ABSTRACT

GRANITZ, HALLEY MARCELLE. Improving the North Carolina Cut Flower Industry: A Production and Marketing Survey, Field and Postharvest Cut Flower Variety Evaluations, and Preemergence Herbicide Trials on Unlabeled Cut Flower Crops. (Under the direction of J. L. Kornegay).

The cut flower industry is a small segment of North Carolina's floriculture industry with over $6.8 million in annual sales. In 2012 and 2013, a survey was conducted among NC cut flower growers to determine their production and marketing practices, and to identify their biggest concerns. Forty-five responses were received from a representative sample of growers from different areas of the state. Results were analyzed to obtain a current portrait of the growing industry. Over 70% of farms have been growing cut flowers commercially for less than 10 years. The majority of farms are small with an acre or less in flowers; many also produce other agricultural commodities. Most of the farms are organic (75%), but only 14% are certified organic or certified naturally grown. By far, most cut flower production (81%) is field grown in open ground. The crops are highly diverse with producers growing up to 40 varieties of flowers from over 75 different species. Annuals comprise over half of all crops grown, followed by bulbs (20%), herbaceous perennials (14%), and woody perennials (8%). Most farms trial new varieties yearly, but only 25% make significant changes to what they grow on a yearly basis. Most farms have cold storage facilities (71%) and use commercial floral preservatives (56%), although only 37% use hydrating solutions. Approximately 79% of

farm sales are retail, and 66% of retail sales are made at farmers markets. Most farms (80%) utilize social media or an online farm blog to promote their flowers.

Of the 75 different species of cut flowers identified in the survey, many of which are old favorite varieties, 31 varieties, which had not been previously tested, were selected for field performance and production studies at the Horticultural Field Lab in Raleigh, NC and stage one postharvest studies during 2012 and 2013. A subset of these varieties was also evaluated at the Mountain Horticultural Research and Extension Center in Mills River, NC in 2013. The results of these studies benefit NC cut flower growers by helping them select the most productive and longest lasting cut flower varieties for their farms.

Survey respondents also noted that weed control is one of their biggest production challenges. Research was conducted to expand the weed control options for cut flower growers by 1) increasing the number of preemergence herbicides labeled for specific cut flower species, 2) documenting the effects of weed competition on cut flower production, and 3) comparing the safety and efficacy of a herbicide-impregnated mulch with other weed control treatments. Weed competition in weedy check plots greatly impacted plant quality and marketable stem production. Weed control provided by hardwood mulch was comparable to that of the least effective herbicide tested. Herbicide-impregnated Preen Mulch Plus provided over 90% weed control both years and was among the top performing treatments in the study. Pendulum 2 GR, Snapshot 2.5 G, Freehand 1.75 GR, Preen Southern Gardens 0.27 GR, Barricade 4 L, Pennant Magnum 7.62 EC, and Preen Mulch Plus (trifluralin 0.0032% and isoxaben 0.0008%) did not injure Ammi, Platycodon and Eryngium. Freehand

1.75 G and Pennant Magnum 7.62 EC were safe on Ammi and Platycodon but caused injury to Eryngium and Amaranthus. Amaranthus was also injured by Barricade 4 L. Nigella was injured by Snapshot 2.5 G, Freehand 1.75 G, and Barricade 4 L. All treatments appeared safe on Solidago.

Improving the North Carolina Cut Flower Industry: A Production and Marketing Survey, Field and Postharvest Cut Flower Variety Evaluations, and Preemergence Herbicide Trials on Unlabeled Cut Flower Crops

by
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BIOGRAPHY

Halley Granitz is a horticulturist from Forsyth, Georgia. She earned her B.S.A. in horticulture from the University of Georgia in 2007. Following her undergraduate studies, Halley worked in ornamental horticulture as a golf course horticulturist at the Atlanta Country Club and in agricultural education at the University of Georgia. In 2012, she began work on her M.S. in Horticultural Science at North Carolina State University. Halley's lifelong love of flowers stems from a family full of plantswomen. Both of her grandmothers were avid vegetable and flower gardeners, and that relationship with plants has been passed down through subsequent generations. Thanks to her aunt, Camille Ragsdale, an organic gardener and fine landscaper in Atlanta, Georgia, Halley learned landscape design principles and new varieties of ornamentals. She hopes to inspire future generations of plant lovers in her career.

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I am very grateful for all the support I have been so graciously given throughout this process, both academic and personal. Admittedly, I got lucky and was able to work on a very interesting project with some excellent coworkers. Thank you to Julia Kornegay for your infinite patience and guidance throughout this process. I appreciate my committee, John Dole, Joe Neal, and Charles Safley, for sharing your experience and extensive knowledge. To Luna Gu, Chris Harlow, Ingram McCall, Alicain Carlson, Iftikhar Ahmad, and Bruno Trevenzoli Favero, thank you so much for your advice and help with my research. I couldn't have done it without you, and I enjoyed working with you and getting to know you. Thank you to my family for helping me get here and giving me a love for nature and agriculture. If I hadn't grown up in the country and spent weekends at the farm, I most likely wouldn't think twice about grubbing in the dirt. The times we spent outside together walking in the woods, hunting, working in the garden, banding geese, visiting Callaway Gardens, and chopping fire wood are some of my fondest memories.

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CHAPTER 1

LITERATURE REVIEW

Introduction

Cut flower production is a growing, but little known segment of the larger NC floriculture industry. Thirty years ago, more than 80% of U.S. cut flower production consisted of just four species: carnations, chrysanthemums, roses and gladiolus. However, as these four species began to be imported at competitive prices, the U.S. cut flower industry was largely decimated. In recent years, however, domestic production has rebounded through the production of specialty cut flower crops (Bachmann, 2006; Bonarriva et al., 2003).

A specialty cut flower may be any species other than carnations, chrysanthemums, roses or gladiolus (Armitage and Laushman, 2003). Many times, specialty cut flowers are new and unusual varieties, species that do not ship long distances well, or those that cannot be boxed and shipped dry (NC Cooperative Extension, 2013). Today, specialty cut flowers account for over 80% of domestic production, and carnations, chrysanthemums, and roses account for about 15% (Bachmann, 2006).

In 2012, cut flowers sales totaled $342 million in the U.S. and $6.8 million in NC (USDA, 2013). Growth in NC cut flower sales increased more than 70% from the 2011 value of $4 million (USDA 2012, 2013;). This figure excludes smaller growers whose annual sales are less than $10,000.

Cut flower production

Among larger producers in NC, lilies, iris, peonies, and snapdragons are commonly grown (USDA, 2013). Among smaller producers, however, there is little information on the cut flower species and varieties being grown, their production practices, and marketing strategies. It is thought that smaller producers grow a diversity of cut flower crops and varieties that may change quickly from year to year to keep up with trends and consumer demand (NC Cooperative Extension, 2013). Having current knowledge of the diversity of cut flower species/varieties and production units in the state allows researchers to concentrate their efforts on relevant crops and production practices. This benefits growers by helping them tailor production to best management recommendations for each species or variety grown, saving them time and money, and improving the quality of their product.

A 2003 industry survey of cut flower growers in the Southeast found that field-grown cut flowers accounted for 89% of total cut flower sales, with smaller amounts produced in high tunnels and greenhouses (Weddington, 2003). Installation of field grown cut flowers generally requires no or little additional equipment or overhead in established farms and is usually lower and more economical than starting a greenhouse cut flower operation (Whipker and Cavins, 2000). Site location is very important. For the majority of cut flower crops, the best field site is full sun, fairly level and well drained, with access to water for irrigation. Most growers plant in rows that are between 2.5 and 4 feet wide with multiple rows of flowers in each row to best maximize use of field space and still allow easy access to flowers on each side (Whipker and Calvins, 2000). Depending on seed size, ease of transplant and personal preference, annual cut flowers are either transplanted or directly sown into rows, while perennial or woody species are grown in established beds. Generally, field grown cut flowers are drip irrigated to minimize water loss to evaporation and keep leaves and flowers dry (Whipker and Cavins, 2000). Fertilizer may be applied through the drip irrigation system.

