of the shortest vine lengths (Table 1) and internode lengths, 2.9 cm (Table 2). The other dwarf cultigens, ‘Companion’, ‘Sidekick’, ‘TP91’, and ‘WC5108-1216’, had similar internode lengths. Two cultigens with a standard vine type also had internode lengths which were similar to the dwarf cultigens; they were ‘High Set 11’ which had an internode length of 7.4 cm and ‘Pinnacle’ which had an internode length of 7.3 cm. In 2006, no cultigens with standard vine length had the same internode length as any of the dwarf cultigens. The cultigens with the shortest internodes were ‘WC5108-1216’ and ‘TP91’ and ‘TPS92’ (Table 2). The internode lengths of ‘Companion’ and ‘Sidekick’ were longer than ‘WC5108-1216’, but were less than the cultigens with a standard vine type. Although not measured directly, it was obvious that the amount of branching varied between cultigens. ‘High Set 11’ and ‘SP1’ appeared to have side branching from the main vines. ‘Sidekick’ tends to have considerable branching from the crown of the plant which results in vines being clustered towards the center of the plant.

The vegetative development of the pollenizer may have an effect on the quantity and quality of the triploid fruit. The dwarf types might be less ideal for the separate row planting method (Figure 1) because it would take a long time for the vines to intertwine and be in close proximity to the triploid plants for easier transfer of pollen. However, if the dwarf plants were planted in the same row as the triploids, the reverse principal would apply. Planting in the same row as triploids minimizes space between triploid plants and the pollenizer. Thus, the dwarf vine type pollenizer would likely be better suited to minimize the competition with triploid plants. The use of standard vine length types may be better suited for the separate row planting method (Figure 1) instead of the dwarf vine types. The separate row planting method maximizes the amount of space between the triploid and pollenizer plants. The larger space likely would result in less competition for nutrients, water, and light between the pollenizer and the triploid plants. A vigorous vining pollenizer may act much like a weed and could reduce the yields and quality of the crop. It is common knowledge that weed competition can reduce the yields and quality of many crops; however, a pollenizer is typically not considered in this manner. Another factor that may influence the ability of the crop to compete is genetics, which dictate vine vigor and growth. Neppl (2001) reported differences in vine vigor and growth among watermelon cultivars. In order to determine the real effects of how specific triploid cultigens and pollenizers affect yields and quality when inter-planted with one another, they need to be planted together in a similar manner as practiced by a commercial grower.

The short internode lengths resulting from the dwarf pollenizer types may affect the accessibility of the staminate flowers to bees especially if the triploid plants quickly cover the pollenizer plant, while the longer internodes of the standard vine types may result in the vines more effectively competing with the triploid plants by growing over them and being more completely distributed throughout the field. This wider internode spacing conversely, may make the flowers more accessible for bees.

Staminate flower production, 2005. The earliest peak production of staminate flowers was obtained with ‘Companion’ 5 and 6 WAT (Table 3). Although this was the peak time for ‘Companion’, it did not produce the most staminate flowers compared with the other pollenizers in the experiment. The latest peak production time of staminate flowers was with ‘Jenny’ and ‘Mini Pool’ from 7 and 8 WAT. All the other cultigens had peak production of staminate flowers 6 and 7 WAT, including the triploid cultigens. The three cultigens which produced the most staminate flowers per plant per day at 6 and 7 WAT were ‘High Set 11’, ‘SP1’, and ‘Sidekick’. ‘SP1’ produced the most staminate flowers, 59.3 and 92.6, on a given day 6 and 7 WAT, respectively, during these time periods. ‘Sidekick’ produced the highest number of staminate flowers 4 WAT and 9 WAT relative to the other cultigens. Five and 8 WAT, ‘Sidekick’ and ‘SP1’ produced a similar number of staminate flowers per day and were the leading producers of staminate flowers among other cultigens. Of these three cultigens which produced the highest number of staminate flowers, ‘High Set 11’ was the lowest performer and only produced a similar number of staminate flowers per day as the top producer, ‘Sidekick’, 8 WAT. ‘High Set 11’ produced 22.8 and ‘Sidekick’ produced 31.8 staminate flowers per day. An intermediate response with respect to staminate flower production was obtained with the dwarf cultigen ‘WC5108-1216’ and the commercially marketed diploid cultivar ‘SF800’. ‘TP91’ and ‘TPS92’, dwarf cultigens, produced the fewest staminate flowers during the entire experiment peaking at 4.1 and 6.1 staminate flowers per day, respectively. The triploid cultigens produced a similar number of staminate flowers as the standard pollenizer vine types.

Staminate flower production, 2006. Before transplanting, some cultigens were showing signs of dampening off and transplants were smaller than the previous year. Staminate flower production peaked later in 2006 compared to 2005. This delay was likely due to the smaller transplant size in 2006 versus 2005. The peak production of staminate flowers per day for ‘Companion’ was 6 and 7 WAT (Table 4). The peak production of staminate flowers for the other cultivars was 8 and 9 WAT. Any decline in staminate flower production after the peak production period was not examined since flower counts were stopped at 9 WAT because fruit set had occurred on the triploid plants. ‘SP1’ and ‘Sidekick’ produced the most staminate flowers per day at any one given time 8 and 9 WAT. ‘High Set 11’ produced the next highest number of staminate flowers per day as either ‘SP1’ or ‘Sidekick’ 6 and 9 WAT. The dwarf vine cultigens, ‘Companion’, ‘TP91’, ‘TPS92’, and ‘WC5108-1216’, typically produced fewer staminate flowers per day than the standard vine types 7, 8, and 9 WAT, while at 4, 5, and 6 WAT these cultigens produced a similar number of staminate flowers. ‘TP91’ and ‘TPS92’ produced very few staminate flowers per plant and never exceeded 5 per plant on a given day over the 6 week period flowers were counted. The triploid cultigens produced the same number of staminate flowers per day as many of the standard vine length pollenizers.

Pistillate flower production, 2005. Pistillate flower production followed some of the same trends as the staminate flowers. The highest number of pistillate flowers was produced by ‘SP1’ and ‘Sidekick’ (Table 5). The only exception was ‘WH6818’, which produced more flowers 4 WAT. ‘SP1’ and ‘Sidekick’ alternated as to which produced the most pistillate flowers in a given week. Six and 8 WAT, ‘SP1’ produced the most pistillate flowers per day, while the other alternating weeks, 7 and 9 WAT, ‘Sidekick’ produced more pistillate flowers than ‘SP1’. Other cultigens which produced more than one pistillate flower per plant per day at a given time over the six week period included ‘High Set 11’, ‘Mickylee’, ‘Mini Pool’, ‘Pinnacle’, and ‘WH6818’. All of these cultigens produced more than one pistillate flower at 4 or 5 WAT. The exception was ‘High Set 11’, which produced more than one pistillate flower at 6 and 7 WAT as well. All other cultivars produced less than 1 pistillate flower per day for the duration of the experiment. ‘Jenny’ was the only standard vine type to produce less than 1 pistillate flower per day throughout the entire experiment. The standard types ‘Mickylee’, ‘Mini Pool’, ‘SF800’, and ’WH6818’ produced more than 1 pistillate flower per day at only 1 time of measure during the experiment time. ‘Pinnacle’ produced more the 1 pistillate flower per day for 4 and 5 WAT. The peak production of pistillate flowers for the triploid cultigens was 5 to 7 WAT for ‘Precious Petite’ and 4 to 6 WAT for ‘Tri-X-313’.

Pistillate flower production, 2006. Smaller transplant size was likely the reason for delaying the cultigens from producing more than 1 pistillate flower per day until 6 WAT in 2006 compared to 4 WAT in 2005 (Table 6). ‘High Set 11’, ‘Mini Pool’, ‘Nun6017’, and ‘Pinnacle’ produced more than 1 pistillate flower and ‘Sidekick’ produced 2.1 pistillate flowers per day 6 WAT. The dwarf cultivars, except for ‘Sidekick’, did not produce more than 1 pistillate flower during the experimental time. There was a large drop in the number of pistillate flowers 7 WAT in all of the cultigens, except ‘Jenny’. The peak production of pistillate flowers per day for the triploid cultivars, ‘Precious Petite’ and ‘Tri-X-313’ was 6 through 9 WAT.

The vine habit of the cultigen has an effect on the number of staminate and pistillate flowers that are produced on the plant. In cucumbers, the little leaf type cucumber produces more branching than normal leaf cucumber. The additional branching of the little leaf type causes it to produce more flowers and fruit (Bowers et al., 1981; Goode et al., 1980; Goode et al. 1989). The flowers on watermelon develop in the nodes of the plants (Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi 1997); the additional branching on ‘Sidekick and ‘SP1’ creates more locations for the flowers to be developed. The extensive branching in ‘SP1’ causes it to produce more flowers than the other standard vine length pollenizers. ‘Sidekick’ had more side branching than the other dwarf cultigens and was able to produce more flowers.

The production of staminate flowers on pollenizer cultigens should overlap with the production of pistillate flowers on triploid plants to maximize the pollination and set of the triploid fruit. Maynard and Elmstrom (1992) discussed that earlier or later flower habit of the different pollenizers affected the timing of the triploid fruit harvest. In this study, several cultivars had consistent, prolific staminate flower production through the season. This continuous production of staminate flowers might promote triploid fruit production for extended time and expand the length of harvest time. ‘Companion’ had production of staminate flowers earlier in the season, which may lead to earlier triploid fruit set and harvest being earlier. In 2005, pistillate flower production of ‘Tri-X-313’ overlapped best with ‘Companion’ staminate flower production. ‘Precious Petite’ had peak production of pistillate flowers at the same time as the peak production of staminate flowers on ‘WC5108-1216’ as the other cultigens were a week earlier or later. In 2006, the peak production of the pistillate flowers per day on the triploid fruit overlapped with the peak production of staminate flowers on the pollenizers. Peak production of staminate flowers does not necessarily need to overlap with triploid pistillate flower production as there likely is an adequate amount of viable pollen being produced by pollenizers during some of the off-peak times. However, for the best chance of triploid fruit set and quality, it would seem best if peak staminate flower production coincided with pistillate flower production.

Fruit development. In 2005, most cultigens had set about one fruit per plant 5 WAT (Table 7). ‘SF800’ and ‘WC5108-1216’ set its first fruit per plant one week later (6 WAT). Beginning 5 WAT, ‘Sidekick’ and ‘SP1’ continued to set 1 fruit or more throughout the 5 week period. ‘High Set 11’ had 0.5 or more fruit set each week between 5 and 9 WAT. ‘Companion’ fruit set was complete 5 WAT with about 2 fruits per plant. A total of 8 fruit and 13 fruit were set per ‘SP1’ and ‘Sidekick’ plant, respectively, 9 WAT. The other cultigens set between two and five fruits per plant between 5 and 9 WAT. Most cultigens set about two or three fruit per plant by 6 WAT and 1 to 2 additional fruits were set in the subsequent 3 weeks. ‘Precious Petite’ set most of its fruit 5, 6, and 9 WAT and ‘Tri-X-313’ set most of its fruit 5 and 8 WAT.

In 2006, the delay in staminate flowers caused fruit set to be later compared to 2005 and most cultigens did not set fruit until 6 WAT (Table 8). ‘Jenny’, ‘SF800’, and ‘WC5108-1216’ did not set at least 1 fruit until 8 WAT. ‘Ace’, ‘SP1’, and ‘Sidekick’ set the most fruit through 9 WAT. ‘Companion’, ‘TP91’, and ‘TPS92’ set their initial fruit set and then stopped. The other cultivars had their first fruit set 6 or 7 WAT and then a second 8 to 9 WAT. The triploids set fruit 8 WAT and then a second fruit set 9 WAT.

‘SF800’ had the longest, widest (Appendix A table 1), and heaviest fruit both years (Table 9). ‘SF800’ is commonly produced in Georgia, Indiana, and Texas for markets in which seeded watermelons are sold (Maynard, 2000). ‘Mickylee’ was the second heaviest diploid cultigen with a similar width fruit. Other diploid cultigens with comparable sized fruit to ‘Mickylee’ were ‘Mini Pool’, ‘TP91’, and ‘TPS92’. The smallest fruit were produced by ‘Ace’, ‘High Set 11’, ‘Jenny’, ‘Sidekick’, and ‘SP1’ and ranged from 0.9 to 3.3 kg. ‘Sidekick’ tended to be the smallest fruit with an average weight of 1 kg or less.

The fruit interior was examined to determine the viability of cultigens for further research and potential sales of seeded watermelon. In 2005 and 2006, the pollenizer cultigens with a rind thickness greater than 10 mm were ‘Companion’, ‘Mickylee’, ‘SF800’, ‘TP91’, ‘TPS92’, and ‘WC5108-1216’ (Appendix A table 2). All the cultigens except ‘Companion’, ‘TP91’, ‘TPS92’, and ‘WC5108-1216’ had the same rind width as ‘Petite Perfection’. In 2006, ‘High Set 11’, ‘Jenny’, ‘Nun6017’, ‘Pinnacle, and ‘WH6818’ had the same rind thickness as ‘Petite Perfection’. The cultigens with the thinnest rinds were ‘Ace’, ‘High Set 11’, ‘SP1’, and ‘Sidekick’.

Thicker fruit rinds are necessary for fruit to be stacked in bins for transport. ‘SF800’ and ‘Tri-X-313’ have a thick rind and are shipped in this manner. Based on rind thickness alone, ‘Companion’, ‘Mickylee’, ‘TP91’, ‘TPS92’, and ‘WC5108-1216’ all meet the criteria for shipment and marketing in bins. ‘Petite Perfection’ is a mini watermelon cultivar that has a thinner rind than the standard size triploid fruit such as ‘Tri-X-313’. Mini watermelons require special designed single layer boxes that keep the fruit from stacking on top of each other. If ‘Ace’, ‘High Set 11’, ‘SP1’, and ‘Sidekick’ were to be used in the seeded watermelon market then consideration for packaging and shipping would likely need to be done in boxes comparable to those used for mini watermelons. ‘Ace’, ‘High Set 11’, ‘SP1’, and ‘Sidekick’ are cultigens with a thinner rind that easily collapses if stepped on in the field.

A watermelon should have a minimum ˚Brix (soluble solids) of 10.0 and a bright red flesh. The only cultivars to have soluble solids at this level in 2005 were ‘Companion’, ‘Pinnnacle’, ‘SF800’, and ‘WC5108-1216’ (Appendix A table 2). In 2006, additional cultivars included ‘Jenny’, ‘Mickylee’, ‘Mini Pool’, and ‘TPS92’. The cultigens with the lightest red flesh color were ‘Mickylee’, ‘Sidekick’, ‘TP91’, and ‘TPS92’. ‘SP1’ has a white flesh color that turns cream as it ages. ‘High Set 11’ appeared to be segregating because the flesh color was red, pink, white, and orange colored. Most of the cultigens which had thick rinds did not meet the minimal quality standard of a ˚Brix of 10.0 and therefore would not be suited for market. These cultigens include: ‘TP91’, ‘TPS92’, and ‘WC5108-1216’.

The rind pattern of ‘Mickylee’, ‘Mini Pool’, ‘Nun6017’, ‘WH6818’ have a ‘Charleston Grey’ rind pattern and are round (Appendix A table 2). ‘Ace’, ‘High Set 11’, and ‘SP1’ have a rind pattern that has an indistinct medium green stripe on a light green background and are oblong. The rind pattern of ‘Jenny’ and ‘Petite Perfection’ is a distinct ~1.3 cm dark green stripe on a light green background and are round. The ‘Pinnacle’ rind has a distinct ~1.3 cm dark green stripe on a light green background and is oblong with nearly pointed or tapered ends. ‘SF800’ is oblong and its rind has dark green stripes 3.8 cm wide on a light green background. ‘Sidekick’ fruits are round and rinds have 2.5 cm thick medium green stripes on a light green background. ‘WC5108-1216’ fruits are blocky with a rind that has medium green stripes on a light green background. ‘TP91’ is round with a solid dark green to almost black rind. ‘TPS92’ has a ‘Moon and Stars’ rind pattern.

Rind patterns are an important consideration when selecting a pollenizer since they must be easily distinguished from the triploid fruit being grown (Kihara, 1951; Maynard and Elmstrom, 1992; Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi, 1997). This consideration is especially true when planting pollenizers with small fruit in mini watermelon production and pollenizers with large fruit in regular size watermelon production.

This research was not to focus on pollenizer cultigens that were suitable for market. However, we would be remiss if we did not at least consider their potential since they are an economic consideration should the producer want to consider their suitability for market. Some of the new dedicated pollenizer cultivars which would seem to meet the fruit quality criteria for market are ‘Pinnacle’ and ‘Mini Pool’. ‘Jenny’ is currently sold in Europe but not in the United States. This conclusion is based on their acceptable red flesh color and high sugars. ‘Pinnacle’ and ‘Jenny’ have thinner rinds and may require special packaging. Other cultivars included in this test that are used as pollenizers in North and South America and routinely sold are ‘Mickylee’ and ‘SF800’.