To help growers make economically sound choices about which varieties of specialty cut flowers to grow, NC State University trials new and commonly grown varieties every year. These include those in the Association of Specialty Cut Flower Growers (ASCFG) national trials (Granitz et al., 2013, 2014). The ASCFG trials evaluate promising new annual, perennial, and woody cut flower varieties across a wide range of growing environments for production parameters such as flower quality, stem length and stem number, hardiness, overall vigor, and postharvest vase life.

Weed management in cut flowers

Whether cut flower farms use conventional or organic production systems, weed management is time consuming and contributes greatly to labor costs (Rutgers, 2013; Weddington, 2003;). Large amounts of weeds in production areas can reduce flower and stem quality and make insect and disease control more difficult (Whipker and Calvins, 2000). Because of the diversity of cut flower crops, it is difficult for conventional growers to find effective herbicides labeled for all species grown. Organic growers have even less options as they are precluded from using conventional preemergence and postemergence herbicides.

Physical barriers such as plastic or organic mulch help control weeds across a wide variety of species. Mulches shade the soil and help prevent weed seed germination, plus they have the added benefit of also preventing water evaporation from the soil surface. Different colored mulches can be used to reflect or absorb the sun’s rays and cool or warm the soil a few degrees (Kumar and Lal, 2012). This can be especially helpful for cut flowers that prefer cool or warm roots because it extends the growing season. In some cases, mulches applied on top of preemergent herbicides have resulted in taller plants overall (Kuhns, 1992), which is desirable in cut flower production. Hoeing, tilling, and other manual weed removal techniques are also commonly used.

Determining an appropriate chemical weed control plan can be tricky, especially for cut flower producers that grow a wide variety of different crops and species. Until recently, Methyl Bromide was widely used in conventional systems to sterilize the soil and kill weed seeds and other pathogens (Klose et al., 2007). Because it was applied prior to planting, Methyl Bromide was a highly effective option for weed control across a broad spectrum of species. However, because of environmental concerns and strict regulations, the use of Methyl Bromide to control weeds is very restricted (Kolbe, 2013). The response of many cut flower species to herbicides is not well known (Senesac and Neal, 2011). Because herbicides can cause stunting, epinasty, and yellowing in some species, growers must be careful selecting appropriate formulations for the crops they plan to cultivate. Even minor stunting or physical blemishes from herbicide injury can render an entire crop unmarketable. Because of these concerns, it is difficult for growers to find an effective herbicide that is also safe on the majority of their cut flower crops. Consequently, additional research is needed to determine safe and effective weed management options for specialty cut flower production.

Postharvest handling of cut flowers

Unlike seeds, bulbs, tubers, or other plant storage organs, flowers are meant to be short lived. Biologically, their purpose is to attract a pollinator, whether that is a bird, bee, bat, or other organism. Petals are costly to plants because they use valuable energy and nutrients, and lose water through their large surface areas (Reid and Chen, 2007). Once pollination occurs, a flower's biological purpose has been served and the plant has no more use for showy petals. The ovary becomes the nutrient sink and petals either abscise or wilt. In the cut flower industry, however, flowers are the commodity of interest. The goal of cut flower postharvest handling is to extend the life of the flower petals or bracts.

The vase life of cut flowers can last anywhere from one day to over a month (Reid and Jiang, 2012). Flowers that only last a day or two on the plant generally only last a day or two in the vase. The same rule of thumb applies to most long lasting flowers. For example, cosmos flowers open, last two to three days on the plant, and then the petals abscise. Their vase life is similarly short. Eucomis flowers, however, may last weeks on and off the plant, and once the petals senesce and abscise the bracts and seedpods remain on the fleshy stems for an aesthetically pleasing appearance (Carlson, 2010). The length of the flower's life while attached to the plant does not always determine vase life. Zinnia inflorescences can last up to two weeks on the plant, but, once cut, wilt and brown within a few days.

The vase life of all species of cut flowers benefits from sound cultural practices at the farm. Healthy growing conditions, clean harvesting and postharvest equipment, and cutting at the optimum stage of flower opening help prolong postharvest life (Bachmann, 2006). Cutting in the morning when it is cool in the field helps keep stems hydrated, and submerging the stems in water immediately after cutting helps to minimize the formation of air emboli in the stems which block water uptake. Most species of cut flowers last longer when refrigerated. Sanitation in the cooler is important as well. If old flowers are left to senesce, they release ethylene and host bacterial and fungal infections (Bachmann, 2006).

To understand how postharvest treatments affect vase life of cut flowers, it is important to know how flowers senesce. The degradation and reallocation of resources in the flower is both rapid and tightly controlled by the plant (Jones, 2012). On the plant, flower senescence can be initiated in response to biotic or abiotic factors such as pollination, drought, water, or temperature stress, or in response to attack by pathogens, insects, or herbivores (Reid and Jiang, 2012). In the cut flower industry, the main factors that induce or hasten flower senescence include pollination, stress from harvest, fungal and bacterial infections in the stem, and cavitation in the xylem (Gast, 1997).

In some flowers like carnation, alstroemeria, delphinium and dendrobium, ethylene is the main senescence regulator and it acts as a signal for the senescence process to begin in ethylene sensitive species (Reid and Chen, 2007). Other types of inflorescences do not senesce in response to ethylene. These are known as ethylene insensitive species. In ethylene insensitive species, abscisic acid (ABA) is thought to be the main senescence regulator (Reid and Chen, 2007). All flowers experience ethylene-independent senescence pathways triggered by ABA, even if they also respond to ethylene (Jones, 2012).

Once the senescence process is triggered by ethylene or ABA, it is irreversible and highly programmed. There are two main types of senescence in flowers: petals can abscise first and fall off, or they can remain attached to the flower while they senesce (Reid and Chen, 2007). Cell walls begin to lose permeability. Levels of protective enzymes decrease while oxidative enzymes increase (Tripathi and Tuteja, 2007). Cell components are disassembled and moved to actively growing parts of the plant like developing seeds and the petals begin to wilt. In the final steps of flower senescence, nucleases, proteases, and cell wall modifiers disassemble DNA, RNA, proteins, and organelles in petal tissue (Tripathi and Tuteja, 2007). As many resources as possible are moved to nutrient sinks for reuse by the plant. At this point, the petals either remain attached to the plant or abscise, but either way they appear dry, crispy, and brown.

Just as fruits and vegetables require different postharvest treatments, cut flowers do as well. Tropicals, like anthurium, must be stored at temperatures above 50°F to avoid chill injury, but other flower types, such as roses, can be stored just above freezing to prolong shelf life (Almeida et al., 2009). Some flowers ship well in Modified Atmosphere Packaging (MAP) bags, but others must be kept in water at all times (Ahmad et al., 2012). Different combinations of hydrating and holding solutions affect different species of cuts differently (Ahmad et al., 2013). Since there is such a wide variety of cut flowers being grown, it is important for growers to be cognizant of the appropriate postharvest treatment (or treatments) for each individual species. Cut flower postharvest research focuses on determining which treatment or combination of treatments work best for which type of flower (Rule et al., 1986).

Extensive research is conducted by commercial floriculture companies such as Chrysal and Floralife to determine the best formulations for vase solutions. Hydrating solutions such as Chrysal Professional #1 Hydrating Solution® and Floralife Hydraflor®/100 are used as a first treatment for freshly harvested flowers of some species. Hydrating solutions contain a combination of three ingredients: a biocide, a wetting solution, and an acidifier (Gast, 1997). Commercial hydrating solutions generally have a pH of 3.0 to 3.5 and are most effective without sugars (Bachmann, 2006).