When selecting a pollenizer , their vegetative, floral, and fruit characteristics should be considered. The three factors that could have the most impact on the yield of triploid watermelon production are the quantity of staminate flowers, peak production of staminate flowers, and vine growth of the pollenizer. Staminate flowers are required for the production of triploid production (Kihara, 1951; Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi 1997). Although a cultigen may have higher quantities of staminate flowers per plant compared to other cultigens, the higher number of staminate flowers may not coincide with a high quantity of pollen (Stanghellini and Schultheis, 2005). Pollen production should be quantified further on these cultigens in subsequent studies. Maynard and Elmstrom (1992) discuss the effects that earlier and later blooming pollenizers have on triploid fruit. But they do not discuss the implications of a pollenizer that blooms repeatedly through the growing season and the effect on triploid yield.

Motsenbocker and Arancibia (2002) and Sanders et al. (2002) showed that tightening the spacing between the cultivars in watermelon causes fruit quantity and quality to decline. These two research studies did not include multi-branching or dwarf watermelon cultigens. In cucumber spacing, tightening the spacing had the same effect on little-leaf cucumber with a multi-branching and regular-leaf cucumber. Thus, the multi-branching habit of ‘SP1’ and ‘Sidekick’ with more side branching may have limited effect on the production of triploid fruit (Schultheis, et al., 1998). Dwarf plant structure has been used in other crops such as apple, peach, and nectarine to maximize the planting density (Vizzotto and Costa, 1997; Weber, 2001). The cultigens used in this stud with a dwarf vine structure could be planted at higher quantities with trilpllid watermelons to maximize the number of staminate flowers in the field with potentially little effect on the yield of the triploid fruit.

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a)Separate rows

R1	R2	R3	R4	R5
T	T	T	P	T
T	T	T	P	T
T	T	T	P	T
T	T	T	P	T
T	T	T	P	T
T	T	T	P	T

b)Same row: hill

R1	R2	R3	R4	R5
T	T	T	P	T
P	T	T	T	P
T	P	T	T	T
T	T	P	T	T
T	T	T	P	T
P	T	T	T	P

c)Same row: inter-planted

R1	R2	R3	R4	R5
T	T	T	T	T
P			P	
T	T	T	T	T
	P			P
T	T	T	T	T
		P		
T	T	T	T	T
P			P	
T	T	T	T	T
	P			P
T	T	T	T	T

Figure 1. Planting methods for pollenizer plants in triploid watermelon production with a 1 pollenizer : 3 triploid planting ratio. T represents triploid plants, P represents pollenizer plants.

Table 1. Length of the longest vine on one plant one day per week for different cultigens.

Treatment	Seed Source[z]	2005 4 WAT		2005 5 WAT		2006 4 WAT		2006 5 WAT	
		cm							
Dwarf pollenizer cultigens									
Companion	SM	61.9	fg[y]	99.4	g	30.9	fg	58.0	gh
Sidekick	HM	73.6	f	96.6	g	43.5	def	77.2	fg
TP91	AC	75.5	f	103.8	g	25.7	fg	50.5	gh
TPS92	AC	59.1	fg	75.2	g	24.0	fg	50.8	gh
WC5108-1216	SM	44.5	g	79.3	g	12.7	g	27.7	h
Standard pollenizer cultigens									
Ace	SE	---[x]		---		90.5	ab	151.8	bcd
High Set 11	DN	159.3	de	172.8	f	79.2	bc	133.4	de
Jenny	NU	173.6	bcd	244.1	de	41.0	ef	104.7	ef
Mickylee	OP	186.8	b	292.8	abc	113.7	a	183.5	ab
Mini Pool	HZ	184.2	bc	297.3	ab	110.6	a	193.8	a
Nun6017	NU	---		---		66.1	cd	138.6	cde
Pinnacle	SW	166.1	cde	237.1	e	108.9	a	171.0	abc
SF800	AC	152.2	e	276.9	bcd	95.1	ab	165.1	abcd
SP1	AY	163.4	de	260.4	cde	91.6	ab	159.3	abcd
WH6818	WH	215.0	a	312.2	a	73.4	bc	136.9	cde
Triploid cultigens									
Petite Perfection	SY	175.5	bcd	271.0	bcd	64.1	cde	137.5	cde

(*Table 1*, continued)

Tri-X-313	SY	177.1	bcd	286.8	abc	81.0	bc	143.8	cd
LSD		19.9		33.7		23.5		36.4	

[z]Seed Source: AC = Abbott & Cobb (Feasterville, Pa.), DN = Danson Seed (Los Angeles, Calif.), HM = Harris Moran, HZ = Hazera (Berurim M.P. Shikmim, Israel), NU = Nunhems (Acampo, Calif.), OP = Open pollinated, Willhite Seed (Poolville, Texas), SE = Seedway (Hall, N.Y.), SM = Seminis (Oxnard, Calif.), SW = Southwestern (Casa Grande, Ariz.), SY = Syngenta (Boise, Idaho), WH = Willhite (Poolville, Texas).

[y]Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

[x]Cultigen not evaluated in 2005.

Table 2. Length of internode between the third and fourth fully expanded leaf from the tip of the longest vine on one plant one day per week for different cultigens.

	2005				2006	
Treatment	4 WAT		5 WAT		4 WAT	
	cm					
Dwarf pollenizer cultigens						
Companion	4.3	d[z]	4.6	def	3.2	d
Sidekick	4.8	bcd	4.8	cdef	3.3	d
TP91	4.5	cd	8.7	ef	2.5	de
TPS92	6.8	abcd	2.9	f	2.7	de
WC5108-1216	5.3	bcd	3.4	ef	1.8	e
Standard pollenizer cultigens						
Ace	---[y]		---		5.1	c
High Set 11	8.0	abcd	7.4	bcdef	6.0	bc
Jenny	8.3	abc	9.3	bcde	6.3	bc
Mickylee	8.4	ab	11.1	b	7.6	a
Mini Pool	7.3	abcd	11.5	b	6.8	ab
Nun6017	---		---		6.3	bc
Pinnacle	8.5	ab	7.3	bcdef	7.7	a
SF800	9.8	a	12.5	ab	7.2	ab
SP1	9.7	a	11.0	bc	7.3	ab
WH6818	10.3	a	9.6	bcde	6.9	ab
Triploid cultigens						

(*Table 2*, continued)

Petite Perfection	7.0	abcd	17.9	a	7.7	a
Tri-X-313	7.1	abcd	10.3	bcd	7.2	ab
LSD	3.8		6.2		1.3	

[z] Means within in the column followed by the same letter are not significantly different at the 0.05 level determined using LSD.

[y] Cultigen not evaluated in 2005.

Table 3. Total number of staminate flowers/plant/day for different cultigens in 2005.

	Weeks after transplant (WAT)											
Treatment	4		5		6		7		8		9	
Dwarf pollenizer cultigens												
Companion	5.5	bcde[z]	12.7	cde	7.3	fg	3.8	i	4.1	c	3.3	fgh
Sidekick	12.2	a	32.0	a	40.9	b	58.5	b	31.8	a	25.3	a
TP91	6.1	bcde	4.9	f	4.4	g	6.1	hi	3.0	c	2.1	h
TPS92	2.9	de	4.1	f	4.0	g	4.1	i	3.4	c	3.3	gh
WC5108-1216	5.2	cde	15.6	c	21.3	cd	16.2	fg	9.4	c	7.8	defg
Standard pollenizer cultigens												
High Set 11	6.3	bcd	20.7	b	25.7	c	58.5	b	22.8	ab	16.0	b
Jenny	7.6	bc	13.8	cd	19.4	cde	27.0	d	23.1	ab	14.2	bc
Mickylee	7.9	bc	11.8	cde	15.9	def	25.4	de	13.2	bc	5.4	efgh
Mini Pool	5.1	cde	12.1	cde	11.2	efg	12.0	ghi	12.3	bc	8.7	def
Pinnacle	9.5	ab	13.3	cde	11.2	efg	14.1	fgh	7.5	c	5.1	efgh
SF800	2.2	e	11.8	cde	17.1	cde	22.5	def	10.2	c	12.5	bcd

(*Table 3*, continued)

SP1	5.5 bcde	28.8 a	59.3 a	92.6 a	30.9 a	9.5 cde
WH6818	9.0 abc	15.4 c	20.9 cd	16.3 efg	14.0 bc	12.3 bcd
Triploid cultigens						
Petite Perfection	3.0 de	8.6 ef	12.7 defg	14.4 fgh	8.6 c	4.7 efgh
Tri-X-313	3.3 de	8.9 def	11.2 efg	14.4 fgh	4.0 c	3.3 fgh
LSD	4.0	4.93	9.3	9.2	12.1	5.4

[z] Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

Table 4. Total number of staminate flowers/plant/day for different cultigens in 2006.

	Weeks after transplant (WAT)											
Treatment	4		5		6		7		8		9	
Dwarf vine pollenizer cultigens												
Companion	0.8	abcd[z]	1.7	ab	8.3	cdef	11.1	cd	5.6	fg	4.3	d
Sidekick	0.6	abcd	1.8	ab	19.5	b	22.6	b	40.8	a	47.9	a
TP91	1.0	abc	0.6	def	4.6	f	3.7	e	3.4	g	4.5	d
TPS92	0.6	abcd	0.2	f	3.8	f	3.3	e	3.6	g	4.4	d
WC5108-1216	0.5	bcd	1.3	bcd	7.8	cdef	12.1	c	18.5	bc	19.8	bc
Standard vine pollenizer cultigens												
Ace	1.4	a	1.2	bcde	12.5	c	11.5	cd	13.0	cde	15.1	cd
High Set 11	1.3	ab	2.1	a	17.4	b	19.2	b	25.5	b	29.1	b
Jenny	0.3	cd	0.5	def	5.3	f	7.4	cde	13.2	cde	21.6	bc
Mickylee	1.1	abc	1.8	ab	10.3	cde	12.3	c	15.2	cde	18.6	bc
Mini Pool	1.3	ab	1.4	abc	8.3	cdef	11.3	cd	12.6	cdef	18.2	bc
Nun6017	0.3	cd	1.5	abc	8.5	cdef	9.3	cd	13.6	cde	16.7	c

(*Table 4*, continued)

Pinnacle	0.9 abcd	1.2 bcde	11.7 cd	11.3 cd	11.6 cdef	11.4 cd
SF800	0.3 cd	0.6 def	8.4 cdef	8.0 cde	17.5 cd	16.8 c
SP1	1.0 abc	1.8 ab	26.5 a	36.3 a	45.1 a	42.3 a
WH6818	0.8 abcd	1.1 bcde	7.1 def	6.0 de	10.6 defg	15.3 cd
Triploid cultigens						
Petite Perfection	0.1 d	0.4 ef	6.4 ef	7.3 cde	8.8 efg	10.2 cd
Tri-X-313	0.5 bcd	0.8 cdef	4.7 f	6.9 cde	11.6 cdef	12.2 cd
LSD	0.8	4.8	4.8	5.7	7.2	11.9

[z] Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

Table 5. Total number of pistillate flowers/plant/day for different cultigens in 2005.

	Weeks after transplant (WAT)					
Treatment	4	5	6	7	8	9
Dwarf vine pollenizer cultigens						
Companion	0.3 de[z]	0.8 cde	0.0 c	0.1 d	0.1 b	0.2 bc
Sidekick	1.2 abc	2.1 a	1.4 bc	3.9 a	0.0 b	1.1 a
TP91	0.3 de	0.3 cde	0.7 bc	0.6 cd	0.0 b	0.1 c
TPS92	0.1 e	0.1 e	0.3 bc	0.3 d	0.1 b	0.1 c
WC5108-1216	0.0 e	0.9 bcde	0.5 bc	0.2 d	0.0 b	0.1 c
Standard vine pollenizer cultigens						
High Set 11	1.1 abc	1.9 ab	1.6 b	1.8 b	0.2 b	0.3 bc
Jenny	0.8 cd	0.8 cde	0.7 bc	0.7 cd	0.0 b	0.5 abc
Mickylee	1.3 abc	0.5 cde	0.9 bc	0.7 cd	0.0 b	0.2 bc
Mini Pool	1.4 ab	0.2 de	0.6 bc	0.0 d	0.0 b	0.0 c
Pinnacle	1.4 ab	1.2 abcd	0.3 bc	0.3 d	0.0 b	0.2 bc
SF800	0.0 e	0.7 cde	1.0 bc	0.7 bcd	0.0 b	0.1 c

(*Table 5*, continued)

SP1	0.8 cd	1.3 abc	3.8 a	1.4 bc	0.5 a	0.1 c
WH6818	1.7 a	0.9 bcde	0.9 bc	0.8 bcd	0.1 b	0.2 bc
Triploid cultigens						
Petite Perfection	0.2 de	1.0 bcde	1.1 bc	0.8 bcd	0.2 b	0.8 abc
Tri-X-313	1.0 bc	1.2 abcd	0.8 bc	0.4 cd	0.1 b	0.2 bc
LSD	0.7	1.1	1.4	1.1	0.3	0.7

[z] Means followed by the same letter are not significantly different at the 0.05 level determined using LSD.

Table 6. Total number of pistillate flowers/plant/day for different cultigens in 2006.

	Weeks after transplant (WAT)									
Treatment	4	5		6	7	8		9	
Dwarf vine pollenizer cultigens									
Companion	0.1	0.0	c[z]	0.4	0.1	0.2	d	0.4	abc
Sidekick	0.2	0.6	a	2.1	0.4	1.6	ab	1.1	abc
TP91	0.0	0.1	c	0.7	0.0	0.3	d	0.1	c
TPS92	0.1	0.0	c	0.6	0.1	0.2	d	0.2	bc
WC5108-1216	0.0	0.0	c	0.3	0.8	0.9	bc	0.4	abc
Standard vine pollenizer cultigens									
Ace	0.0	0.2	bc	0.9	0.6	0.5	cd	0.3	abc
High Set 11	0.1	0.2	bc	1.4	0.6	1.1	bc	1.2	abc
Jenny	0.0	0.0	c	0.3	1.2	1.3	ab	0.5	abc
Mickylee	0.0	0.0	c	0.7	0.3	0.2	d	0.3	bc
Mini Pool	0.2	0.2	bc	1.1	0.2	0.6	cd	1.4	a
Nun6017	0.0	0.1	c	1.2	0.4	0.6	cd	0.8	abc

(*Table 6*, continued)

Pinnacle	0.1	0.5 ab	1.3	0.5	1.0 bc	0.7 abc
SF800	0.0	0.0 c	0.8	0.2	1.1 bc	0.7 abc
SP1	0.1	0.6 a	0.9	0.8	1.9 a	1.4 a
WH6818	0.0	0.0 c	0.6	0.2	0.7 cd	1.0 abc
Triploid cultigens						
Petite Perfection	0.0	0.0 c	1.4	0.7	0.9 bc	1.0 abc
Tri-X-313	0.1	0.0 c	0.9	0.8	1.3 ab	1.3 ab
LSD	NS	0.4	NS	NS	0.6	1.1

[z] Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

Table 7. Total number of set fruit/plant/day for different cultigens in 2005.

Treatment	Weeks after transplant (WAT)											
	4		5		6		7		8		9	
Dwarf pollenizer cultigens												
Companion	0.1	d[z]	1.9	bcd	2.1	efgh	1.8	efg	1.8	gh	2.0	e
Sidekick	0.0	d	5.0	a	6.3	a	7.4	a	11.9	a	13.6	a
TP91	0.8	a	1.2	cde	1.3	gh	1.3	gf	2.1	gh	2.1	e
TPS92	0.8	ab	1.2	cde	1.1	h	1.0	g	1.4	h	2.2	e
WC5108-1216	0.0	d	0.3	e	2.6	cdef	3.3	bcd	3.8	cde	4.3	cde
High Set 11	0.3	cd	1.8	bcd	3.5	bc	4.0	b	4.8	cd	5.6	cd
Jenny	0.2	d	1.7	bcd	3.3	bcd	3.3	bcd	3.9	cde	5.3	bc
Mickylee	0.0	d	1.7	bcd	2.1	efgh	3.7	bcd	4.3	cd	3.8	cde
Mini Pool	0.2	d	2.2	bcd	2.3	defg	2.7	cde	2.9	efg	4.1	cde
Pinnacle	0.5	bc	2.3	bc	2.8	bcdef	3.3	bcd	3.8	def	3.9	cde
SF800	0.0	d	0.5	e	1.6	fgh	2.5	def	2.5	fgh	2.4	e

(Table 7, continued)

SP1	0.2	d	1.1	ed	3.5	bc	6.7	a	6.3	b	8.3	b
WH6818	0.1	d	2.6	b	3.0	bcde	3.7	bcd	5.1	bc	5.2	cd
Triploid cultigens												
Petite Perfection	0.0	d	1.4	cde	3.9	b	3.9	bc	4.0	cde	5.8	bc
Tri-X-313	0.3	cd	1.9	bcd	2.2	efgh	2.6	def	3.8	efg	3.1	de
LSD	0.3		1.1		1.2		1.3		1.3		2.5	

[z] Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

Table 8. Total number of set fruit/plant/day for different cultigens in 2006.

	Weeks after transplant (WAT)					
Treatment	4	5	6	7	8	9
Dwarf vine pollenizer cultigens						
Companion	0.0	0.3 bc[z]	1.2 cde	1.5 de	1.4 h	1.6 g
Sidekick	0.0	0.2 bc	4.2 a	4.9 a	6.9 a	10.9 a
TP91	0.0	0.3 bc	1.2 cde	1.4 de	1.6 gh	1.6 g
TPS92	0.0	0.3 bc	1.1 cde	1.3 def	1.7 fgh	1.9 fg
WC5108-1216	0.0	0.0 c	0.1 e	0.3 g	1.7 fgh	2.9 efg
Standard vine pollenizer cultigens						
Ace	0.0	0.8 a	2.5 b	3.1 b	4.8 bc	5.9 bc
High Set 11	0.1	0.6 ab	0.9 de	1.8 cd	3.2 defg	5.4 bcd
Jenny	0.0	0.0 c	0.6 de	0.8 efg	2.8 defgh	4.9 bcde
Mickylee	0.0	0.0 c	1.4 bcd	1.5 de	2.8 defgh	3.3 defg
Mini Pool	0.0	0.2 bc	1.5 bcd	1.8 cd	3.4 bcd	3.5 defg
Nun6017	0.0	0.0 c	1.2 cde	1.3 def	3.3 cde	5.3 bcd

(*Table 8*, continued)

Pinnacle	0.0	0.5 ab	2.1 bc	2.5 bc	3.6 bcd	4.8 cde
SF800	0.0	0.0 c	0.4 de	0.4 fg	1.8 efgh	3.3 defg
SP1	0.0	0.2 bc	1.0 cde	1.5 de	5.0 b	7.1 b
WH6818	0.0	0.0 c	1.1 cde	1.2 defg	2.3 defgh	3.9 cdef
Triploid cultigens						
Petite Perfection	0.0	0.0 c	0.5 de	0.9 defg	3.1 defg	4.8 cde
Tri-X-313	0.0	0.0 c	0.5 de	0.8 defg	3.3 cdef	4.3 cde
LSD	NS	0.4	1.1	0.9	1.6	2.2

^{z}Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

Table 9. Average fruit weight of pollenizer and triploid cultigens

Treatment	2005		2006	
	kg			
Dwarf pollenizer cultigens				
Companion	3.9	def	3.8	de
Sidekick	0.9	i	1.0	i
TP91	4.8	cd	4.2	cd
TPS92	4.7	cde	4.2	cd
WC5108-1216	3.4	defg	3.3	def
Standard pollenizer cultigens				
Ace	---^{y}		1.7	hi
High Set 11	2.0	ghi	2.5	fgh
Jenny	2.6	fgh	3.3	fgh
Mickylee	5.5	bc	5.1	c
Mini Pool	3.3	efg	3.9	de
Nun6017	---		2.9	efg
Pinnacle	3.1	fg	2.9	efg
SF800	7.8	a	10.7	a
SP1	1.4	hi	2.0	ghi
WH6818	3.0	fg	2.9	efg
Triploid cultigens				
Petite Perfection	2.4	fgh	3.1	efg
Tri-X-313	6.6	ab	8.3	b

(*Table 9*, continued)

LSD	0.8	0.6

[z] Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

[y] Cultigen not evaluated in 2005.

Chapter 2

Utilization of Commercially Available Pollenizers for Optimizing Triploid Watermelon Production

(In the format appropriate for submission to HortScience)

Utilization of Commercially Available Pollenizers for Optimizing Triploid Watermelon Production

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Abstract

An experiment was conducted in 2005 and repeated in 2006 in Kinston, NC, with the objective of maximizing triploid watermelon fruit yields and quality by optimizing the choice and use of pollenizers in a commercial production system. One group of pollenizer treatments included the comparison of ‘Companion’, ‘Super Pollenizer 1’ (SP1’), ‘Summer Flavor 800’ (‘SF800’), and ‘Mickylee’ as the only pollen source. A second group of pollenizer treatments evaluated the use of two pollenizer cultivars as pollen sources. The following combinations of pollenizers were tested: ‘Companion’ + ‘SP1’, ‘Companion’ + ‘SF800’, and ‘SP1’ + ‘SF800’. All pollenizers from these seven treatments were inter-planted with the triploid cultivar ‘Tri-X-313’. The effect of pollenizer placement on triploid fruit size and yields was evaluated. Planting arrangement was compared by establishing ‘SF800’ in a hill (treatment #8) versus an inter-planted field arrangement. Time of pollenizer establishment effects on triploid fruit yields and quality was evaluated by establishing ‘SP1’three weeks after planting (treatment #9) and comparing it with the establishment of ‘SP1’ at the time of triploid plant establishment. Finally, a treatment (#10) with a triploid planting with no pollenizer was included to determine if pollen movement occurred outside of the treatment area. Some pollen did move beyond the treatment plots; however, pollen movement was minimal among plots and differences in yield and fruit quality could be attributed to pollenizer treatment. Fruit yield from the no pollenizer plots was 20% at most compared with all other treatments which contained a pollenizer, and less than 10% in the initial or early harvests. For individual pollenizer treatments in 2005, the use of ‘Companion’, ‘SP1’, or ‘Mickylee’ produced similar total yields while the lowest yields of triploid fruit were obtained with the ‘SF800’ treatment. In 2006, similar trends occurred; the use of ‘Companion’ produced more large triploid fruit than the other individual pollenizer treatments. Combining the pollenizers which resulted in the best yields when used alone generally did not enhance triploid yields or quality. Inter-planting of pollenizers resulted in better yields than if the pollenizer occupied a hill since the later had fewer triploid plants in the plots. The late planting of ‘SP1’ increased the amounts of severe hollow heart in the marketable sized fruit and yields were decreased compared to when ‘SP1’ was planted at the same time as the triploid plants. The selection of pollenizer, planting arrangement, and time of pollenizer establishment are all important considerations to optimizing triploid yield and quality.

Introduction

Triploid (seedless) watermelons (*Citrullus lanatus* (Thunb.) Matsum. and Nak.) have grown in popularity and make up three quarters of the watermelon production in the United States (USDA-Economic Research Service, 2005). Triploid watermelons produce nonviable pollen and require a plant to be established nearby which produces viable pollen (pollenizer). Diploid (seeded) watermelons are used as pollenizers (Kihara, 1951 Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi 1997).

Pollenizer selection affects triploid fruit quantity, quality, and timing of harvest. Maynard and Elmstrom (1990) reported that icebox-type watermelons that produce flowers early in the season result in an early harvest of triploid fruit. They also reported that later flowering cultivars will result in a later triploid fruit harvest (Maynard and Elmstrom, 1990). ‘Millionaire’, a triploid watermelon, produced more large fruit (>7.2 kg), marketable fruit, and total yields when ‘Crimson Sweet’ was utilized as the pollenizer compared to ‘Fiesta’ as the pollenizer (Fiacchino and Walters, 2003). The use of ‘Fiesta’ as a pollenizer caused ‘Millionaire’ to produce more fruit having hollow heart (Fiacchino and Walters, 2003). Hollow heart is a physiological disorder that is seen when fruit are cut and appears as a separation of the flesh. Shipments of watermelon fruit can be refused for containing hollow heart (Maynard and Hopkins, 1999).

Pollenizer plants can be planted in a triploid production field using three different arrangements: 1) separate dedicated rows next to rows of triploid plants, 2) in the same rows as triploid plants in which hills typically planted with triploid plants are used for the pollenizer plant, 3) in the same row inter-planted between triploid plants. The separate dedicated row planting method has a row of pollenizers planted the length of the field. The next 2 to 4 rows are planted with triploid watermelons the length of the field and the pattern is repeated the width of the field. In the hill planting method, 2 to 4 triploid plants are transplanted, then a pollenizer plant is transplanted instead of a triploid in the next hill. This pattern is repeated the length of the field. If triploid plants are spaced 0.9 m apart then spacing between a triploid and pollenizer is also 0.9 m. In the inter-planted arrangement, triploid watermelon are transplanted the entire length of the field. After every second to fourth triploid plant a pollenizer is planted between triploid plant hills in the same row. This pattern is repeated the length of the field. If triploid plants are planted 0.9 apart then the spacing between triploid and pollenizer plants is 0.45 m.

Regardless of pollenizer arrangement, triploid plants need to be located near a pollenizer plant so that triploid fruit set and quality are maximized. Yields declined when a triploid plant, ‘Genesis’, was more than 6 m from the pollenizer ‘Ferarri’ (NeSmith and Duval, 2001). While placement of pollenizers in rows with the triploid plants can complicate planting and harvesting (Maynard and Elmstrom, 1992) the strategic placement of pollenizers in this manner may lead to better fruit set and quality. Rind pattern of the pollenizer is another important point to consider when selecting a pollenizer. The rind pattern of the pollenizer must differ and be easily distinguishable from the triploid fruit (Kihara, 1951; Maynard and Elmstrom, 1992; Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi 1997).

The pollenizer and triploid watermelon plants can be planted at different ratios. A high ratio, 1 pollenizer row: 2 rows of triploid, can be used in seedless watermelon production (Maynard and Elmstrom, 1990). A low ratio, 1 pollenizer : 4 to 5 triploid, can also be utilized (Kihara, 1951). Utilizing ‘Crimson Sweet’ and ‘Fiesta’ as a pollenizer for production of ‘Millionaire’, a pollenizer frequency of 20% to 30% resulted in greater yields of triploid fruit compared to an 11% pollenizer frequency (Fiacchino and Walters, 2003). A ratio of 1 pollenizer row : 4 triploid rows at a row spacing of 1.5 m resulted in the greatest yields, with ‘Ferrari’ as the pollenizer and ‘Genesis’ as the triploid (NeSmith and Duval, 2001). Beyond 4 rows at 1.5 m spacing, the number of triploid fruit per m^2 decreases due to a dilution of the pollination. Narrowing the ratio from 1:4 to 1:1 or 1:2 increases the number of pollenizer plants and decreases the number of triploid plants resulting in fewer triploid fruit produced (NeSmith and Duval, 2001).

The primary objective of this research was to optimize the production of triploid watermelon by comparing the use of commercially available pollenizers. Individual pollenizers were compared as well as combinations of two pollenizers. Planting arrangement was tested by comparing inter-planted with hill planted treatments, and delayed pollenizer planting was evaluated for triploid production and quality.

Materials and Methods

Cultural practices. Transplants were started in the greenhouse by seeding on 14 Apr 2005 and 31 Mar 2006. The seeds were sown into a soilless media (Fafard 4P; Conrad Fafard, Inc., Agawam, Mass.) and grown in 4 x 4 x 5.5-cm (length x width x depth, respectively) transplant trays (LE1803 pack; Landmark Plastic Corp., Akron, Ohio). After 2 weeks of growth in the greenhouse, transplants were moved to a cold frame for conditioning plants for the field environment. Plants were transplanted 18 May 2005 and 15 May 2006 at the Cunningham Research Station, Kinston, N.C., in a Norfolk sandy loam (fine loamy, siliceous, thermic, typic Kandiudults) soil. Black polyethylene mulch (1.25 mil thick, 1.5 m wide; Reddick Fumigants, Williamston, N.C.) was laid in rows with 2.0 m between row centers. Before transplanting, 616 kg/ha of fertilizer (10N-20P-20K) was broadcast applied, rows were then bedded and fumigated with 1,3-dichloropropene (Telone II; Dow AgriSciences, Indianapolis, Ind) at 4.7 L/ha just before black polyethylene mulch and drip tubing were placed in the field. Triploid plants were transplanted with 0.9 m in-row spacing. Both years, 4 honey bee hives/ha were placed in the center of the field at the end of the rows. Two of the hives in 2006 had less than optimal bee populations and eventually had few or no bees in the hives as the production season progressed. Six weeks after transplanting 2 new hives were placed in the same location of the field. Pesticides were applied on a rotational basis based on North Carolina cultural recommendations (Sanders, 2004; 2005).

Treatments. Each treatment included one pollenizer cultivar or a combination of two pollenizer cultivars; the exception was the control treatment. The control treatment contained no pollenizer and was included to determine the amount of pollen movement between treatment areas and overall effectiveness of the field design. The individual and combination pollenizer treatments were inter-planted between the second and third triploid plants and then after every third plant in the treatment area for a 1:3 (pollenizer:triploid) ratio. Spacing between the triploid plants and the pollenizer were 0.45 m. apart. All pollenizer treatments except one (‘SP1’ late planting) were transplanted the same time as the triploid transplants. The following were used exclusively as single pollenizer treatments: ‘Companion’ (Seminis Vegetable Seed;

Oxnard, Calif.), ‘Mickylee’ (Willhite Seed; Poolville, Texas), ‘Summer Flavor 800’ (SF800) (Abbott & Cobb Inc.; Feasterville, Pa.), and ‘Super Pollenizer 1’ (‘SP1’) (Syngenta; Boise, Idaho). A second ‘SF800’ treatment was hill planted after every third triploid plant and spacing between the pollenizer and triploid plant was 0.9 m. In addition to ‘SP1’ being planted at the same date as the triploid plants; a second ‘SP1’ treatment was included in which the pollenizer plants were transplanted in the field 3 weeks after the triploid plants. This treatment was used to improve fruit set and quality by preventing crown fruit set since hollow heart occurs more often in the crown fruit set (Maynard and Hopkins, 1999). Combinations of ‘Companion’ + ‘SF800’, ‘Companion’ + ‘SP1’, and ‘SF800’ + ‘SP1’ were also included as treatments. Treatments were arranged in a randomized complete block design with four replications.

Experimental design. Plots were four rows wide. At the beginning of each row was an 11.9 m border of ‘Tri-X-Palomar’ (Syngenta; Boise, Idaho) plants without pollenizer plants (Figure 1). After the border was the plot, 11.0 m long. The outside two rows of the plot were planted with ‘Tri-X-Palomar’ plants and the center two rows were planted with ‘Tri-X-313’ plants (Syngenta; Boise, Idaho). Following the treatment area and each subsequent plot was an 11.9 m border of ‘Tri-X-Palomar’ plants without any pollenizers. Following the border of ‘Tri-X-Palomar’ plants, a 1.5 m break with no plants was included to separate plots. The total row length between each treatment was 13.4 m. The plot (treatment area plus border) and break was repeated the length of the row. Next to the 4 row plots, a two row border of ‘Tri-X-Palomar’ plants without pollenizer plants was planted. On either side of these two rows was a 6.1 m space/drive row for spray and harvest equipment. This experiment included the ‘Tri-X-Palomar’ borders without pollenizers between and across plots to prevent pollen contamination between treatments.

Harvest and statistical analysis. Fruit were harvested from the center two rows of ‘Tri-X-313’. Plots were harvested twice in 2005 (27 July and 4 Aug) and four times in 2006 (17 July, 24 July, 3 Aug, and 10 Aug). All fruit were weighed and fifteen randomly selected market size watermelon fruit from each plot were cut in half longitudinally to examine for hollow heart in the initial harvests for each treatment. Five of the fifteen fruit were measured for soluble solids with a hand held refractometer (Q-A supplies, LLC, model number NT-032ATC; Norfolk, Va.) by removing a sample of flesh from the interior of the fruit. Hollow heart was rated from 0 (none) to 4 (severe). Fruits rated 0 through 2 were considered to be marketable. If the rating was a 3 or 4, the fruits were considered nonmarketable. Fruits from ‘Mickylee’ and ‘SF800’ from all four rows were harvested and weighed. These cultivars can be sold in the seeded watermelon market. Data with respect to diploid production are not presented in this manuscript since the objectives of this study was to determine the effect that the choice or use of pollenizer had on triploid production and quality. When including diploid production, the economics of the various pollenizer systems should be evaluated. This requires considerable additional analysis and should be addressed separately in which this is the study’s primary focus. ‘Companion’ and ‘SP1’ are not considered marketable for the seeded watermelon market. Thus, these fruit were not harvested. All data were analyzed using GLM and means were separated with lsd ($P<0.05$) and linear contrasts (SAS, 2002). The linear contrasts provide the key comparisons to questions this study tried to answer wile the lsd comparisons allow for specific comparisons among two treatments.

Results

Individual pollenizer treatments. Total fruit weight and number is the cumulative weight or number of all fruit greater than 2.3 kg. Marketable fruit weight and number is the cumulative weight or number of all fruit greater than 3.6 kg (Fiacchino and Walters, 2003). In 2005, the total and marketable weight from plots with a single pollenizer treatment separated into two different groups (Table 1). Treatments that used 'Companion', 'SP1', and 'Mickylee' had similar total yields; 89.1, 97.4, and 100.5 MT/ha, respectively. The use of 'SF800' resulted in lower yields (75.9 MT/ha) than the other single pollenizer treatments. In 2006, the 'Companion', 'Mickylee', 'SP1', and 'SF800' inter-planted treatments had similar yields. As in 2005, plots which included 'SF800' as the sole inter-planted pollenizer tended to have lower yields than the other single pollenizer treatments. Similar results were obtained for marketable yields as for total yields.