Biocides help prolong the life of cut flowers by keeping fungal and bacterial pathogen colonies to a minimum. Fungi and bacteria thrive on plant tissue and vase water, and can be introduced by clippers or knife blade at harvest (Gast, 1997) or by contaminated stems. These organisms colonize and clog up vascular bundles, limiting water and carbohydrate flow to plant parts. The stress of pathogen invasion and lack of water and carbohydrates can induce early flower senescence. Biocides help mitigate these harmful effects.

Wetting solutions and acidifiers help cut plant tissue take up water more easily. When stems are cut at harvest, cavitation occurs in xylem cells exposed to air. Cavitation is when tracheids in the xylem pull in air bubbles, effectively blocking water from being taken up by the plant. Wetting solutions make it easier for water to move through the stem by capillary action, overcoming cavitation. Acidifiers lower the pH of water, making it less habitable for bacteria and fungi and easier for the plant's xylem to take up (Gast, 1997).

Holding solutions, also called floral preservatives, contain the same three ingredients as a hydrator, a biocide, wetting agent, and acidifier, plus a sugar solution. Usually, this is sucrose. Holding solutions provide all the benefits of a hydrator plus extra carbohydrates to help flowers last longer. They are usually used once flowers reach the florist or homeowner. Sugars feed bacteria and other pathogens and encourage faster infection of cut plant tissue (Gast, 1997). If sugars are introduced into the vase water immediately after harvest, pathogens will develop into large colonies by the time the product reaches consumers, and vase life will be shortened. If the retailer or end consumer adds a preservative solution, it can prolong vase life.

Although hydrating and holding solutions can extend vase life in some species, they can also cause quicker senescence in others (Ahmad et al., 2013). Some flowers do not respond well to one or more ingredients in commercial solutions. Wetting agents and detergents can cause certain flowers to wither and die almost immediately. Sugar solutions, while advantageous for many species, provide no added benefit to others. Because of the added cost of vase life solutions, combined with the possibility they might actually shorten vase life, growers must make informed decisions about which products to use.

Marketing

Common markets for NC grown cut flowers include farmers markets, specialty supermarkets and health food stores, community supported agriculture (CSA) subscriptions, cut-your-own farms, restaurants, retail florists, and wholesale florists (Bachmann, 2006). Many beginning growers sell their cut flowers at farmers markets. Markets are a venue to meet potential new customers, network with other growers, and compare notes on growing practices. Weddington (2003) found that travel expenses of NC retail cut flower businesses were positively correlated with sales, and that visits to markets and retail venues translated to more retail sales. Other growers sell flowers as part of Community Supported Agriculture (CSA) subscriptions. Sometimes the subscription is for flowers only and other times it includes fruits and vegetables.

Supermarkets, wholesale florists, and retail florists demand high quality flowers that are just beginning to open. Generally, they have business relationships with established, high volume growers that produce a uniform, quality product (Bachmann, 2006). Many of the cut flowers are sold on contracts, so growers must be able to time crops for holidays and seasons. It can also be time consuming to deliver flowers, so growers must take the additional labor and transportation costs into account. Despite these considerations, wholesale cut flower businesses in North Carolina, South Carolina, and Virginia had higher sales than retail businesses (Weddington, 2003).

Conclusions

The NC cut flower industry is a small, but growing segment of the larger floriculture industry. Little is known about this group of producers, their crops and production practices, and major constraints. As important as it is to have a more complete understanding of the cut flower industry, it is equally important to make that information available to growers. Increased communication between growers and research professionals will result in a more accurate picture of the cut flower industry. Accurate statistics about farm numbers and size, value of sales, production practices, and markets, will allow for a stronger case to be made to dedicate more resources to improving the NC cut flower industry. The availability of relevant research information to growers will improve the efficiency of resource utilization on the farm. With more information, research time and funds can be dedicated to the most pressing issues facing cut flower farmers today, fostering the expansion of this high value specialty crop industry.

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CHAPTER 2

PRODUCTION AND MARKETING SURVEY OF THE NC CUT FLOWER INDUSTRY

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Abstract

The cut flower industry is a small segment of North Carolina's floriculture industry, currently valued by the USDA Economic Research Service at $6.8 million in annual sales (USDA, 2013). In 2003, an economic and cost analysis survey of the industry was conducted by Megan Weddington(2003). Since then, there has been little information collected about cut flower production and marketing. In 2012 and 2013, a survey was conducted among NC cut flower growers to determine their production and marketing practices, and to identify their greatest concerns. Forty-five responses were recorded from a representative sample of NC growers from different areas of the state. Results were analyzed to obtain a current portrait of the growing industry. Over 70% of farms have been growing cut flowers commercially for less than 10 years and, therefore, did not participate in the 2003 economic and cost analysis survey. The majority of farms are small: 64% have an acre or less in cut flowers and 84% hire less than two workers per year. Many of these farms also produce fresh fruits, vegetables, potted plants, meat or eggs. On average, 43% of surveyed farms' incomes come from cut flowers. Most of the farms are organic (75%), but only 14% are certified organic or certified naturally grown. By far, most cut flower production (81%) is field grown in open ground and the crops are diverse: growers grow up to 40 varieties of cut flowers from over 75 different species. Annuals comprise over half of all crops grown, followed by bulbs (20%), herbaceous perennials (14%), and woody perennials (8%). Most farms trial new varieties yearly, but only 25% make significant changes to what they grow

on a yearly basis. Weed control is the number one production challenge listed by growers. Many growers use plastic or organic mulches, hand weeding, and flame weeding to control infestation. Most farms have cold storage facilities (71%) and use commercial floral preservatives (56%), although only 37% use hydrating solutions. Approximately 79% of farm sales are retail, with 66% of retail sales made at farmers markets. Most farms (80%) utilize social media or an online farm blog to promote their flowers. Production and marketing challenges were identified and will guide future research.

Introduction

North Carolina has a thriving floriculture industry with sales that are fifth in the U.S. Over 235 producers have annual sales of $10,000 or more (USDA, 2013). The cut flower industry represents a small, but growing, segment of the state's floriculture industry. North Carolina cut flower sales were valued at $6.8 million in 2012, an increase of more than 70% from the 2011 value of $4 million (USDA, 2012, 2013). Thirty years ago, more than 80% of domestic cut flower production consisted of just four species: carnations, chrysanthemums, roses and gladiolus. As these four species began to be imported at competitive prices, local growers began to seek alternative, specialty crops (Bonarriva, 2003). At first, a specialty cut flower was defined as anything other than carnations, chrysanthemums, roses or gladiolus (Armitage and Laushman, 2003). However, as the industry has grown and cut flower products have diversified, the definition of specialty cut flowers has changed to flowers that are only available seasonally or for a short time period during the year (Armitage and

Laushman, 2003). Many specialty cut flowers are field grown, so they are only available for a few months per year during the growing season. Today, specialty cut flowers account for over 80% of domestic production (Bachmann, 2006).

Many small farmers have added cut flowers to their production list as a cost effective way to increase farm diversification and supplement income (Whipker and Cavins, 2000). Installation of field grown cut flowers requires no or little additional equipment or overhead in established farms. Mixed bouquets provide a colorful, attractive option for add-on sales at the farmers market or farm stand. However, because these farmers sell less than $10,000 per year in cut flowers, they are not included in USDA statistics. More research is needed to obtain an accurate picture of the industry.

Varieties of cut flowers commonly grown in North Carolina are diverse and change quickly from year to year to keep up with trends and consumer demand. Having current knowledge of species and varieties grown in the state allows researchers to concentrate their efforts on relevant crops. This benefits growers by helping them tailor production to the different best management recommendations for each species or variety grown, saving them time and money and improving the quality of their product.