Fruit were separated into three weight classes: small (<3.6 kg), medium (between 3.6 and 7.3 kg), and large (>7.3 kg) (Table 2). In 2005 and 2006, no differences in the weight of small watermelons due to a single pollenizer treatment occured. Small triploid watermelon weight was no greater than 5.0 MT/ha for any given single pollenizer treatment over both growing season. In 2005, plots with 'Mickylee' and 'SP1' yielded more medium-sized triploid fruit, 44.7 and 47.5 MT/ha, respectively, than with

‘Companion’ (31.1 MT/ha) (Table 2). The use of ‘Companion’ resulted in greater yield of large triploid fruit, 58.7 MT/ha, than the other single pollenizer treatments. In 2006, the ‘Mickylee’ treatment had greater yields of medium size triploid fruit (55.8 MT/ha) than the ‘SF800’ inter-planted and ‘Companion’ treatments (42.4 and 30.3 MT/ha, respectively). The plots which had ‘Companion’ yielded the greatest weight of large triploid fruit (58.2 MT/ha) and only differed from the ‘SF800’ inter-planted treatment (30.5 MT/ha). Yields of large triploid fruit resulting from the ‘Mickylee’ and ‘SP1’ treatments were between ‘Companion’ and ‘SF800’ treatments. For both years, the largest individual fruit size was obtained with the ‘Companion’ pollenizer treatment (Table 3). Fruits averaged 7.5 kg in 2005 and 7.7 kg in 2006. In both years, ‘Mickylee’, ‘SP1’, and ‘SF800’ treatments produced fruit of similar size.

Since results for total weight and marketable weight were similar, only the marketable weight separated by harvest is presented. In 2005, the plots were harvested twice. For the four single pollenizer treatments, greater yields were obtained in the first harvest than in the second harvest (Table 4). In the first harvest, the greatest yields were obtained from the ‘Companion’ treatment (80.7 MT/ha). After ‘Companion’, yields from treatments with ‘Mickylee’ and ‘SP1’ were the same in the first harvest (68.1 and 69.3 MT/ha, respectively). The lowest yields were obtained with the ‘SF800’ inter-planted treatment (56.8 MT/ha). Yields from the second harvest did not differ between the individual pollenizer treatments. In 2006, yields for the four individual inter-planted pollenizer treatments for the first harvest were not different. Yields ranged from 23.2 MT/ha, ‘Companion’ treatment, to 11.8 MT/ha for the ‘SF800’ inter-planted treatment.

In the second harvest, the use of ‘Companion’ as a pollenizer yielded the greatest marketable triploid fruit weight, 39.9 MT/ha, while treatments containing ‘SP1’, ‘Mickylee’, and ‘SF800’ yielded similar marketable fruit weight in the second harvest. Yields for the third and fourth harvests were not different among the single pollenizer treatments.

The pollenizer treatment influenced the amount of hollow heart that occurred and impacted the marketability of the fruit. In 2005, the ‘SF800’ inter-planted pollenizer treatment resulted in more fruit with minimal or no hollow heart (97.8%), than the ‘Companion’ treatment (75.6%) (Table 5). Triploid fruit produced with ‘Mickylee’ and ‘SP1’ had a similar percentage of fruit that had minimal or no hollow heart (93.3 and 86.7%, respectively). In 2006, the percentage of fruit with little or no hollow heart could not be distinguished among the four individual inter-planted pollenizer treatments. The difference between the lowest and highest amounts of marketable hollow heart varied by 17.5% for the individual pollenizer treatments.

‘Companion’ alone vs. in combination. For both years, combining ‘Companion’ either ‘SF800’ or ‘SP1’ generally did not improve total and marketable triploid yields compared to when ‘Companion’ was planted alone (Table 1, see contrasts). In 2006, using lsd comparisons, planting ‘SP1’ with ‘Companion’ increased the total yield of ‘Tri-X-313’ (87.3 MT/ha) compared to ‘Companion’ planted alone. Combining ‘SF800’ with ‘Companion’ was not statistically different than using ‘Companion’ alone, but triploid yields were numerically higher (about 25%). In 2006, use of ‘Companion’ alone or in

combination with the other pollenizers resulted in similar triploid yields of marketable fruit, and followed the same trend as total fruit yield (Table 1).

Combining an additional pollenizer with ‘Companion’ increased the yield of small fruit in 2005, but not in 2006 (Table 2, see contrasts). In 2005, combining ‘SP1’ with ‘Companion’ increased the yield of medium-size triploid fruit compared to ‘Companion’ alone by 45.4 MT/ha (Table 2, see lsd comparisons). However, the increase in medium-size triploid fruit when ‘Companion’ was combined with either ‘SF800’ or ‘SP1’ resulted in a decrease in large-size fruit when pollenizers were combined in 2005 but not 2006. The higher quantities of medium-size fruit in 2005 resulted in the individual fruit size in the ‘Companion’ + ‘SP1’ and ‘Companion’ + ‘SF800’ treatments, 7.0 and 6.9 kg, respectively, to be less than the average individual fruit size when ‘Companion’ alone, 7.5 kg (Table 3). In 2006, the yield of large-size triploid fruit was not affected when ‘Companion’ was combined with the other pollenizers (Table 2). There were no differences in the individual fruit weight when ‘Companion’ was used as the sole pollenizer or in combination with other pollenizers (Table 3).

Combining ‘Companion’ with another pollenizer decreased triploid yields in the first harvest of 2005 by 18.6 MT/ha compared to using only ‘Companion’ as the pollenizer (Table 4, see contrasts). Specifically, using lsd comparisons, ‘Companion’ combined with ‘SF800’ decreased yields by 18.5 MT/ha compared with using ‘Companion’ alone. Yields in the second harvest in 2005 were not affected when either ‘SF800’ or ‘SP1’ were combined with ‘Companion’. In 2006, in all the harvests the combination of a pollenizer with ‘Companion’ had no measurable effect on yield of marketable fruit. The exception was the last harvest in which triploid yields were increased by combining ‘Companion’ with another pollenizer (Table 4, see contrasts).

Using lsd comparisons, in 2005, combining ‘SP1’ with ‘Companion’ increased the amount of marketable yield 22% by reducing the incidence and severity of hollow heart compared to using ‘Companion’ as the only pollenizer (Table 5). The combination of ‘Companion’ with ‘SF800’ had no effect on percentage of marketable size fruit with minimal or no hollow heart (Table 5). In 2006, the pollenizer treatment had no effect on the percentage of marketable fruit with hollow heart.

‘SF800’ alone vs. in combination. In 2005, better triploid yields were obtained in the total and marketable fruit weight when ‘SF800’ was combined with ‘Companion’ or ‘SP1’ than ‘SF800’ alone (Table 1, see contrasts). Combining ‘SF800’ with ‘SP1’ or ‘Companion’ increased marketable yield over 9 MT/ha. In 2006, combining ‘SF800’ with ‘Companion’ or ‘SP1’ increased marketable yields, but had no significant effect on yields (Table 1, see contrasts). Although improvement in total or marketable triploid yields as a result of combining either ‘SP1’ or ‘Companion’ with ‘SF800’ compared with using ‘SF800’ as the only pollenizer was not significant in all cases, the addition of these pollenizers consistently resulted in a numerical gain that ranged from 8 MT/ha to 34 MT/ha. The combination of ‘Companion’ or ‘SP1’ with ‘SF800’ had no effect on small- or medium-size fruit both years (Table 2). ‘Companion’ with ‘SF800’ improved the yield of large-size triploid fruit (57.2 MT/ha) compared to ‘SF800’ alone (30.5 MT/ha) (Table

2). The tendency was increased yields of medium- and large-size fruit both years when either ‘Companion’ or ‘SP1’ pollenizers were combined with ‘SF800’. This same trend was apparent for the individual fruit weight when the same treatments were compared (Table 3). Combining ‘SF800’ with ‘SP1’ or ‘Companion’ had no effect on yield when separated by harvest or the percentage of marketable fruits as affected by hollow heart (Table 4, Table 5).

‘SP1’ alone vs. in combination. For both years, there were no differences in total and marketable fruit yields when ‘SP1’ was used as a pollenizer alone or in combination with ‘Companion’ or ‘SF800’ using lsd comparisons (Table 1). However, total fruit weight was increased when ‘SF800’ or ‘Companion’ pollenizers were combined with ‘SP1’ (Table 1, see contrasts). No differences in fruit weight classes (Table 2) or individual fruit size occurred when ‘SP1’ was alone or used in combination with other pollenizers (Table 3). The combination of pollenizers with ‘SP1’ also had no effect on the amounts of marketable fruit affected by hollow heart (Table 5). When lsd comparisons were made, differences were found in the first harvest of 2005 (Table 4). The combination of ‘SP1’ with ‘SF800’ caused yields to drop to 57.1 MT/ha compared to using ‘SP1’ alone which resulted in yields of 69.3 MT/ha. Also in 2006, the addition of ‘Companion’ to ‘SP1’ resulted in a greater second harvest than if ‘SP1’ was planted alone. For the first, third, and fourth harvests, there were no treatment differences when ‘SP1’ was used alone or in combination with ‘Companion’ or ‘SF800’.

'SF800'; Inter-planted vs. hill planted. In 2005, total and marketable yields of triploid fruits from the inter-planted 'SF800' plots (74.4 MT/ha) were greater than the hill planted (57.2 MT/ha) (Table 1). The yields of marketable fruit weights for these treatments were the same. When using the lsd analysis, in 2006, the total and marketable fruit weights were similar when the 'SF800' inter-planted and hill planted treatments were compared. The number of triploid plants in the plots for the inter-planted treatment was greater than the hill planted treatment. The primary difference due to placement of 'SF800' plants in fruit size class was the weight of large fruit in 2005 (Table 2). The 'SF800' hill planted treatment yielded 21.2 MT/ha and the inter-planted yielded 34.5 MT/ha large triploid fruit. The weight of the individual 'Tri-X-313' fruit did not differ between the two treatments (Table 3).

The first harvest of 2005 had differences between the hill planted and inter-planted 'SF800' treatments. Fruits obtained from the hill planting weighed 36.6 MT/ha and the inter-planted yielded 56.8 MT/ha (Table 4). The next harvest had no differences between the two treatments. In 2006, no differences were found in each harvest; the exception was when the contrast was made between treatments and slightly higher yields were obtained in the first harvest when 'SF800' was inter-planted rather than hill planted. Percentage of marketable fruit with no or minimal hollow heart was similar for the hill planted and inter-planted 'SF800' treatments (Table 5).

'SP1'; 0 vs. 3 weeks after triploid planting. In 2005, planting 'SP1' three weeks later greatly affected total and marketable triploid fruit yields. The late planting of 'SP1'

resulted in nearly 40 MT/ha less triploid fruit than when planting ‘SP1’ at the same time as the triploid plants (Table 1). In 2005, the earlier planting of ‘SP1’ resulted in 20 MT/ha more medium-size fruit and 13.3 MT/ha more large-size fruit than with the late ‘SP1’ planting (Table 2). No differences were found in 2006 for total fruit weight, marketable fruit weight (Table 1), and individual weight classes (Table 2).

The first harvest of 2005 had greater yields when ‘SP1’ was planted the same time as the triploid plants (69.3 MT/ha) than with the later planting of ‘SP1’ (37.6 MT/ha) (Table 4). By the second harvest, both treatments had similar yields. In 2006, no statistical differences were found between the two treatments at any of the harvests. Generally, the earlier planting of ‘SP1’ tended to result in higher yields for the first two harvests while the later planting of ‘SP1’ tended to result in better yields for the two last harvests (Table 4).

Timing of transplanting ‘SP1’ affected the percentage of marketable fruit with hollow heart. In 2005, 86.7% of the fruit harvested from plots in which ‘SP1’ was planted at the same time as the triploid plants had fruit without hollow heart or fruit with hollow heart that could be marketed, while the late planting had 48.9% (Table 5). In 2006, the early planting had 77.8% and the late planting had 53.3% of fruits with acceptable hollow heart (Table 5). In both years, the later ‘SP1’ planting treatment produced fruits with the same percentage of marketable hollow heart as the control treatments with no pollenizer.

Discussion

The two studies differed in the time period in which watermelon fruit were set. In 2005, the fruit set was concentrated; there were only two harvests that were only one week apart. In 2006, there were four harvests, and fruit were harvested over a 4 week period. The difference in pattern of fruit set can and does occur in commercial plantings and may occur for a variety of reasons. Environment can play a key role in fruit set. For example, rainy weather or cool temperatures can hinder bee activity and reduce the quality or quantity of fruit set. A reduction in the number of bee visits was reported to result in less yields and fruit quality in watermelon (Adlerz, 1966; Stanghellini, 1997; Walters, 2005). In 2006, limited activity in two bee hives was during the time that fruit set was occurring. The extended time of fruit set in 2006 may have been caused in part by the reduction in honey bees and extended the time it took for the triploid vines to reach maximum fruit load. Walters and Taylor (2006) reported that pumpkin yields were increased when more bee hives were used. No work has been conducted in triploid watermelons to determine what number of honey bee hives or bees are necessary to maximize fruit yields and quality.

The need of a viable pollen source was obvious as fruit set and yield was very limited in the treatment that lacked a pollenizer cultivar. Theoretically, no fruit should have been set in the plots that contained no pollenizer. However, fruit yield was 20% at most compared with all other treatments which contained a pollenizer, and less than 10% in the initial or early harvests. This observation indicated that there was some movement of pollen between plots but the primary effect on yield and fruit quality could be attributed to differences in pollenizer treatment, especially the initial or early harvests. Many of the reduced number of fruits that were set in the no pollenizer treatment were of inferior quality with approximately one half of the fruit having severe hollow heart rendering the fruit nonmarketable. Fiacchino and Walters (2003) have reported that hollow heart can be more prevalent when certain cultivars are used as pollenizers. It would appear that the limited amount of pollen in the no pollenizer plots may have contributed to more occurrences of severe hollow heart in triploid watermelon.

The use of a single pollenizer cultivar is a highly effective pollenizer strategy for producing triploid fruit. Certain cultivars were better than others. Use of the hybrids ‘Companion’ and ‘SP1’, and the open pollinated cultivar ‘Mickylee’ consistently produced better total and marketable weight than ‘SF800’. The open pollinated cultivar ‘Mickylee’, which has been on the market for a long time (Maynard, 2003), is an effective pollenizer and its use has resulted in triploid yields similar to triploid yields obtained with the newer hybrid cultivars. The newer hybrid cultivars have been intentionally developed strictly as pollen sources for triploid fruit production and not for production and sales of the seed fruit

The use of a combination of pollenizers provided minimal benefit when compared to the use of a single pollenizer (i.e. ‘Companion’, ‘SP1’, ‘Mickylee’). However, in some cases the earlier triploid yields can be slightly increased if ‘Companion’is planted with another pollenizer. Contrarily, the later harvests of triploid fruit can be increased if another pollenizer that flowers later is planted with ‘Companion’. An early triploid fruit harvest likely occurs when using ‘Companion’ as the pollenizer since it has higher counts of staminate flowers earlier in the season than other commercially sold pollenizers (Dittmar et al., 2006). ‘SP1’ provided minimal improvement or increase in yields when combined with the other pollenizers. Shortly after staminate flowers were produced with ‘Companion’, ‘SP1’ consistently produced a higher number of staminate flowers over a longer time period compared with the other cultivars that were tested (Dittmar et al., 2006). Thus, ‘SP1’ is likely providing ample amounts of the pollen during most of the production season. When lower yielding pollenizers are used, it would be beneficial to use a combination of pollenizers. In this study, triploid yields were generally increased when ‘SF800’ was combined with ‘Companion’ or ‘SP1’. The lower triploid yields obtained when ‘SF800’ was used alone were increased with ‘Companion’ or ‘SP1’ since they produced better yields as the sole pollenizer than did ‘SF800’ when used by itself. Rather than combining pollenizers; however, it would probably be more prudent to choose pollenizers that result in best overall triploid yields.

The effect of planting the ‘SF800’ pollenizer in a hill that could be dedicated to a triploid fruit than if inter-planted resulted in the former having nearly one third less fruit being produced in the 2005 study. This likely occurred because ther wer one-third less plants for triploid fruit production with the hill planting arrangement as discussed by NeSmith and Duval (2002). In the 2006 study, yields were equivalent with these same treatments. The reason that no yield gain was realized with the inter-planted ‘SF800’ versus the hill planted ‘SF800’ treatment in 2006 as in 2005 was not understood.

Generally, a linear relationship exists between reducing the space between cultivars and yield of fruit (Bracy and Parish 1994; Brinen et al.; Gilreath et al.; Motsenbocker and Arancibia, 2002; NeSmith, 1993). Reducing the in-row spacing decreases the the size of the watermelon fruit (Duthie et. al., 1999a, 199b; Motsenbocker and Arancibia, 2003; NeSmith, 1993). In our studies, triploid fruit size was not affected by the closer inter-planting spacing versus the hill planting.

The purpose of planting the 'SP1' plants 3 weeks after the triploid plants was to decrease the incidence of hollow heart present in the triploid fruit, especially since hollow heart is more prone to occur in the crown set (Maynard and Hopkins, 1999). However, we found the opposite to be true as hollow heart was more extensive in the late planting of 'SP1'. We also found the earlier yields to be less. Apparently, planting the 'SP1' plants three weeks after transplanting the triploid plants was too late as triploid vine growth was extensive when 'SP1' was transplanted. The establishment of pollenizer transplants from 'SP1' and other pollenizer cultivars should be evaluated nearer to the time when the triploid plants are transplanted (i.e. 1 or 2 weeks after planting) when the triploid plants have less vegetation and growth.

In addition to yields, watermelon fruit quality is an important consideration, especially hollow heart. Severe hollow heart caused as many as 67% of the fruit to be nonmarketable in the no pollenizer control treatment to a little as 2% of the fruit being nonmarketable in the 'SF800' pollenizer treatment. When pollenizer plants were transplanted the same time as the triploid plants, the percentage of nonmarketable fruit caused by hollow heart ranged from 2 to 22% among treatments. Although these percentages are considerably less than the no pollenizer treatment, there are still substantial differences in the amount of hollow heart as a result of which pollenizer is used. Subsequent research should focus more on the effects that the pollenizer has on hollow heart. Most of the fruit were cut during the first harvest in our research studies when mostly crown fruit has been set and are prone to have higher amounts of hollow heart (Maynard and Hopkins, 1999) are harvested.

Summary

The use of dedicated pollenizers ‘Companion’ and ‘SP1’ resulted in better triploid yields than the diploid ‘SF800’. Similar triploid yields were obtained with ‘Companion’, ‘SP1’, and ‘Mickylee’ pollenizer. Unlike ‘Companion’ and ‘SP1’, ‘Mickylee’ and ‘SF800’ both have the advantage of producing marketable seeded fruits that provide additional revenues, if they can be marketed. If a pollenizer which results in high yields of triploid fruits is selected, then combining two different pollenizers does not increase yields of triploid fruit and complicates planting due to the additional care that needs to be taken to ensure that the two pollenizers are planted properly. The use of inter-planting a pollenizer improved yields with hill planting when fruit set was more concentrated. The average size of triploid fruit was minimally affected due to inter-planting the pollenizer plants between the triploid plants. Transplanting the pollenizer 3 weeks after the triploid plants were transplanted is not advantageous.

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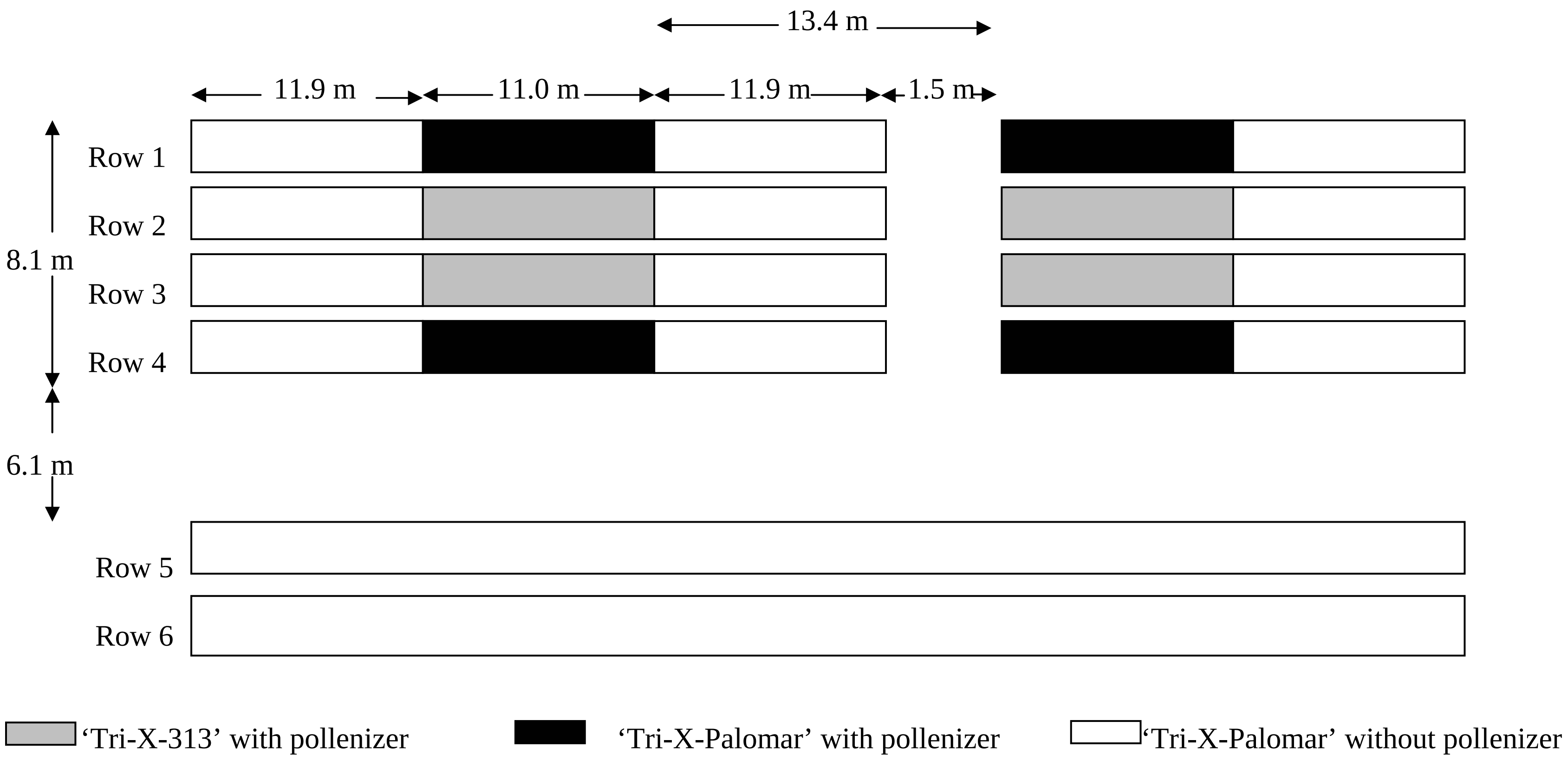

Figure 1. Experimental design of treatment area and borders of two plots. A plot consisted of four rows. The beginning of each row had a border of 'Tri-X-Palomar' plants planted without pollenizer plants. After the border, outer rows were planted with 'Tri-X-Palomar' plants and the designated treatment pollenizer plants and the center two rows were planted with 'Tri-X-313' plants and the

(*Figure 1,* continued)

designated treatment pollenizer plants. Following the treatment area was a second border of ‘Tri-X-Palomar’ plants without pollenizer plants and an unplanted break. The treatment area, second border, and break were repeated the length of the field.

Table 1. Effect of different diploid watermelon pollenizer treatments on total and marketable fruit weights of ‘Tri-X-313’.[z]

	Total fruit weight (MT/ha)[y]				Market fruit weight (MT/ha)[x]			
Treatment	2005		2006		2005		2006	
1. Companion	91.4	a[w]	89.1	bc	89.8	a	88.4	ab
2. Mickylee	86.2	a	100.5	abc	85.2	ab	95.5	ab
3. SP1	89.0	a	97.4	abc	87.5	ab	93.2	ab
4. SF800 (inter-planted)	74.4	b	75.9	c	71.9	c	72.9	b
5. Companion & SP1	87.3	a	115.7	a	86.4	ab	110.9	a
6. Companion & SF800	82.1	ab	110.2	ab	81.5	b	105.2	ab
7. SF800 & SP1	83.0	ab	97.8	abc	81.6	b	94.2	ab
8. SP1 (late planting)	52.5	c	105.6	ab	48.4	d	101.8	a
9. SF800 (hill planted)	57.2	c	75.7	c	45.5	d	72.8	b
10. Control	11.8	d	14.9	d	9.7	e	14.9	c
LSD (0.05)	8.7		26.5		8.2		26.0	

(Table 1, continued)

Contrasts				
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	***	***	***	***
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS	**	NS	*
Mickylee (2) vs. combined (5, 6, 7)	NS	NS	NS	NS
Companion alone (1) vs. Companion combined (5, 6)	NS	*	NS	NS
SP1 alone (3) vs. SP1 combined (5, 7)	NS	NS	NS	NS
SF800 alone (4) vs. SF800 combined (6, 7)	*	*	**	*
SF800; Inter-planted (4) vs. hill planted (9)	***	NS	***	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	***	NS	***	NS

[z] Interior fruit quality such as hollow heart was not considered with regards to marketable yields

[y] Cumulative weight of all fruit harvested.

[x] Cumulative weight of fruit >3.6 kg.

[w] Any two means within a column followed by the different letters are significantly different.

[NS, *,**, ***] Nonsignificant or significant at the 5%, 1%, and 0.01%, respectively.

Table 2. Effect of different diploid watermelon pollenizer treatments on the weight class distribution of the total fruit weight of 'Tri-X-313'.

	Total weight (MT/ha)									
	Small[z]		Medium[y]				Large[x]			
Treatment	2005	2006	2005		2006		2005		2006	
1. Companion	1.6	0.4	31.1	cd[w]	30.3	c	58.7	a	58.2	a
2. Mickylee	1.0	5.0	44.7	ab	55.8	a	40.4	b	39.7	abc
3. SP1	1.6	3.9	47.5	a	50.4	ab	40.0	b	42.8	abc
4. SF800 (inter-planted)	2.5	3.1	37.4	abcd	42.4	abc	34.5	b	30.5	cd
5. Companion & SP1	0.9	4.0	45.4	ab	49.7	ab	41.1	b	61.2	a
6. Companion & SF800	1.3	5.0	41.1	abc	48.0	ab	40.4	b	57.2	ab
7. SF800 & SP1	1.2	3.1	43.6	ab	47.4	ab	37.9	b	46.8	abc
8. SP1 (late planting)	4.1	3.5	27.5	d	48.6	ab	20.8	c	53.3	ab
9. SF800 (hill planted)	0.7	2.3	35.3	bcd	37.8	bc	21.2	c	35.1	bc

(*Table 2,* continued)

10. Control	2.2	0	4.4 e	5.6 d	5.2 d	9.2 d
LSD (0.05)	NS	NS	11.0	14.0	10.0	22.3
Contrasts						
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	NS	*	***	***	***	***
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS	NS	NS	NS	NS	NS
Mickylee (2) vs. combined (5, 6, 7)	NS	NS	NS	NS	NS	NS
Companion alone (1) vs. Companion combined (5, 6)	NS	*	*	**	***	NS
SP1 alone (3) vs. SP1 combined (5, 7)	NS	NS	NS	NS	NS	NS
SF800 alone (4) vs. SF800 combined (6, 7)	NS	NS	NS	NS	NS	*
SF800; Inter-planted (4) vs. hill planted (9)	NS	NS	NS	*	***	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	*	NS	***	NS	***	NS

[z] Cumulative weight of fruit <3.6kg.

[y] Cumulative weight of fruit between 3.6 and 7.3 kg.

[x] Cumulative weight of fruit >7.3 kg.

(*Table 2,* continued)

[w]Any two means within a column followed by the different letters are significantly different.

[NS, *,**, ***]Nonsignificant or significant at the 5%, 1%, and 0.01%, respectively.

Table 3. Effect of different diploid watermelon pollenizer treatments on average ‘Tri-X-313’ fruit weight.

	Individual fruit weight (kg)			
Treatment	2005		2006	
1. Companion	7.5	a[z]	7.7	a
2. Mickylee	6.7	b	6.1	b
3. SP1	6.6	bc	6.4	b
4. SF800 (inter-planted)	6.5	bc	6.3	b
5. Companion & SP1	6.9	b	6.9	ab
6. Companion & SF800	7.0	b	7.0	ab
7. SF800 & SP1	6.7	b	6.4	b
8. SP1 (late planting)	6.2	bc	7.0	ab
9. SF800 (hill planted)	6.7	b	6.5	ab
10. Control	5.3	d	6.7	ab
LSD (0.05)	0.8		1.3	

(*Table 3,* continued)

Contrasts		
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	***	NS
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS	NS
Mickylee (2) vs. combined (5, 6, 7)	NS	*
Companion alone (1) vs. Companion combined (5, 6)	**	NS
SP1 alone (3) vs. SP1 combined (5, 7)	NS	NS
SF800 alone (4) vs. SF800 combined (6, 7)	NS	NS
SF800; Inter-planted (4) vs. hill planted (9)	NS	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	NS	NS

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[z] Any two means within a column followed by different letters are significantly different.

[NS, *,**, ***] Nonsignificant or significant at the 5%, 1%, and 0.01%, respectively.

Table 4. Effect of different diploid watermelon pollenizer treatments on the distribution of marketable fruit weight of 'Tri-X-313' by harvest.

	Weight of marketable fruit[z] (MT/ha)									
	First				Second			Third		Fourth
Treatment	2005		2006		2005	2006		2006		2006
1. Companion	80.7	a[y]	23.2	a	9.1	39.9	a	18.8	bc	6.6
2. Mickylee	68.1	bc	23.0	a	17.1	26.1	bc	24.7	b	22.7
3. SP1	69.3	bc	15.9	ab	18.2	26.3	bc	32.5	ab	18.5
4. SF800 (inter-planted)	56.8	d	11.9	abc	15.1	25.2	bc	22.8	b	12.9
5. Companion & SP1	71.7	ab	23.0	a	14.8	40.1	a	24.9	b	22.9
6. Companion & SF800	62.1	cd	11.8	abc	19.4	35.2	ab	26.8	b	31.4
7. SF800 & SP1	57.1	d	11.6	abc	24.5	31.4	ab	27.7	b	23.5
8. SP1 (late planting)	37.6	e	7.1	bc	10.7	17.0	c	47.3	a	30.4
9. SF800 (hill planted)	36.6	e	8.9	bc	19.9	25.9	bc	21.9	b	16.2

(*Table 4*, continued)

10. Control	3.2 f	0.7 c	6.6	0.4 d	6.2 c	7.6
LSD (0.05)	9.2	12.0	NS	11.5	15.6	NS
Contrasts						
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	***	**	*	***	*	NS
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS	NS	NS	NS	NS	*
Mickylee (2) vs. combined (5, 6, 7)	NS	NS	NS	*	NS	NS
Companion alone (1) vs. Companion combined (5, 6)	**	NS	NS	NS	NS	*
SP1 alone (3) vs. SP1 combined (5, 7)	NS	NS	NS	NS	NS	NS
SF800 (4) vs. SF800 combined (6, 7)	NS	NS	NS	NS	NS	NS
SF800; Inter-planted (4) vs. hill planted (9)	***	*	NS	NS	NS	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	***	NS	NS	NS	NS	NS

[z] Cumulative number of fruit between 3.6 and 7.3 kg.

[y] Any two means within a column followed by different letters are significantly different, NS is no significant differences.

[NS, *,**, ***] Nonsignificant or significant at the 5%, 1%, and 0.01%, respectively.

Table 5. Effect of different diploid watermelon pollenizer treatments on percent of marketable fruit size with marketable amounts of hollow heart.

	Marketable hollow heart (%)			
Treatment	2005		2006	
1. Companion	75.6	bc[z]	82.2	a
2. Mickylee	93.3	ab	93.3	a
3. SP1	86.7	abc	77.8	a
4. SF800 (inter-planted)	97.8	a	82.2	a
5. Companion & SP1	97.8	a	86.7	a
6. Companion & SF800	91.1	ab	82.2	a
7. SF800 & SP1	86.7	abc	84.4	a
8. SP1 (late planting)	48.9	d	53.3	b
9. SF800 (hill planted)	88.9	ab	91.1	a
10. Control	67.3	cd	34.4	b

(*Table 5,* continued)

LSD (0.05)	21.4	24.3
Contrasts		
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	*	***
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS	NS
Mickylee (2) vs. combined (5, 6, 7)	NS	NS
Companion alone (1) vs. Companion combined (5, 6)	NS	NS
SP1 alone (3) vs. SP1 combined (5, 7)	NS	NS
SF800 alone (4) vs. SF800 combined (6, 7)	NS	NS
SF800; Inter-planted (4) vs. hill planted (9)	NS	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	**	NS

[z] Any two means within a column followed by different letters are significantly different.

[NS, *,**, ***] Nonsignificant or significant at the 5%, 1%, and 0.01%, respectively.