To help growers make economically sound choices about which varieties of specialty cut flowers to grow, North Carolina State University trials new and commonly grown varieties yearly. The NCSU floriculture program participates in the Association of Specialty Cut Flower Growers (ASCFG) national trials. The ASCFG trials evaluate promising new annual, perennial, and woody cut flower varieties across a wide range of growing zones for production parameters such as stem length and stem number, hardiness, overall vigor, and postharvest vase life. Results of this research are published yearly in the ASCFG Cut Flower Quarterly.

Because of the diversity of cut flower crops, it is difficult for conventional growers to find effective products labeled for all species grown. Organic growers have even less options as they are precluded from using conventional preemergence and postemergence herbicides. Whether farms employ conventional or organic systems, weed management is time consuming and contributes greatly to labor costs (Rutgers, 2013; Weddington, 2003). Identifying major weed control concerns and determining the production practices of cut flower growers would benefit growers by targeting research to relevant weed control issues.

Currently, there is little information about cut flower production in NC. The results presented in this survey contribute to a greater understanding of the NC cut flower industry by providing relevant production, postharvest, and weed control information for the most commonly grown cut flowers in the state, and current marketing and income information about this little-known industry.

Materials and methods

We developed a 55 question survey (Table 2.1) for cut flower growers in NC. The survey was beta tested with two growers and modifications were made according to their suggestions. To identify growers, we used several approaches. First, we obtained a list of members from the Association of Specialty Cut Flower Growers (ASCFG) in January 2012 and the NC members were added to the survey distribution list. Then, by researching online farmers market and grower web pages, many smaller growers were identified and added to the list. The last method of identifying NC cut flower growers was asking known growers and extension professionals in different areas of the state to name other flower farms in their geographic areas. Once these three methods were complete, the list of survey recipients included 174 cut flower growers.

Online and paper versions of the survey were prepared. We chose to use Qualtrics® Research Suite online survey software to distribute the survey to encourage more exact answers and save postage and other resources. With the Qualtrics® software, we specified what kind of answer we wanted for each question. If the question was about percentages, the answer boxes were set to allow only numerical values. For example, a respondent could not type 'a lot' in the box instead of an actual numerical value. For questions where respondents numerically ranked statements in order of concern or severity, a number could not be used more than once. Some questions were set up to allow respondents to select more than one option, and others only allowed users to select one response. By customizing each question in the survey in this way, more accurate responses were encouraged.

In February 2012, an email with a link to the online survey was sent to 165 growers who had email addresses. After two weeks, a follow up email reminder was sent to those growers who had not yet completed the survey. In March 2012, only 24 growers had completed the questions in the survey. We called the remaining 150 growers twice more to ask them to complete the survey. If they indicated they would not or did not want to participate, they were marked off the distribution list. Then, 94 paper surveys were mailed to the remaining non-respondents. To encourage returns, an addressed, stamped envelope was included in each package. Of the paper surveys, 21 were returned and the data was entered into the Qualtrics software. In total, 45 grower surveys were received. The survey results were exported to Excel and analyzed using ANOVA.

Results and discussion

Demographics

About 70% of the farms surveyed have been growing cut flowers commercially for less than 10 years (Table 2.2). These farms were not included in the 2003 industry survey conducted by Weddington. The majority of farms are classified as individual or family owned (74%), followed by corporations (20%). The vast majority of farms (96%) are located in the central and western part of the state (data not presented). The farmers tend to be older (71% are 50 years old or older) and hire less than two workers per year on 84% of farms. On average, 43% of surveyed farms' income is from cut flowers (Table 2.2).

Production Practices

Most NC cut flower farms are small; the majority have an acre or less in cut flower production (Table 2.3). In addition to cut flowers, many cut flower growers also produce fresh fruits, vegetables, potted plants, meat or eggs (data not shown). Three quarters of NC cut flower farms are organic, but only 14% are certified organic or certified naturally grown (Table 2.3). Most of production is field grown in open ground (82%). About 37% of the crop area is direct seeded; the rest is either planted with transplants started from seed or with commercially purchased plugs. The greenhouse space on most surveyed farms is less than 10,000 sq ft, reflecting the fact that most crops are field grown (Table 2.3).

NC cut flower crops are diverse. Annuals comprise over half of all cuts grown, followed by bulbs (20%), herbaceous perennials (14%), and woody perennials (8%) (Table 2.3). Cut flower growers may grow up to 40 varieties from over 75 different species (Table 2.7). Most growers in NC include both zinnias (90%) and sunflowers (87%). Other commonly grown crops include celosia, lilies, snapdragons, Dutch iris, larkspur, gomphrena, and dianthus (Table 2.7). The 50 most commonly grown varieties were identified for field and postharvest testing in the 2012 and 2013 NCSU summer cut flower trials (Granitz et al, 2013, 2014).

Planting materials are obtained mainly from seed companies (95%), but additionally from commercial propagators and bulb companies (Table 2.3). Interestingly, 59% of the growers save seed from previous crops. Most farms (75%) trial new varieties yearly, but only 25% make significant changes to what they grow on a yearly basis. Most cut flower growers (58%) say they are not planning to increase their cut flower production in the next five years (Table 2.3).

Because the majority of NC cut flower producers employ organic production practices, compost and/or organic fertilizers are commonly used to provide nutrients to their crops (Table 2.3). About 55% of field grown cut flowers are watered by drip irrigation and 15% use overhead irrigation (Table 2.3). Drip irrigation is advantageous to cut flower growers because it eliminates water splashing on the crop's leaves and reduces the potential for foliar diseases. Only 18% of the growers apply nutrients through the drip irrigation system (Table 2.3).

The most common type of disease problem noted by the survey respondents is foliar diseases, but only half of the growers use fungicides to control them (Table 2.4). Powdery mildew is the number one disease problem reported by NC cut flower growers, while aphids, Japanese beetle, and thrips are the top three insect pests (listed as key challenges, data not presented). Insect pests are controlled by insecticides on 55% of farms. Soil fumigants are not widely used; only 3% of farms reported using them to control soil-borne pests before planting (Table 2.4).

Weed control is a major issue for cut flower growers, especially those employing organic practices. More than half of farms use cover crops to enrich the soil and control weeds (Table 2.3). Many use plastic or organic mulches, hand weeding, mechanical cultivation, and/or flame weeding to control weed infestation (Table 2.4). The cost of hand weeding is the growers' number one challenge or cost associated with weed control (listed as a key challenge). Only 13% of growers report using preemergence herbicides or selective postemergence herbicides for weed control, while only 15% use nonselective herbicides (such as roundup or vinegar) for spot weed control around crops. None of the growers reported using non-selective herbicides for site preparation only (Table 2.4).

Postharvest Management

Most farms (71%) have cold storage facilities to store cut flowers after harvest (Table 2.5). More than half use commercial floral preservatives such as Floralife Professional Fresh Flower Food® or Chrysal #2® to prolong vase life, and 37% use hydrating solutions like Floralife Quick Dip 100® or Chrysal OVB®. All growers report using buckets to transport flowers to market, while 7% also use boxes. Most stems reach consumers either the same day they are harvested or the following day; all reach customers within three days of harvest (Table 2.5).

More than half of NC cut flower growers are able to target production for special occasions. Nearly three quarters grow specifically for weddings, and over half grow crops for Mother's Day. Other holidays targeted include Valentine's Day, December holidays, and Thanksgiving (Table 2.5).

Marketing

Approximately 78% of farm sales are retail and 66% of retail sales are made at farmers markets (Table 2.6). Other retail sales are made through florists, roadside stands, community supported agriculture (CSA), weddings, and internet sales. Of wholesale flower sales, most are made to florists, mass marketers, flower markets, and garden centers. Most surveyed farms (63%) reported sales under $20,000 per year; but 10% of growers reported sales over $100,000 (Table 2.6).

In recent years, most growers (67%) have noticed an increase in demand for their cut flowers because of an increase in demand for locally sourced products (Table 2.6). The majority of flowers (74%) are sold in mixed, premade bouquets directly to the consumer. Many cut flower businesses utilize social media and/or an online farm blog or website to promote their product. Their main sources of information about crops, production practices, and markets come from other cut flower growers, NC Cooperative Extension agents and publications, and trade publications such as the ASCFG Cut Flower Quarterly (Table 2.6).

Key Challenges

Growers ranked their key challenges in order of their impact on cut flower production. The number one challenge ranked by growers is weed control in field grown cut flower production. Next in importance is a lack of skilled manpower to care for crops. Because cut flower production is labor intensive, the cost of manpower is the third most pressing challenge listed. Competition from other flower growers, the high cost of fuel and other transportation costs, and the short postharvest vase life of some commonly grown species are also major challenges faced by growers today.

Conclusions

In the past ten years, few details have been known about the NC cut flower industry. From this study, 174 farms producing cut flowers for sale were identified and 45 growers responded to the production and marketing survey. The majority of these growers' cut flower sales are not included in the annual USDA Floricultural Crop Summary because they are less than $10,000. The survey identified a number of cut flower production and marketing challenges that will guide future research. The most commonly grown cut flowers crops and varieties were identified for field performance and postharvest vase life trials. From the weed management issues identified in this survey, weed management trials were designed to help improve best management practice recommendations for growers.

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Table 2.1. Questions included in the 2012 survey of the North Carolina cut flower industry

A. Demographics

1. What is your gender?
2. What is your age group?
3. How long have you been growing cut flowers commercially?
4. How is your farm business classified?
5. What percent of your farm business income is cut flower production?
6. What other crops do you grow on your farm?

B. Production practices

7. How would you describe your approach to growing practices?
8. What percentage of your production is grown under glass greenhouses, fiberglass/other rigid greenhouses, plastic film greenhouses, high tunnels, shade houses/other temporary cover, open ground?
9. What is your current area (acreage) in outdoor cut flower production?
10. What is your average area under greenhouse cover?
11. Approximately how many cut flower varieties/cultivars do you grow every year?
12. Approximately how many cut flower species do you grow every year?
13. What percentage of crops grown can be classified in the following groups: herbaceous perennials, woody perennials, annuals, bulbs, other?
14. What percentage of your crop acreage is direct-seeded?
15. How often do you trial, try out, or test new species, varieties, or crop categories of cut flowers?
16. How often do you make significant changes to the list of cut flower crops you grow?
17. Where do you source your planting materials?
18. Are you planning to increase your cut flower production this year?
19. Are you planning to increase your cut flower production in the next five years?
20. What sources of plant nutrients do you apply to your field grown cut flower crops?
21. Do you use cover crops?
22. What type(s) of irrigation do you use?
23. What are your major categories of disease problems?
24. Please list your major plant diseases and crops affected.
25. Do you use fungicides to control plant diseases?
26. What are your major insect pest problems and crops affected?
27. Do you use insecticides to control insect pests?

Table 2.1 Continued

28. Do you use soil fumigants to control soil-borne pests before planting?
29. What weed control practices do you use?
30. What are your major weed management challenges or costs?
31. If you use herbicides, what are your most commonly used preemergence herbicides?
32. What are your most commonly used postemergence herbicides?
33. List other herbicides used rarely, but that you consider important for specific weed problems.

C. Postharvest management

34. Do you have cold storage facilities on your farm?
35. Do you use floral preservatives?
36. If yes, which preservatives do you use most commonly?
37. Do you use hydrating solutions or dips?
38. If yes, which preservatives do you use most commonly?
39. What do you transport your flowers to market in?
40. After the flowers are harvested, how long is it before they reach the customers on average?
41. Are you able to target production for special occasions?
42. Which holidays do you target production for?

D. Employees

43. Other than yourself, how many part time employees do you hire on an annual basis?
44. Other than yourself, how many full time employees do you hire on an annual basis?

E. Marketing

45. What percentage of your cut flowers is sold wholesale?
46. What percentage of your cut flowers is sold retail?
47. If wholesale, what percentage of your flowers is sold to: mass marketers, flower markets, florists, bouquet manufacturers, garden centers, other growers, other wholesale sales?
48. If retail, what percentage of sales is through: florists, farmers markets, roadside stands, U-cut, CSAs, supermarkets, restaurants, hotels, caterers, weddings, internet, export or international sales, other retail sales?
49. Have you noticed an increase in demand for your cut flowers recently because of an increase in demand for locally sourced products?
50. Do you retail your flowers primarily as mixed flower bouquets?

Table 2.1 Continued

51. What marketing strategies do you use to promote sales?	
52. What are your primary sources of information on cut flower crops/varieties, production practices, and markets?	
53. What were your annual gross sales in 2011?	
F. Key Challenges	
54. What challenges have the greatest effect on your cut flower business?	
G. Cut flower crops grown	
55. Please list the cut flower crops that you have grown over the last 2 years and add the names of the most commonly grown specific varieties within each crop.	

Table 2.2. Demographic profile of NC cut flower growers

Respondent characteristic	Response (%)
Gender (n = 46)*	
Male	30
Female	50
Couple	26
$\chi2$ = 4.127, P = 0.127	
Age group (n = 46)*	
30-39 years of age	11
40-49 years of age	17
50-59 years of age	37
60-69 years of age	30
70 years and over	4
$\chi2$ = 16.909, P = 0.002	
Years growing cut flowers commercially (n = 46)	
1-5 years	46
6-10 years	24
11-15 years	9
16-20 years	9
Greater than 20 years	13
$\chi2$ = 18.500, P = 0.001	
Part time employees hired annually (n = 38)	
0-2	84
3-5	8
6-9	3
10 or more	5
$\chi2$ = 71.263, P < 0.0001	
Full time employees hired annually (n = 30)	
0-2	83
3-5	10
6-9	0
10 or more	7
$\chi2$ = 33.800, P < 0.0001	

Table 2.2 Continued

Classification of farm business (n = 46)	
Individual or family owned	74
Corporation	20
Partnership	7
$\chi2 = 31.882$, $P < 0.0001$	
Percent of farm business income from cut flower production (n = 44)	43

*Respondents selected multiple options

Table 2.3. Production practices of NC cut flower growers

Respondent characteristic	Response (%)
Growing practices (*n* = 44)	
Certified organic	5
Certified naturally grown	9
Use organic practices as much as possible, but not certified organic	61
Conventional growing practices, organic when economically advantageous	14
Production practice decisions not based on organic vs. inorganic approaches	11
$\chi 2 = 48.045$, $P < 0.0001$	
Growing conditions (*n* = 44)**	
Glass greenhouses (heated)	1
Fiberglass and other rigid greenhouses (heated)	1
Plastic film greenhouses (heated)	8
High tunnels (unheated)	6
Shade house or other temporary cover	3
Open ground	82
Current area (acreage) in outdoor cut flower production (*n* = 44)	
Less than a quarter acre	30
¼ - ½ acre	18
½ - 1 acre	16
1-2 acres	18
3-5 acres	7
6-10 acres	7
Greater than 10 acres	5
Area under greenhouse cover (*n* = 40)	
Less than 10,000 sq ft	83
10,000–24,999 sq ft	10
25,000-49,999 sq ft	0
50,000-74,999 sq ft	3
75,000-99,999 sq ft	0
100,000 sq ft or greater	5