Chapter 3

Effects of POST and POST-directed Halosulfuron on Watermelon (*Citrullus lanatus)*

(In the format appropriate for submission to Weed Technology)

Effects of POST and POST-directed Halosulfuron on Watermelon (*Citrullus lanatus*)[1]

PETER J. DITTMAR, DAVID W. MONKS, JONATHAN R. SCHULTHEIS, and KATHERINE M. JENNINGS[2]

Abstract: Studies were conducted in 2006 at Clinton and Kinston, NC, to determine the influence of halosulfuron POST or POST-directed on growth and yield of Precious Petite and Tri-X-313 triploid watermelon. Treatments included a nontreated, 39 g ai/ha halosulfuron applied to 25% of the plant (distal or proximal region), 50% of the plant (distal or proximal) (Precious Petite only) and POST (complete plant coverage). Watermelon treated with halosulfuron had chlorotic leaves, shortened internodes, and increased stem splitting. Vines were longest (Tri-X-313 = 146 cm, Precious Petite = 206 cm) in the nontreated but were shortest (Tri-X-313 = 88 cm, Precious Petite = 77 cm) in the POST treatment. Halosulfuron POST to watermelon caused the greatest injury (Tri-X-313 = 64%, Precious Petite = 67%). Halosulfuron directed to 25 or 50% (distal or proximal) of the plant caused less injury than halosulfuron applied POST. Stem splitting was greatest when halosulfuron was applied to the proximal area of the stem. Internode shortening was greatest in treatments where halosulfuron was applied to the distal region of the stem. However, Tri-X-313 in the 25% distal treatment produced similar total and

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marketable fruit weight as the nontreated at Clinton. Fruit number did not differ among treatments for either cultivar. At Kinston, Precious Petite nontreated and 25% distal end treatment had greater marketable fruit weight than the 50% proximal and POST treatments. Current registration of halosulfuron POST is for application between rows or preemergence. Limiting halosulfuron to no more than 25% of the watermelon plant will likely improve crop tolerance.

Nomenclature: Halosulfuron; watermelon, *Citrullus lanatus* (Thun.) Matsum. and Nak. Tri-X-313 and Precious Petite.

Additional Index Words: sulfonylurea, nutsedge control.

Abbreviations: PRE, preemergence; POST, postemergence over-the-top; POST-directed, postemergence-directed; POST, postemergence-over-the-top.

Introduction

Triploid (seedless) watermelon [*Citrullus lanatas* (Thun.) Matsum. and Nak.] is established into commercial production fields using transplants because of low germination and high cost of triploid watermelon seed. These transplants are commonly field grown in a plasticulture production system utilizing beds with drip tubing for irrigation and fertigation, and covered with black polyethylene mulch.

Black polyethylene mulch provides excellent control of broadleaf and grass weeds with the exception of the hole in the mulch created for crop establishment. However, purple (*Cyperus rotundus* L.) and yellow nutsedge (*Cyperus esculentus* L.) are becoming among the worst weeds in watermelon (personal communication, Bill Jester) as these weeds can penetrate through mulch 127 μm in density (Henson and Little 1969). Nutsedges compete with many horticultural crops for space, sunlight, water, and nutrients required for plant growth (Johnson and Mullinix 1999; Morales-Payan et al. 1997; Santos et al. 1997). In transplanted watermelon, two yellow nutsedge plants/m^2 caused 10% decline in total yields of ‘Fiesta’ watermelon and 25 yellow nutsedge plants/m^2 lowered yields 50%. Yellow nutsedge density above 25 plants/m^2 had limited additional impact on yield above 50% reduction (Buker et al. 2003).

Halosulfuron PRE or POST controls yellow and purple nutsedge (Ackley et al. 1996, Molin et al. 1999, Vencil et al. 1995). Yellow nutsedge was controlled 78 and 85% by 0.03 and 0.95 kg ai/ha halosulfuron PRE in watermelon (Talbert and Wells 1998). Halosulfuron applied PRE at 53 g ai/ ha provided 80, 70, and 23% control of yellow nutsedge 3, 6, and 9 wk after treatment, respectively (Talbert et al. 1997). Halosulfuron applied at 39 g/ha controlled yellow nutsedge 97% 3 and 6 weeks after treatment (Brandenberger et al. 2005).

Buker et al. (1997) reported halosulfuron PRE at 0 to 100 g ai/ ha resulted in over 80% watermelon vigor and less than 30% visible crop injury. A linear ($Y=82-0.766x$) relationship resulted with halosulfuron POST rates ranging from 0 to 108 g ai/ha and watermelon yield. Thus, halosulfuron is safer when applied PRE than when applied POST. Halosulfuron PRE is registered in watermelon; however, halosulfuron is not registered POST in watermelon. In contrast, halosulfuron can be applied POST to direct seeded cantaloupe and cucumber having at least 3 to 5 true leaves or transplanted cantaloupe and cucumber after 14 d (Anonymous 2006).

Halosulfuron POST is more effective in controlling nutsedge but is more injurious to watermelon than halosulfuron PRE (Brandenberger et al. 2005; Buker et al. 1997; Talbert et al. 1997). Halosulfuron POST-directed resulted in the same amount of visual injury (6%) and total yields (13820 fruit/ha) in cantaloupe as a preplant incorporated (6%, 13,450 fruit/ha) treatment. Halosulfuron at 36 g ai/ha applied over cantaloupe resulted in greater visual injury (13%) and lower total yield (10,830 fruit/ha) (Johnson and Mullinix 2005). Thus, the objective of this research was to determine the influence of halosulfuron POST or POST-directed application treatments in the crop row on the growth and yield of triploid watermelon.

Materials and Methods

The experiment was conducted in a grower's field near Clinton, NC, and at the Cunningham Research Station in Kinston, NC. The triploid watermelon Tri-X-313[3], standard seedless type, and Precious Petite[3], a mini watermelon type, and 'Super Pollenizer 1'[3], a pollenizer type, were sown into transplant trays[4] on March 31 and April 5, 2006. Transplants were grown in the greenhouse for 2 wk and then moved to cold frames for hardening to the environment. Watermelon plants were transplanted on May 5, 2006 at Clinton and on May 1, 2006 at Kinston in bedded plasticulture consisting of black polyethylene mulch and drip tape, and fumigated with 4.7 L/ha 1,3-dicholoropropene[5] applied just prior to black polyethylene mulch being laid. Soil at Clinton was a Goldsboro sandy loam (fine-loamy, siliceous, thermic Aquic Paleudults)

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[3] Syngenta Seed Company, P.O. Box 4188, Boise, ID 83704-4188.

[4] LE1803 transplant trays, Landmark Plastic Corp., Akron, OH 44306.

[5] Telone II, DowAgriSciences, LLC, Indianapolis, IN 46268.

having 3.2% humic and pH 6.2, and soil at Kinston was a Norfolk sandy loam (fine loamy, siliceous, thermic, typic Kandiudults) having 2% humic matter and pH 5.9.

Bed centers at Clinton were 3.0 m apart and row width was 1.5 m wide, while at Kinston bed centers were 2.0 m apart and row width was 0.9 m wide. Tri-X-313 was planted to a 0.9 m in-row spacing and Precious Petite was planted to a 0.3 m in-row spacing. Plant stands were determined 7 and 14 d after transplanting, and missing or weak plants were replaced with transplants of the same age. The design of the studies was a randomized complete block design with four replications.

Halosulfuron was applied to watermelon having 46 to 61 cm long vines on May 24 (Kinston) and 27 (Clinton). Treatments for both cultivars included halosulfuron at 39 g ai/ha applied with 0.25% (v/v) nonionic surfactant[6,7] POST (over-the-top), or to 25% of the proximal (crown) region of the plant, or 25% of the distal (tip) region of the plant, and a nontreated (Figure 1). Two additional treatments were included with Precious Petite and consisted of halosulfuron applied to 50% of the plant (proximal or distal). The 50% treatments were not applied to 'Tri-X-313' because preliminary research conducted with this cultivar in 2004 resulted in no differences between the 25% and 50%

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[6] Induce, a mixture of alkyl aryl polyoxylkane ethers, free fatty acids, and dimohtyl polysiloxane. Helena Chemical Company, 225 Schilling Boulevard, Suite 300, Collierville, TN 38017.

[7] Alkyl and alkylaryl polyoxyethylene glycol; Royster Clark, Inc., 999 Waterside Dr., Suite 800, Norfolk, VA 23510.

treatments. Treatments were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 187 L/ha using an 8003EVS tip[8] at 152 kPa at the pace 4.8 km/h.

Crop injury was estimated visually (0% = no damage, 100% = complete plant death) and longest vine length of 4 randomly selected plants were determined 7 d after spraying. Additional data collected included length of stem splitting on the longest vine and the number of nodes on 30 cm of the stem (distal end) of Tri-X-313 or 20 cm of the stem (distal end) of Precious Petite. Precious Petite was harvested July 5 and 12 and Tri-X-313 on July 18, 25, and 31 at Clinton. At Kinston, Precious Petite was harvested on July 7 and 14 and Tri-X-313 on July 14, 20, and 27, and August 10. All data were analyzed using analysis of variance and means were separated with LSD (*P=0.1*) (SAS Institute, 2002).

Results and Discussion

‘Tri-X-313’

Growth. Herbicide damage occurred on watermelon treated with halosulfuron and included chlorosis, increased stem splitting and shortening of developing internodes (Figure 2). Plants in the nontreated had no herbicide damage (0%) and vine length of 146 cm (Table 1). Watermelon was injured the least (16%) when halosulfuron was applied to 25% distal. In contrast, plants in the 25% proximal treatment were injured 36%. Visual injury increased to 64% when halosulfuron was applied POST and resulted in the lowest

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[8] Spraying Systems Co., P.O. Box 7900, Wheaton, IL 61089-7900.

vine length, 88 cm. Vine length for both (distal and proximal) 25% treatments was similar.

Limited stem splitting (3 cm) occurred in the nontreated and was likely from wind and handling at or soon after transplanting. Stem splitting was similar for plants in the 25% distal treatment and the nontreated (Table 1). However, splitting in the 25% distal treatment was observed to be 20 cm from the crown of plants where spray solution made contact with the stem, while splitting in the nontreated appeared randomly along the stem (data not shown). The greatest stem splitting occurred when halosulfuron was applied to 25% of the proximal (45 cm) or POST (54 cm) (Table 1). Compacting the internodes increased the number of nodes that were at the tips of watermelon vines. Plants in the nontreated had the least number of nodes at the watermelon vine tips, where as, plants in the distal treatments resulted in the most nodes. Watermelon in the 25% proximal, 25% distal, and POST treatments had 5, 7, and 9 nodes, respectively.

Yield. Fruit were divided into the three weight classes: small (< 3.6 kg), medium (between 3.6 and 7.3 kg), and large (>7.3 kg). Total weight was the combination of all three weight classes and marketable yield included medium and large watermelon fruit.

No differences were observed in total fruit weight. However, the greatest marketable yield was in the nontreated (123,650 kg/ha) and 25% distal treatment (119,350 kg/ha). The lowest yields were in the halosulfuron POST treatment (104,550 kg/ha). The individual weight was greatest (7.0 kg) in the 25% distal treatment. The lowest individual fruit weight (6.3 kg) occurred in the POST treatment.

‘Precious Petite’

Growth. The 25% and 50% distal treatments caused 10 and 19% injury, respectively. The 25% and 50% proximal treatment resulted in visual injury ratings of 39 and 40%, respectively (Table 2). Plants in the POST treatment had halosulfuron applied to both the distal and the proximal regions and had the highest rating (67%). The longest vines (206 cm) were observed in the nontreated. Vine length in the 25% distal treatment (136 cm) was similar to those in the nontreated. However, plants in the 25% and 50% proximal treatments had similar vine length (110 and 98 cm, respectively) as plants in the other halosulfuron treatments. The shortest vines (77 cm) were in the POST halosulfuron treatment.

Symptoms (leaf chlorosis, stem splitting, and shortened internodes) caused by halosulfuron in ‘Precious Petite’ were similar as those for ‘Tri-X-313’ (Table 2). The most stem splitting occurred in treatments in which the proximal region of the plant was sprayed with halosulfuron. Plants in the 25% proximal, 50% proximal, and over-the-top treatments had stem splits that totaled 43, 47, and 51 cm, respectively. Preventing halosulfuron from contacting the proximal region of the plant prevented severe splitting. Plants in the nontreated had the least (6 cm) stem splitting, which was similar to the amount of splitting in the 25% distal treatment (8 cm). The severity of stem splitting in the 50% distal treatment was similar to the severity in the 25% proximal treatment. The halosulfuron POST (8.3 nodes) and 50% distal (7.8 nodes) treatments had the most nodes near the vine tip. The 25% distal treatment had the same number as the 25 and 50% proximal treatments. The fewest number of nodes occurred in the nontreated (3 nodes) which was similar to the 25% and 50% proximal, and 25% distal treatments.

Yield. No differences were observed in total yield. Differences were found in marketable fruit weight. Over all the halosulfuron treatments marketable yields were highest in the 25% distal (41,260 kg/ha), which was similar to those yields in the nontreated treatment (36,460 kg/ha). The 50% distal treatment had the same effect on marketable yields (34,380 versus 33,450 kg/ha, respectively) as applying halosulfuron to 25% of the proximal end. The largest (1.47 kg) individual fruit size was in the 25% distal treatment. Where as, the smallest individual fruit weight (1.22 kg) resulted from halosulfuron POST.

Halosulfuron can be used for weed control in seedless watermelon production and is registered for application between crop rows. POST application of halosulfuron in the watermelon row is not currently registered. Johnson and Mullinix (2005) discussed halosulfuron applied POST-directed to cantaloupe had less effect on crop injury and yield than halosulfuron POST. However, the visual injury and yield loss were the same for halosulfuron POST-directed and PPI. Halosulfuron PRE to watermelon resulted in <30% phytotoxicity and 36 g ai / ha halosulfuron did not affect yield compared to the nontreated (Buker et al. 1997). Based on this research, halosulfuron POST-directed to 25% distal ends of the plants may result in minimal injury (16% or less), and yield loss is minimal (3% or less) in Tri-X-313 and Precious Petite.

Plant stunting and leaf chlorosis were previously reported for watermelon (Buker et al. 1997), cucumber (Trader 2002), squash (Starke et al. 2006, Webster et al. 2003, Webster and Culpepper 2005), honeydew (Brandenberger et al. 2005), and pumpkin (Trader 2002). Stem splitting resulting from halosulfuron has not been reported on other Cucurbit crops.

Yield reduction from yellow nutsedge at 25 plants/m^2 is high (Buker et al. 2003) relative to injury from most halosulfuron treatments in our study. The halosulfuron POST treatment in our study resulted in 14 and 15% total yield loss relative to the nontreated in Tri-X-313 and Precious Petite, respectively. Thus halosulfuron POST caused only slightly more (15 to 16 versus 10%) crop yield loss than yellow nutsedge at 2 plants/m^2. Thus, if registered growers should compare the potential loss of yield from nutsedge with the possible injury from halosulfuron POST or POST-directed, as well as, the long term benefit of applying halosulfuron in watermelon and achieving control of nutsedge in subsequent crops. It also appears that in fields where yellow or purple nutsedge occurs in patches that growers could apply halosulfuron POST-directed contacting only the distal regions of the watermelon plant in the nutsedge patches without significant injury to the crop. This practice would minimize the population of nutsedge in future cropping systems.

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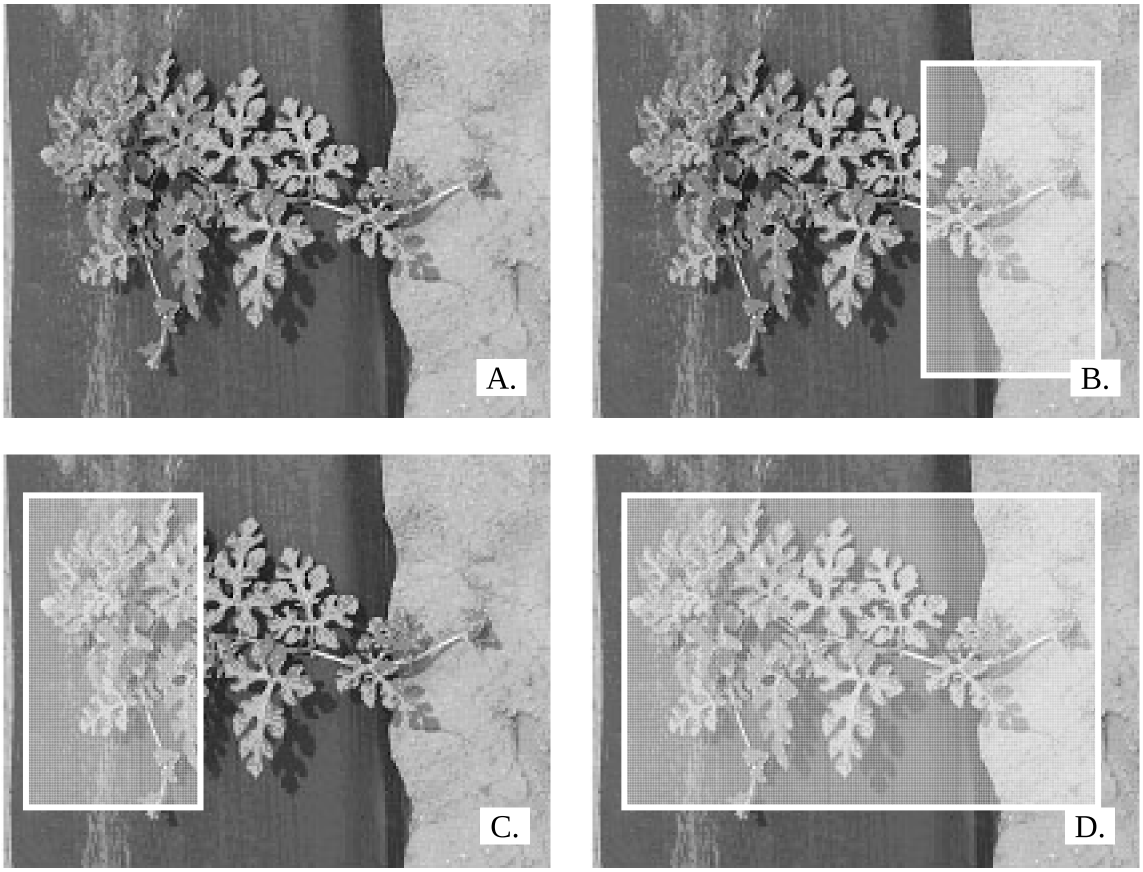

Figure 1. Halosulfuron treatments [(A. nontreated; B. 25% distal; C. 25% proximal; D. POST (over-the-top)] applied to triploid watermelon. Shaded boxes refer to area of watermelon where spray solution was applied.