Table 2.3 Continued

Percentage of crops classified in the following groups (*n* = 40)**	
Herbaceous perennials	14
Woody perennials	8
Annuals	55
Bulbs	20
Other	3
Average percentage of acreage that is direct seeded (*n* = 40)	37
How often do you trial new species, varieties, or crop categories of cut flowers? (*n* = 44)	
Yearly	75
Every 2-5 years	2
Rarely (less than once every 5 years)	7
Never	7
Not applicable: I've not been in business long enough to answer.	9
$\chi2 = 83.727$ $P < 0.0001$	
How often do you make significant changes to the list of cut flower crops you grow? (*n* = 44)	
Yearly	25
Every 2-5 years	18
Rarely (less than once every 5 years)	36
Never	7
Not applicable: I've not been in business long enough to answer.	14
$\chi2 = 11.227$, $P = 0.0241$	
Sources of planting materials (*n* = 44)*	
Seed companies	95
Commercial plant propagators	55
Other farmers	27
Seed saved from previous crops	59
Bulb companies	66
Other	7
$\chi2 = 17.414$, $P = 0.0016$	
Are you planning to increase your cut flower production this year? (*n* = 44)	
Yes	27
No	73
$\chi2 = 9.091$, $P = 0.0026$	

Table 2.3 Continued

Are you planning to increase your cut flower production in the next five years? (*n* = 43)	
Yes	42
No	58
$\chi2 = 1.140 P = 0.2858$	
Sources of plant nutrients applied to field grown cut flower crops (*n* = 40)*	
Compost	83
Organic fertilizers	63
Granular fertilizers	38
Slow release fertilizers	15
Foliar sprays	43
Fertigation (nutrients applied through the drip irrigation system)	18
$\chi2 = 31.522, P < 0.0001$	
Do you use cover crops? (*n* = 39)	
Yes	62
No	38
$\chi2 = 2.077, P = 0.1495$	
Percentage of crops irrigated by the following methods (*n* = 39)**	
Furrow irrigation	1
Overhead irrigation	15
Drip irrigation	55
Other (hose, hand watered, etc.)	9
No irrigation	20

*Respondents selected multiple options

**Respondents selected multiple options, answers totaled to 100%

Table 2.4. Disease, insect, and weed control practices of NC cut flower growers

Respondent characteristic	Response (%)
Major categories of disease problems (n = 38)*	
Soil-borne diseases	45
Foliar diseases	89
Viruses	13
$\chi2 = 22.710$, $P < 0.0001$	
Fungicides used to control plant diseases? (n = 40)	
Yes	50
No	50
$\chi2 = 0$, $P = 1.0$	
Insecticides used to control insect pests? (n = 38)	
Yes	55
No	45
$\chi2 = 0.421$, $P = 0.5164$	
Soil fumigants used to control soil-borne pests before planting? (n = 39)	
Yes	3
No	97
$\chi2 = 35.103$, $P < 0.0001$	
Weed control practices used (n = 39)*	
Chemical fumigation	5
Non-chemical soil sterilization (steam, solarization, other)	26
Plastic or geotextile fabrics (non-biodegradable)	36
Plastic or geotextile fabrics (biodegradable)	8
Organic mulches such as bark, straw, hardwood, leaf mold, etc.	74
Preemergence herbicides	13
Selective postemergence herbicides (like sethoxydim or fluazifop)	13
Non-selective herbicides for site preparation only	0
Spot treatment with non-selective herbicides between and around crops	15
Mechanical cultivation	72
Flame weeding	33
Hand weeding	95
Other	5
$\chi2 = 125.288$, $P < 0.0001$	

*Respondents selected multiple options

Table 2.5. Postharvest management practices of NC cut flower growers

Respondent characteristic	Response (%)
Cold storage facilities on farm? (*n* = 41)	
Yes	71
No	29
$\chi 2 = 7.049$, $P = 0.0079$	
Use of floral preservatives? (*n* = 41)	
Yes	56
No	44
$\chi 2 = 0.610$, $P = 0.4349$	
Use of hydrating solutions or dips? (*n* = 41)	
Yes	37
No	63
$\chi 2 = 2.951$, $P = 0.0858$	
Container used to transport flowers (*n* = 41)*	
Buckets	100
Boxes	7
$\chi 2 = 32.818$, df = 1, $P < 0.0001$	
After the flowers are harvested, how long is it before they reach customers? (*n* = 41)	
Same day	27
Next day	44
2-3 days	29
4-7 days	0
More than 7 days	0
$\chi 2 = 2.093$, $P = 0.3512$	
Able to target production for special occasions? (*n* = 41)	
Yes	56
No	44
$\chi 2 = 0.6098$, $P = 0.4349$	
Holidays and special occasions production is targeted for (*n* = 28)*	
December holidays	21
Valentine's Day	25
Mother's Day	57
Weddings	71
Other	39
$\chi 2 = 11.833$, $P = 0.0186$	

*Respondents selected multiple options

Table 2.6. Marketing practices of NC cut flower growers

Respondent characteristic	Response (%)
Percentage of cut flowers sold wholesale (*n* = 42)	22
Percentage of cut flowers sold retail (*n* = 42)	78
Wholesale sales (*n* = 42)**	
Mass marketers	7
Flower markets	3
Florists	22
Bouquet manufacturers	0
Garden centers	3
Other growers	3
No wholesale	63
Retail sales (*n* = 42)**	
Florists	2
Farmer markets	66
Roadside stands	4
U-Cut	0
Community Supported Agriculture (CSAs)	8
Supermarkets	4
Restaurants	0
Hotels	0
Caterers	0
Weddings	4
Internet	1
Export/international sales	0
No retail	12
Have you noticed an increase in demand for your cut flowers recently because of an increase in demand for locally sourced products? (*n* = 39)	
Yes	67
No	33
$\chi 2 = 4.333$, $P = 0.0108$	
Do you retail your flowers primarily as mixed flower bouquets? (*n* = 39)	
Yes	74
No	26
$\chi 2 = 9.256$, $P = 0.0023$	

Table 2.6 Continued

Marketing strategies used to promote sales (n = 39)*	
Newspaper advertisements	5
Mailers	0
Internet advertisements	10
Trade magazine advertisements	0
Phone calls	15
Social Media	31
Farm blog or website	49
Other	23
None	23
$\chi 2 = 45.524$, $P < 0.0001$	
Primary sources of information on crops, production practices, and markets (n = 39)*	
Other cut flower growers	69
NC Flower Growers Association	5
NC State University specialists	18
NC Cooperative Extension Agents	36
Cut flower product representatives	18
Magazines/trade publications	46
Websites	33
Association of Specialty Cut Flower Growers	46
Other	18
$\chi 2 = 37.638$, $P < 0.0001$	
Annual gross sales in 2011 (n = 39)	
Less than $5,000	38
$5,000-$9,999	10
$10,000-$19,999	15
$20,000-$29,999	8
$30,000-$39,000	3
$40,000-$49,000	10
$50,000-$99,999	5
$100,000-$499,000	5
$500,000 or more	5
$\chi 2 = 7.7$, $P = 0.4633$	

*Respondents selected multiple options

**Respondents selected multiple options, answers totaled to 100%

Table 2.7. Most commonly grown cut flower crops in NC[1]

Genus	Common name	Response (%)
Zinnia	Zinnia	90
Helianthus	Sunflower	87
Celosia	Cockscomb	69
Lilium	Lily	69
Antirrhinum	Snapdragon	64
Iris	Dutch Iris	64
Consolida	Larkspur	62
Gomphrena	Globe Amaranth	62
Dianthus	Sweet William	62
Cosmos	Cosmos	56
Paeonia	Peony	54
Gladiolus	Gladiolus	54
Achillea	Yarrow	51
Ammi	False Queen Anne's Lace	49
Echinacea	Purple Cone Flower	46
Ageratum	Blue Flossflower	46
Hydrangea	Hydrangea	46
Limonium	Statice	46
Narcissus	Daffodil	46
Polianthes	Tuberose	44
Dahlia	Dahlia	44
Delphinium	Delphinium	44
Campanula	Bellflower	41
Lavandula	Lavender	38
Eustoma	Lisianthus	38
Salvia	Velvet Sage, Mexican Bush Sage	36
Tulipa	Tulip	36
Asclepias	Butterfly Weed	36
Solidago	Goldenrod	36
Buddleia	Butterfly Bush	33
Aster	Aster	33
Amaranthus	Love Lies Bleeding	33
Phlox	Garden Phlox	33
Nigella	Love-in-a-Mist	31
Allium	Ornamental Onion	26
Agrostemma	Agrostemma	26

[1]Over 75 species of cut flower crops were reported by the NC cut flower growers

CHAPTER 3

CUT FLOWER VARIETY PRODUCTION AND POSTHARVEST EVALUATION OF THE MOST COMMONLY GROWN CUT FLOWERS IN NC

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Abstract

The NC cut flower industry represents a small, but growing, segment of the state's floriculture industry. NC cut flower sales were valued at $6.8 million in 2012, up 70% from 2011. In 2012, we conducted a production and marketing survey of North Carolina cut flower growers. From the survey, we noted that NC farms are producing more than 75 different species of cut flowers, many of which are old favorite varieties. Thirty one cut flower cultivars that had not been previously evaluated at the Horticultural Field Lab in Raleigh, NC were selected for field production and postharvest vase life trials in 2012 and 2013. A subset of annual cut flower varieties were also grown at Mills River, NC in 2013. Mean number of stems per plant and mean stem length were recorded. Postharvest vase life was evaluated in four vase water treatments. The results of the NCSU cut flower trials benefit cut flower growers by helping them select the most productive, longest lasting cut flower varieties for their farms.

Introduction

The NC cut flower industry represents a small, but growing, segment of the state's floriculture industry. NC cut flower sales were valued at $6.8 million in 2012, up 70% from 2011 (USDA, 2012; 2013). Thirty years ago, more than 80% of domestic cut flower production consisted of just four species: carnations, chrysanthemums, roses and gladiolus. As these four species began to be imported at competitive prices, local growers began to seek alternative, specialty crops (Bonarriva, 2003). Today, specialty cut flowers account for over 80% of domestic production (Bachmann, 2006).

At first, a specialty cut flower was defined as anything other than carnations, chrysanthemums, roses or gladiolus (Armitage and Laushman, 2003). As the industry grew and cut flower products became more diversified, the definition of specialty cut flowers changed to flowers that are only available seasonally or for a short time period during the year (Armitage and Laushman, 2003). In NC, most specialty cut flowers are field grown (Granitz, 2014) and as a result are only available for a few months per year during the growing season. To help growers make economically sound choices about which varieties of specialty cut flowers to grow, NC State University floriculture program trials new and commonly grown varieties yearly and participates in the Association of Specialty Cut Flower Growers (ASCFG) national trials. The ASCFG trials evaluate promising new annual, perennial, and woody cut flower varieties across a wide range of environments and growing zones for production parameters such as stem length and stem number, hardiness, and overall vigor. In addition, the NCSU floriculture program performs stage I postharvest evaluations on ASCFG trial varieties. Stage I postharvest evaluation includes four treatments: hydrator, holding, hydrator and holding, and no floral water additives (deionized water only).

In 2012, we conducted a production and marketing survey of North Carolina cut flower growers (Granitz, 2014). From the survey, we noted that NC farms are producing more than 75 different species of cut flowers, many of which are old favorite varieties.

Many of the most commonly grown cut flowers from the survey had not been evaluated for productivity or postharvest performance.

The objective of this study is to conduct production, marketability, and postharvest evaluations on the most commonly grown cut flowers in NC. The results of the NCSU cut flower trials benefit cut flower growers by helping them select the most productive, longest lasting cut flower varieties for their farms.

Materials and methods

Field trials

In February 2012, we compiled a list of the 31 most commonly grown cut flower varieties obtained from responses to the 2012 Production and Marketing Survey of the North Carolina Cut Flower Industry (Granitz, 2014) that had not been field tested in Raleigh, NC. We sourced seeds, bulbs, bare root plants, and plugs from North Creek Nurseries, Grimes Horticulture, Johnny's Selected Seeds, W. Atlee Burpee & Co., Walters Gardens, Inc., Germania Seed Company, Brent and Becky's Bulbs, and Fred C. Gloeckner & Company Inc. (Table 3.1).

All seeds were planted directly in 48 cell trays filled with Jolly Gardener® Pro-Line 44N Custom Growing Mix. Trays were placed in a greenhouse at 21°C to germinate and fill out the cell packs. They were watered and fertilized with a constant liquid feed of J.R. Peters® 20N-4.4P-16.6K fertilizer. When plants were large enough for transplanting, they were moved outside for one week under a 50% shade cloth for hardening off. Orders of bulbs, bare root plants, and plugs were shipped to the NCSU Horticulture Field Lab (HFL), Raleigh, NC, planted directly into freshly tilled field beds and irrigated immediately after planting.

Trial varieties were planted in a completely randomized design with four replications. Each plot consisted of 16 plants in a 1.2 m by 1.2 m square. All plants were placed 30 cm apart. Beds were hand watered until the transplants were established, then irrigated as needed with drip irrigation. The beds were fertigated through the drip irrigation with Peter's 20N-4.4P-16.6K using a Dosatron® every other week.

In the 2012 growing season, weed pressure was high. We did not mulch the beds and an infestation of galinsoga (*Galinsoga parviflora*) required weekly hand-weeding of all the beds. In 2013, because of wet conditions in the spring at the time of tillage and transplant and high weed pressure, we mulched the beds with a half inch of composted leaves. This made a positive impact on weed pressure and any weeds that emerged were hand pulled.

All marketable flowers were cut, measured, and recorded in the field three days per week. Marketable flowers are defined as 30 cm or more in length with unblemished and unfasciated flowers. Unmarketable flowers (those that were less than 30 cm or had unacceptable flowers) were cut and discarded to prevent them from acting as a nutrient sink to the plant.

In summer 2013, the cut flower trial was repeated at the Horticulture Field Lab in Raleigh, NC using a subset of crops and varieties selected from the 2012 trial and the same production and postharvest testing methods. Annuals that produced an average of at least one marketable stem per plant in 2012 were seeded and transplanted in 2013. All surviving perennials from 2012 were left in the field for the 2013 growing season. An additional subset of 14 annual cut flowers were transplanted into a field at the Mountain Horticulture Crops Research and Extension Center (MHCREC) in Mills River, NC (Table 3.1) using the same production methods as at HFL. Postharvest testing was not made on the MHCREC plantings. Because of environmental differences between 2012 and 2013, and the number of varieties that died or did not produce marketable stems in 2013 at HFL and at MHCREC, only the mean data for number of stems per plant and stem length (cm) is presented.

Postharvest evaluations

The NC State University postharvest lab is kept at 21 ± 2 °C with 20 μmol$\cdot\mathrm{m}^{-2}\cdot\mathrm{s}^{-1}$ light for 12 h$\cdot\mathrm{d}^{-1}$ and 40%-60% relative humidity. These conditions simulate an average consumer's household. Stage one postharvest evaluation was conducted on all varieties that produced enough marketable stems. Stage one postharvest evaluation is a 2 X 2 factorial with four total treatment combinations: hydrator, holding, hydrator and holding, and deionized water. The cut flowers were sorted by head size or openness, depending on the species, to ensure uniform treatment groups. For example, cosmos or zinnia type flowers were sorted by how open the flower was. Celosia or amaranth type flowers were sorted by head size. Next, stems were cut to the same length to ensure that each flower had roughly the same amount of carbohydrate reserves in the stem. Then, they were tagged and grouped into four bundles of 15 stems for a total of 60 stems per variety. The vases were placed on tables in a completely randomized design.