Table 1. Effect of halosulfuron POST and POST-directed on the visual injury, length of stem splitting, vine length, and number of nodes at vine's tip end of Tri-X-313 watermelon 7 DAT, and total, marketable, and average individual fruit weight.[a]

					Yield		
Treatment[b]	Visual injury[c]	Vine length[d]	Length of splitting[e]	Number of nodes at tip[f]	Total weight[g]	Marketable weight[h]	Average weight
	%	cm			kg/ha		kg
Nontreated	0	146	3	3	126,650	123,580	6.7
25% distal	16	114	10	7	122,660	119,350	7.0
25% proximal	36	112	45	5	109,090	105,540	6.5
POST	64	88	54	9	109,140	104,550	6.3
LSD (0.10)	1	12	24	2	NS	18,350	0.4

[a] Data combined across sites (Clinton and Kinston, NC).

[b] Halosulfuron applied at 39 g ai/ha in all treatments except in the nontreated.

[c] Visual plant injury on a scale of 0 to 100% (0 = no injury, 100 = crop death).

[d] Length of vine is the average length of the longest vine from 4 randomly chosen plants.

(*Table 1*, continued)

[e] Length of splitting is the amount of splitting that was on the longest vine averaged over 4 plants chosen randomly from each plot.

[f] Number of nodes within 30 cm of the tip of the longest vine averaged over 4 plants chosen randomly from each plot.

[g] Total weight includes all fruit.

[h] Marketable weight is the cumulative weight of medium (between 3.6 and 7.3 kg) and large (>7.3 kg) watermelon fruit.

ai/ha.

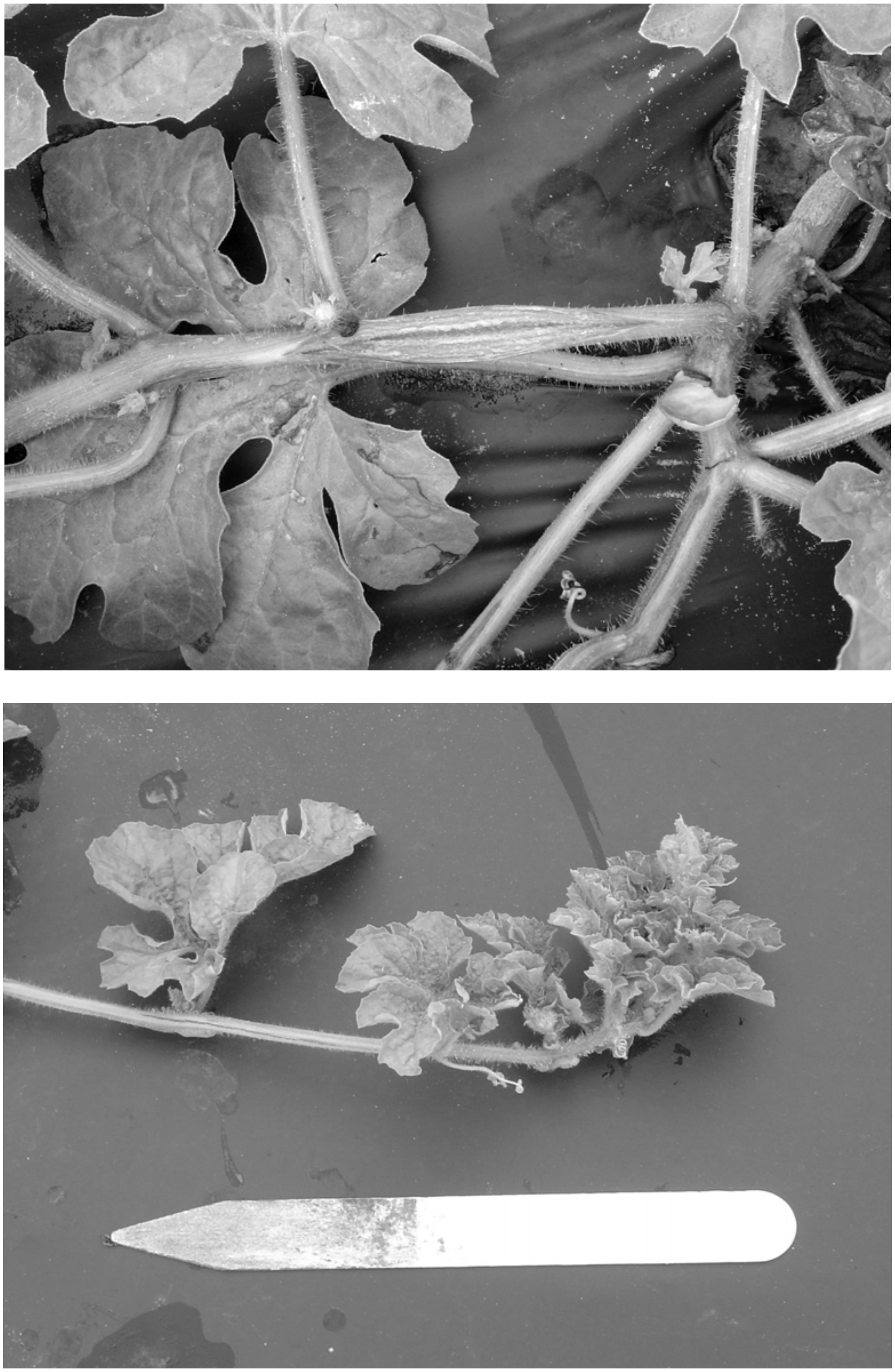

Figure 2. Stem splitting and internode shortening caused by halosulfuron at the rate 39 g ai/ha.

Table 2. Effect of halosulfuron POST treatments on visual injury, vine length, length of stem splitting, and number of nodes at vine's tip end of Precious Petite watermelon 7 DAT, and total, marketable, and average individual fruit weight.[a]

					Yield		
Treatment[b]	Visual injury[c]	Vine length[d]	Length of splitting[e]	Number of nodes at tip[f]	Total weight[g]	Marketable weight[h]	Average weight
	%	cm			kg/ha		kg
Nontreated	0	206	6	3.0	62,530	36,460	1.41
25% distal	10	136	8	4.8	62,490	41,260	1.47
50% distal	19	133	25	7.8	62,010	34,380	1.37
25% proximal	39	110	43	3.9	59,170	33,450	1.35
50% proximal	40	98	47	4.2	55,820	29,530	1.31
POST	67	77	51	8.3	53,260	24,150	1.22
LSD (0.10)	8	71	19	3.2	NS	6330	0.08

[a] Data combined across sites (Clinton and Kinston, NC).

[b] Halosulfuron was applied at 39 g ai/ha in all treatments except in the nontreated.

(*Table 2,* continued)

[c] Visual plant injury on a scale of 0 to 100% (0%= no injury, 100%= crop death).

[d] Length of vine is the average length of the longest vine from 4 randomly chosen plants.

[e] Length of splitting is the amount of stem splitting that was on the longest vine averaged over 4 plants chosen randomly from each plot.

[f] Number of nodes within 30 cm of the tip of the longest vine averaged over 4 plants chosen randomly from each plot.

[g] Total weight includes all fruit.

[h] Marketable weight is the cumulative weight of medium (between 1.4 and 3.2 kg) watermelon fruit.

Appendix A

Additional tables and figures for Chapter 1

Table 1. Evaluation of length, width, rind width, and individual fruit weight of different diploid pollenizer and triploid cultigens.

	Fruit length		Fruit width		L:D ratio[z]	
Treatment	2005	2006	2005	2006	2005	2006
	cm		mm			
Dwarf vine pollenizer cultigens						
Companion	23.3 cdef[y]	22.2 bc	18.7 cde	18.3 abcde	1.2 bc	1.2 bc
Sidekick	14.2 i	12.3 f	13.3 g	11.9 g	1.1 de	1.0 h
TP91	24.9 c	16.4 e	22.9 ab	15.0 efg	1.1 cde	1.1 efgh
TPS92	24.1 cde	19.6 bcde	23.4 ab	18.0 abcde	1.0 e	1.1 fgh
WC5108-1216	20.5 fg	20.4 bcd	21.0 bc	17.3 bcdef	1.0 e	1.2 bcd
Standard vine pollenizer cultigens						
Ace	---[x]	15.7 ef	---	13.9 fg	---	1.1 cde
High Set 11	20.1 g	19.8 bcde	16.6 ef	16.4 cdef	1.2 cd	1.2 b
Jenny	20.7 fg	18.6 cde	18.2 de	16.0 def	1.1 cde	1.1 cdef
Mickylee	24.5 cd	23.4 b	22.8 ab	21.3 a	1.1 de	1.1 defg

(*Table 1,* continued)

Mini Pool	21.6 defg	21.4 bcd	19.1 cde	19.9 abc	1.1 cde	1.1 gh
Nun6017	---	19.9 bcde	---	18.1 abcde	---	1.1 defg
Pinnacle	23.8 cde	21.6 bcd	17.3 def	17.6 abcdef	1.4 b	1.2 b
SF800	42.2 a	33.1 a	24.4 a	20.2 ab	1.7 a	1.6 a
SP1	16.6 hi	17.5 de	14.7 fg	15.4 efg	1.1 cde	1.1 defg
WH6818	21.2 efg	18.1 cde	19.3 cd	16.2 cdef	1.1 cde	1.1 defg
Triploid cultigens						
Petite Perfection	19.1 gh	18.9 cde	17.8 de	17.3 bcdef	1.1 de	1.1 efgh
Tri-X-313	28.2 b	23.5 b	23.6 a	19.7 abcd	1.2 bcd	1.2 bc
LSD	3.0	4.3	2.6	3.8	0.2	0.1

[z] Length: diameter ratio.

[y] Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

[x] Cultigen not evaluated in 2005.

Table 2. Evaluation of the interior characteristics of rind thickness, soluble solids, and flesh color of different cultigens.

	Rind thickness		Soluble solids		Color	
Treatment	2005	2006	2005	2006	2005	2006
	mm		°Brix			
Dwarf vine pollenizer cultigens						
Companion	11.5 bcde[z]	10.6 c	11.7 a	10.4 abcde	7.6 b	3.6 abc
Sidekick	5.6 ef	4.9 ef	9.5 abc	9.0 ef	4.4 c	1.2 e
TP91	20.2 a	13.0 b	6.9 cde	9.4 def	6.5 ab	3.2 cd
TPS92	16.0 abc	12.4 bc	6.0 de	11.0 abcd	5.8 bc	2.7 d
WC5108-1216	17.2 ab	12.9 b	10.1 ab	9.9 abcdef	7.6 a	3.4 abc
Standard vine pollenizer cultigens						
Ace	---[y]	4.7 f	---	8.9 ef	---	3.7 abc
High Set 11	8.3 def	8.6 d	7.5 bcde	8.3 f	white/pink/ yellow	white/pink/ yellow

(*Table 2*, continued)

Jenny	8.0 ef	7.4 d	9.4 abc	10.1 abcde	7.9 a	3.9 a
Mickylee	15.2 abcd	12.8 b	8.2 abc	10.8 abcd	7.9 ab	3.2 bcd
Mini Pool	8.3 edf	12.3 bc	9.2 abc	11.1 abc	7.0 ab	3.4 abc
Nun6017	---	8.6 d	---	8.9 ef	---	3.8 ab
Pinnacle	9.3 cdef	8.4 d	10.3 ab	11.3 ab	7.9 a	4.0 a
SF800	17.4 ab	16.0 a	9.2 abc	11.6 a	7.9 a	3.9 a
SP1	3.4 f	6.7 de	4.7 e	4.5 g	white	white
WH6818	8.7 def	8.5 d	8.2 abc	9.5 cdef	7.6 a	4.1 a
Triploid cultigens						
Petite Perfection	8.4 def	7.9 d	10.5 ab	11.1 abc	7.9 a	3.9 ab
Tri-X-313	17.0 ab	16.5 a	8.5 abcd	11.9 abcd	7.1 ab	3.2 cd
LSD	7.1	1.9	3.0	1.6	1.4	0.7

[z] Means within the column followed by the same letter are not significantly different at the 0.05 level using LSD.

[y] Cultigens not evaluated in 2005.

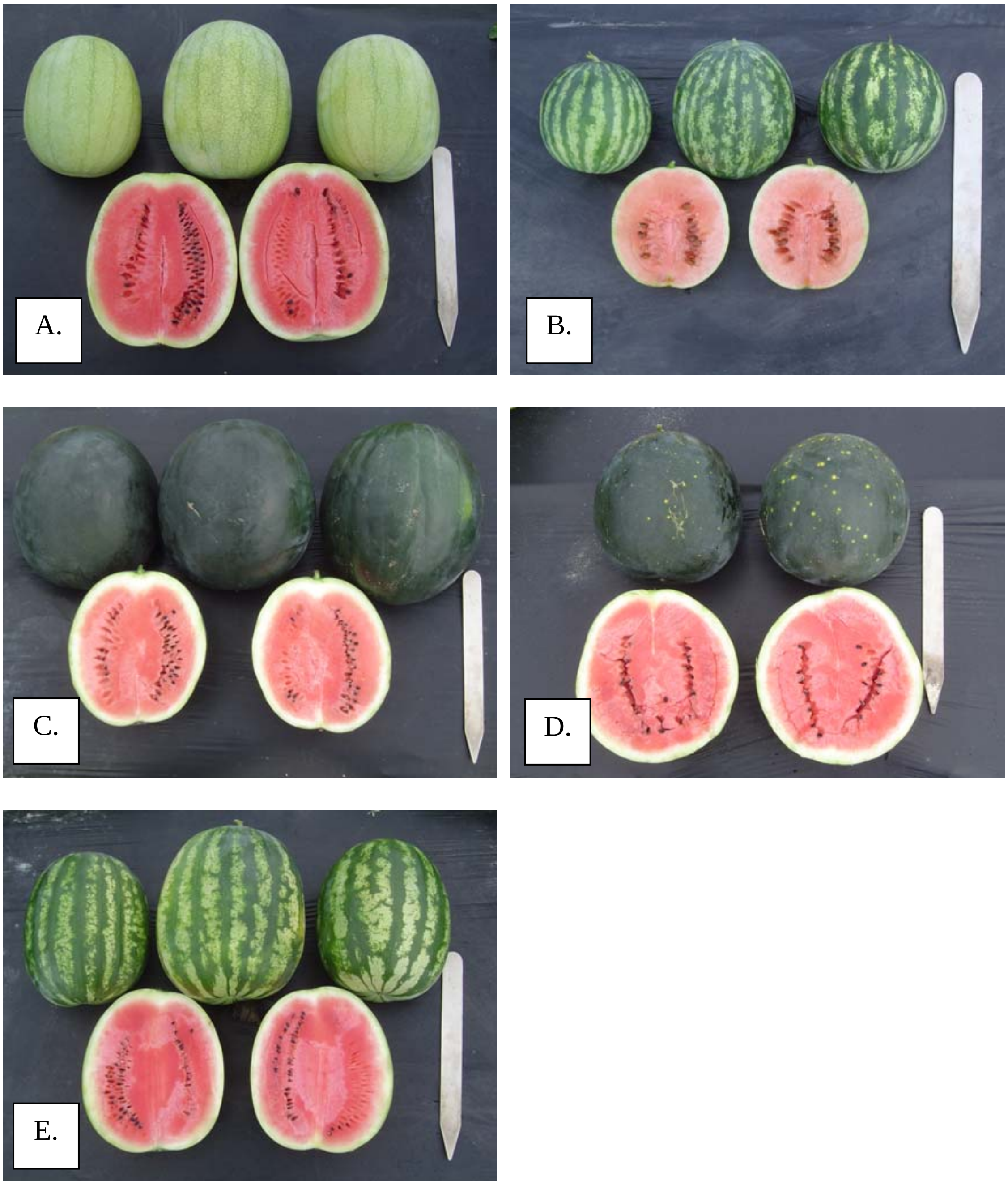

Figure 1. Fruit characteristics of the dwarf vine type pollenizer cultigens. A. ‘Companion’; B. ‘Sidekick’; C. ‘TP91’; D. ‘TPS92’; E. ‘WC5108-1216’.

Figure 2. Fruit characteristics of the standard vine type pollenizer cultigens. A. Ace; B. High Set 11; C. Jenny; D. Mickylee; E. Mini Pool; F. Nun6017; G. Pinnacle; H. SF800; I. ‘SP1’; J. ‘WH6818’.

(*Figure 2*, continued)

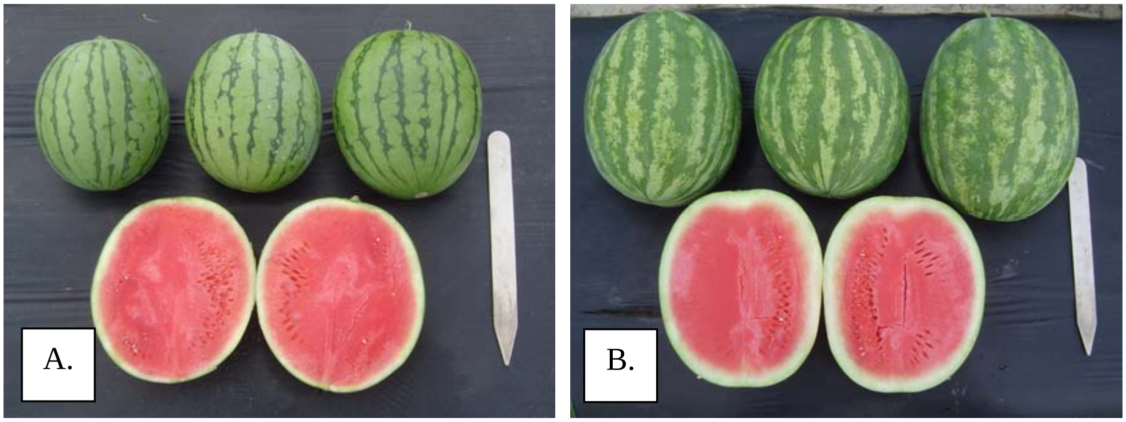

Figure 3. Fruit characteristics of the triploid watermelon cultigens. A. ‘Petite Perfection’; B. ‘Tri-X-313’.

Appendix B

Additional tables for Chapter 2

Table 1. Total and market number of ‘Tri-X-313’ fruit with different diploid watermelon pollenizer treatments.

Treatment	Number of total fruit (fruit/ha)[z]		Number of marketable fruit (fruit/ha)[y]	
	2005	2006	2005	2006
Companion	12422 ab[x]	11674 c	11824 abc	11524 bc
Mickylee	12946 ab	16688 a	12572 ab	14892 a
SP1	13696 a	15491 abc	13171 a	14144 ab
SF800 (inter-planted)	11524 b	12198 bc	10626 c	11150 bc
Companion & SP1	12797 ab	16912 a	12497 ab	15341 a
Companion & SF800	12048 b	15940 ab	11599 bc	14293 ab
SF800 & SP1	12497 ab	15416 abc	12048 ab	14144 ab
SP1 (late planting)	8606 c	15191 abc	7184 d	13844 abc
SF800 (hill planted)	8606 c	11674 c	8381 d	10776 c
Control	2245 d	2245 d	1496 e	2095 d
LSD (0.05)	1619	3855	1363	3347

(*Table 1*, continued)

Contrasts				
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	***	***	***	***
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS	*	NS	*
Mickylee (2) vs. combined (5, 6, 7)	NS	NS	NS	NS
Companion alone (1) vs. Companion combined (5, 6)	NS	**	NS	*
SP1 alone (3) vs. SP1 combined (5, 7)	NS	NS	NS	NS
SF800 (4) vs. SF800 combined (6, 7)	NS	*	NS	*
SF800; Inter-planted (4) vs. hill planted (9)	**	NS	**	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	***	NS	***	NS

[z] Cumulative number of fruit from all harvests.

[y] Cumulative number of fruit >7.3 kg.

[x] Any two means within a column followed by different letters are significantly different

[NS, *,**, ***] Nonsignificant or significant at the 5%, 1%, and 0.01%, respectively.

Table 2. Effect of different diploid watermelon pollenizer treatments on the weight class distribution of the total number 'Tri-X-313'.

	Yield					
	(MT/ha)					
	Small^{z}		Medium^{y}		Large^{x}	
Treatment	2005	2006	2005	2006	2005	2006
Companion	598.7	149.7	5088.7 cd^{w}	4939 c	6735.0 a	6585 a
Mickylee	374.2	1796.0	7707.8 ab	10028 a	4864.2 b	4864 ab
SP1	523.8	1272.2	8231.7 a	8980 ab	4939.0 b	5164 ab
SF800 (inter-planted)	898.0	1122.5	6510.5 abcd	7483 abc	4115.8 b	3667 b
Companion & SP1	299.3	1347.0	7558.2 ab	8756 ab	4939.0 b	6585 a
Companion & SF800	449.0	1646.3	6809.8 abc	8756 ab	4789.3 b	5538 ab
SF800 & SP1	374.2	1122.5	7483.3 ab	8456 ab	4565.8 b	5687 ab
SP1 (late planting)	1421.8	1272.2	4864.2 d	8756 ab	2319.8 c	5089 ab
SF800 (hill planted)	449.0	1496.7	5911.8 bcd	6660 bc	2469.5 c	4116 b
Control	748.3	224.5	898.0 e	973 d	598.7 d	1123 c

(*Table 2,* continued)

LSD (0.05)	NS	1096.5	1881.7	2565.0	1107.0	2432
Contrasts						
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	NS	*	***	***	***	***
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS	NS	NS	NS	NS	NS
Mickylee (2) vs. combined (5, 6, 7)	NS	NS	NS	NS	NS	NS
Companion alone (1) vs. Companion combined (5, 6)	NS	**	*	**	***	NS
SP1 alone (3) vs. SP1 combined (5, 7	NS	NS	NS	NS	NS	NS
SF800 alone (4) vs. SF800 combined (6, 7)	NS	NS	NS	NS	NS	NS
SF800; Inter-planted (4) vs. hill planted (9)	NS	NS	NS	NS	**	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	*	NS	**	NS	***	NS

[z] Cumulative number of fruit <3.6kg.

[y] Cumulative number of fruit between 3.6 and 7.3 kg.

(*Table 2,* continued)

[x] Cumulative number of fruit >7.3 kg.

[w] Any two means within a column followed by different letters are significantly different.

$^{NS, *, **, ***}$Nonsignificant or significant at the 5%, 1%, and 0.01%, respectively.

Table 3. Effect of different diploid watermelon pollenizer treatments on the distribution of the number of marketable 'Tri-X-313' fruit by harvest.

	Number of marketable fruit[z] (number/ha)					
	First		Second		Third	Fourth
Treatment	2005	2006	2005	2006	2006	2006
Companion	10476.7 a[y]	3068.2 a	1347.0	5163.5 ab	2319.8 cd	973
Mickylee	9578.7 bc	3068.2 a	2993.3	3816.5 abc	3891.3 abc	4116
SP1	9878.0 b	2170.2 ab	3292.7	3891.3 abc	4864.2 ab	3218
SF800 (inter-planted)	7857.5 bc	1646.3 b	2768.8	3891.3 abc	336.5 bc	2245
Companion & SP1	10102.5 bc	2319.8 ab	2394.7	5388.0 a	3816.5 abc	3817
Companion & SF800	8605.8 bc	1571.5 b	2993.3	5013.8 ab	3217.8 bc	4490
SP1 (late planting)	5388.0 d	972.8 bc	1796.0	2544.3 c	5762.2 a	4565
SF800 (hill planted)	5013.8 d	1197.3 bc	3367.5	3666.8 bc	3143.0 bc	2769
Control	449.0 e	149.7 c	1047.7	74.8 d	823.2 d	1048

(*Table 3*, continued)

LSD (0.05)	1372.0	1391.9	NS	1634.9	2043.0	NS
Contrasts						
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	***	**	*	***	***	*
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS	NS	NS	NS	NS	*
Mickylee (2) vs. combined (5, 6, 7)	NS	*	NS	NS	NS	NS
Companion alone (1) vs. Companion combined (5, 6)	NS	NS	NS	NS	NS	*
SP1 alone (3) vs. SP1 combined (5, 7)	NS	NS	NS	NS	NS	NS
SF800 alone (4) vs. SF800 combined (6, 7)	NS	NS	NS	NS	NS	NS
SF800; Inter-planted (4) vs. hill planted (9)	***	NS	NS	NS	NS	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	***	NS	NS	NS	NS	NS

[z] Cumulative number of fruit between 3.6 and 7.3 kg.

[y] Any two means within a column followed by different letters are significantly different, NS is no significant differences.

[NS, *,**, ***] Nonsignificant or significant at the 5%, 1%, and 0.01%, respectively.

Table 4. Soluble solids of 'Tri-X-313' fruit with different diploid watermelon pollenizer treatments.

Treatment	˚Brix
Companion	12.3
Mickylee	11.5
SP1	12.1
SF800 (inter-planted)	12.5
Companion & SP1	12.2
Companion & SF800	12.3
SF800 & SP1	12.1
SP1 (late planting)	12.1
SF800 (hill planted)	12.3
Control	11.9
LSD (0.05)	NS
Pollenizer (1, 2, 3, 4, 5, 6, 7, 8, 9) vs. no pollenizer (10)	NS
Individual (1, 3, 4) vs. combined (5, 6, 7)	NS
Mickylee (2) vs. combined (5, 6, 7)	NS
Companion alone (1) vs. Companion combined (5, 6)	NS
SP1 alone (3) vs. SP1 combined (5, 7)	NS
SF800 alone (4) vs. SF800 combined (6, 7)	NS
SF800; Inter-planted (4) vs. hill planted (9)	NS
SP1; 0 (3) vs. 3 weeks after triploid planting (8)	NS

Appendix C

Additional tables for Chapter 3

Table 1. Effect of halosulfuron POST and POST-directed on total and market number of Tri-X-313 watermelon fruit.[z]

	Yield	
Treatment	Total[y]	Marketable[x]
	number/ha	
Nontreated	18960	17950
25% distal	17437	16340
25% proximal	17240	15670
POST	16830	15760
LSD (0.1)	NS	NS

[z] Means followed by the same letter are significantly the same and NS is not significant.

[y] Total number of each weight class/ ha (small fruit <3.63 kg, medium fruit between 3.63 and 7.27 kg, and large >7.27 kg).

[x] Marketable number is the cumulative weights of medium and large.

Table 2. Effect of halosulfuron POST and POST-directed on distribution of weight of Tri-X-313 fruit by class weight.[z]

Treatment	Yield		
	Small[y]	Medium[x]	Large[w]
	kg/ha		
Nontreated	2670	64470	59110
25% distal	3150	54180	65160
25% proximal	3300	60050	45490
POST	4110	62430	42110
LSD	NS	NS	NS

[z] Means followed by the same letter are significantly the same and NS is not significant.

[y] Small fruit are <3.63.kg.

[x] Medium fruit are between 3.63 and 7.27 kg.

[w] Large fruit are >7.27 kg.

Table 3. Effect of halosulfuron POST and POST-directed on distribution of the number of Tri-X-313 fruit by class weight.[z]

	Yield		
Treatment	Small[y]	Medium[x]	Large[w]
	number/ha		
Nontreated	900	11390	6570
25% distal	1050	9570	6770
25% proximal	1100	10530	5130
POST	1350	10980	4770
LSD	NS	NS	NS

[z] Means followed by the same letter are significantly the same and NS is not significant.

[y] Small fruit are <3.63.kg.

[x] Medium fruit are between 3.63 and 7.27 kg.

[w] Large fruit are >7.27 kg.

Table 4. Effect of halosulfuron POST and POST-directed on distribution of the marketable weight of Tri-X-313 fruit by harvest.[a]

	First		Second		Third		Fourth
Treatment	Clinton	Kinston	Clinton	Kinston	Clinton	Kinston	Kinston
	kg/ha						
Nontreated	68970	52770	41940	8690	27130	22110	26270
25% distal	61080	50110	44760	9150	24990	21390	26490
25% proximal	54120	40710	32750	9850	22700	20720	20780
POST	46400	37110	31830	12970	24990	20170	30440
LSD (0.05)	NS	8440	NS	NS	NS	NS	NS

[z] Any two means within a column followed by different letters are significantly different.

Table 5. Effect of halosulfuron POST and POST-directed on distribution of the marketable number of Tri-X-313 fruit by harvest.

	First			Second		Third		Fourth
Treatment	Clinton	Kinston		Clinton	Kinston	Clinton	Kinston	Kinston
	number/ha							
Nontreated	9140	7540	a	5920	1260	4570	2870	4620
25% distal	7930	6140	b	5600	1350	4480	2690	4480
25% proximal	7170	6140	b	4480	1430	3950	3050	5110
POST	6540	5200	b	4530	1880	5020	3050	5290
LSD (0.05)	NS	NS		NS	NS	NS	NS	NS

[z] Any two means within a column followed by different letters are significantly different.

Table 6. Effect of halosulfuron POST and POST-directed on soluble solids of ‘Tri-X-313’ watermelon.^{z}

Treatment	Soluble Solids
	˚Brix
Nontreated	11.4
25% distal	11.0
25% proximal	11.3
POST	11.3
LSD (0.05)	NS

[a] Means followed by the same letter are significantly the same and NS is not significant.

Table 7. Effect of halosulfuron POST and POST-directed on total and market number of Precious Petite watermelon fruit.[z]

	Yield			
	Total number[y]		Marketable number[x]	
Treatment	Clinton	Kinston	Clinton	Kinston
	number/ha			
Nontreated	46660	41960	22590	18290
25% distal	46390	39000	24070	21520
50% distal	49620	40070	23400	14930
25% proximal	47600	40340	22190	15730
50% proximal	47470	37520	20580	12370
POST	47070	40070	15870	12240
LSD	NS	NS	NS	4810

[z] Means followed by the same letter are significantly the same and NS is not significant.

[y] Total number of each weight class/ ha (small fruit <1.4 kg, medium fruit between 1.4 and 3.2 kg, and large >3.2 kg).

[x] Marketable number is the cumulative weight of medium size fruit.

Table 8. Effect of halosulfuron POST and POST-directed on distribution of weight of Precious Petite fruit by weight class.[z]

	Yield		
	Small[y]	Medium[x]	
Treatment		Clinton	Kinston
	kg/ha		
Nontreated	23510	40900	32010
25% distal	18830	43280	39240
50% distal	24670	42420	26340
25% proximal	23710	39530	27360
50% proximal	24460	37350	21710
POST	27460	27760	20550
LSD (0.1)	NS	NS	4810

[z] Means followed by the same letter are significantly the same and NS is not significant.

[y] Small fruit are <1.4 kg, location is not significantly different and are combined.

[x] Medium fruit are between 1.4 and 3.2 kg.

Table 9. Effect of halosulfuron POST and POST-directed on distribution of the number of Precious Petite fruit by class weight.[a]

	Yield		
	Small[y]	Medium[x]	
Treatment		Clinton	Kinston
	kg/ha		
Nontreated	23870	22590	18290
25% distal	19770	24070	21520
50% distal	25480	23400	14930
25% proximal	25010	22190	15730
50% proximal	26020	20580	12370
POST	29520	15870	12240
LSD	6510	NS	8950

[z] Means followed by the same letter are significantly the same and NS is not significant.

[y] Small fruit are <1.4 kg, location is not significantly different and are combined.

[x] Medium fruit are between 1.4 and 3.2 kg.

Table 10. Effect of halosulfuron POST and POST-directed on distribution of the marketable weight of Precious Petite fruit by harvest.[z]

	First		Second	
Treatment	Clinton	Kinston	Clinton	Kinston
	kg/ha			
Nontreated	27280	27890	13620	4130
25% distal	27250	32350	16030	6900
50% distal	24560	20950	17860	5390
25% proximal	13840	22310	25690	5060
50% proximal	14050	16630	23300	5090
POST	11340	16030	16420	4520
LSD (0.1)	6300	6220	NS	NS

[z] Any two means within a column followed by different letters are significantly different.

Table 11. Effect of halosulfuron POST and POST-directed on distribution of the marketable number of Precious Petite fruit by harvest.[z]

	First		Second	
Treatment	Clinton	Kinston	Clinton	Kinston
	kg/ha			
Nontreated	15300	16000	7260	2290
25% distal	15330	17480	8740	4030
50% distal	14120	11970	9280	2960
25% proximal	8200	12640	13990	3090
50% proximal	7930	9550	12640	2820
POST	6860	9550	9010	2690
LSD (0.1)	3540	3490	NS	NS

[z] Any two means within a column followed by different letters are significantly different

Table 12. Effect halosulfuron POST and POST-directed on soluble solids of Precious Petite watermelons.[z]

Treatment	Soluble solids	
	Clinton	Kinston
	˚Brix	
Nontreated	11.5	12.0
25% distal	11.3	12.1
50% distal	11.4	11.7
25% proximal	11.1	11.6
50% proximal	11.1	11.6
POST	11.4	11.6
LSD (0.1)	NS	NS

[z] Means followed by the same letter are significantly the same and NS is not significant.