The bundles were placed into the hydrator treatment, FloraLife Hydraflor / 100 Pretreatment (at 2 $mL \cdot L^{-1}$) or deionized (DI) water, for 4 h. Then they were transferred to the holding solution treatment, FloraLife Professional Fresh Flower Food (10 $mL \cdot L^{-1}$) or DI water, for 48 h. Once the pretreatments were finished, each stem was placed in its own mason jar with 300 ml of DI water. Stems were checked daily and terminated once they reached an agreed-upon stage of expiration specific for each variety. Vase life (termination date) was recorded for each stem and analyzed using analysis of variance (SAS Institute, Cary, NC) and means separation across treatments within varieties was conducted using Tukey's test at $P \leq 0.05$.

Results and discussion

Achillea 'Fireland'. 'Fireland' is the tallest of the two yarrows we trialed, with average stem lengths of 38 cm in 2012 and nearly 56 cm in 2013 (Table 3.1). It has tall, straight stems and muted, rusty red flower heads. 'Fireland' also produced more stems than the other yarrow. First year plants produced an average of 13 marketable stems per plant and the two year old plants tripled that number to 39 per plant (Table 3.1). Its paprika colored flowers were harvested when pollen was visible, the recommended cutting stage for achillea optimum vase life. Flowers were terminated at greater than 50% desiccated petals or wilted florets. 'Fireland,' had an average vase life of 6.8 d, and showed an average 2-day increase in vase life with the use of the holding solution versus DI water (Table 3.2).

Achillea 'Strawberry Seduction'. 'Strawberry Seduction' yarrow had fewer, shorter, sturdier stems than 'Fireland.' Second year plants averaged 26 marketable stems per plant, each around 43 cm long (Table 3.1). Its bright, strawberry red flowers were harvested when pollen was visible, the recommended cutting stage for optimum vase life. Flowers were terminated at greater than 50% desiccated petals or wilted florets. Its average vase life was 9.8 d and showed an average 2-day increase in vase life with the use of a holding solution versus water (Table 3.2).

Ageratum 'Blue Horizon'. This annual ageratum was grown from seed each year. Although average stem length was almost the same both seasons (37 cm), plants produced an average of 10 more stems the second year (31 per plant) than the first year (21 per plant). This is interesting because most cut flowers in our trials fared better during the hot, dry summer of 2012 than the cool, wet summer of 2013 (Table 3.1). 'Blue Horizon' was cut when more than half of the heads in the corymb were fuzzy and terminated when more than half of the florets were brown or wilted. The average vase life was 9.0 d and vase life was unaffected by preservatives (Table 3.2).

Agrostemma 'Purple Queen'. 'Purple Queen,' is the most commonly grown corncockle for cut flowers in NC. Grown from seed both years, stems averaged just over 43 cm tall. However, plants produced less than half the stems the second year than they did the first (Table 3.1) because of the cool, wet conditions. 'Purple Queen' produced an average vase life of 8.7 d when cut just after buds showed color (but before they opened). A hydrator plus a holding solution increased vase life by an average of 1.5 d over the hydrator solution only (Table 3.2).

Amaranthus 'Green Flowered'. Pendulous, spring green 'Green Flowered' amaranthus is commonly grown to hang over the bottom of cut flower arrangements. Grown from seed, stem length remained steady both years at around 63 cm at HFL. The plants averaged 10 marketable stems per plant in 2012, but production was just half that in 2013 (Table 3.1). Amaranthus 'Green Flowered' averaged 9.9 d in the vase. It lasted longer with the holding, hydrator and hydrator/holding solutions, which added an average of almost 3 d of vase life over the DI water (Table 3.2).

Amaranthus 'Hot Biscuits'. The upright, torch-type 'Hot Biscuits' amaranthus grew tall atop sturdy bronze stems. As its name implies, the inflorescence is a toasty brown hue. Unlike the multi-trunked 'Green Flowered,' this amaranthus produces one marketable stem per plant (Table 3.1). It had an average vase life of 9.3 d. It lasted longer with a combination of hydrator and holding solution, which added an average of 5.5 d of vase life over DI water (Table 3.2).

Ammi majus (species). The false Queen Anne's lace we tested is an old standby as frothy, lacy filler. However, there is one drawback to its cultivation. The sap causes skin to become photosensitive and blister in the sun and growers should make *Ammi* the last crop harvested before coming in from the field to minimize sun exposure on skin. Stems of *Ammi majus* averaged around 37 cm. Plants produced an average of only five marketable stems the first season (Table 3.1). A root rot killed the plants during 2013. Ammi flowers lasted an average of 10 d in the vase. Using a holding solution added 2 d over untreated stems (Table 3.2).

Asclepias 'Silky Formula Mix'. 'Silky Formula Mix,' with its tall, sturdy stems and enthusiastic production throughout the season, provided flowers into fall. The mix of oranges, deep reds, and yellows looked right at home in summer bouquets and autumn harvest arrangements alike. Stems averaged around 50 cm long. The first year of trials, we harvested 13 stems per plant, but the second year we only got four (Table 3.1). Overall, average vase life was over 11 d, and neither hydrating nor holding solution provided any significant increase (Table 3.2).

Aster 'Lady in Black'. This is a large, mounding perennial aster with deep purple foliage and a fine texture. 'Lady in Black' is used as a floral filler with its dark purple leaves and multitude of tiny pink flowers. Stems have a very sparse, open habit. As expected, second year plants were much larger in the field with an average stem length of nearly 79 cm (Table 3.1). It will last about 9 d in the vase regardless of treatment (Table 3.2).

Aster 'Vibrant Dome'. This is a small, mounded aster with vibrant purple blooms. Most stems were too short to be marketable (< 30 cm) the first year, and during 2013 all of the 'Vibrant Dome' plants died (Table 3.1). However, with favorable weather this perennial cultivar is expected to produce marketable stems during its second year of production. North Creek Nurseries, where the plugs were purchased, estimates its established height to be 50 cm. 'Vibrant Dome' would benefit from further trials.

Astilbe 'August Light'. All of the astilbes in our trials were planted bare root in the field the first year, wintered over, and then tested the second year. This astilbe bloomed both the first and second seasons. Predictably, stems were an average 12 cm longer the second year than the first (Table 3.1). It had an average vase life of 6.2 d, but it lasted an average of 3 d longer with a holding treatment (Table 3.2).

Astilbe 'Bridal Veil'. This white astilbe bloomed both the first and second years of our trial. Stems were much taller and more prolific the second year (Table 3.1). 'Bridal Veil' flowers had the most open habit of the three astilbes. It had an average vase life of 5.1 d and lasted about 2 d longer with a holding treatment (Table 3.2).

Astilbe 'Fanal'. 'Fanal' did not bloom the first year. However, the cool, rainy spring the second year of trials encouraged a nice showing. It produced an average of five, 50 cm stems per plant (Table 3.1). 'Fanal' lasted a little over 5.4 d in deionized water only and an average of 2 d longer with a holding treatment (Table 3.2).

Cosmos 'Double Click'. Cosmos 'Double Click' flowered all season long. Growers can expect an abundance of stems around 35 cm tall (Table 3.1). Flowers were cut as soon as the buds began to open and before petals unfurled. Cosmos's reputation for having a short vase life holds true for 'Double Click.' It lasted an average of only 5.3 d and performed similarly across treatments (Table 3.2).

Cosmos 'Sonata Mix'. 'Sonata Mix' features large, single flowers in clear colors atop compact plants. Many stems were too short to be marketable in both 2012 and 2013 (Table 3.1). This cosmos was highly susceptible to powdery mildew. 'Sonata Mix' was cut as soon as the bud began to open and before petals unfurled. The flowers lasted an average of 7.9 d and was unaffected by treatments. Among the three cosmos trialed, 'Sonata Mix' had the longest vase life (Table 3.2).

Cosmos 'Versailles'. 'Versailles' was the largest cosmos of the three cultivars trialed. By the end of the season, it had very large trunks up to 5 cm wide at the base. Most of its single flowers were lavender, but were some pink and white. 'Versailles' was the only cosmos that produced more stems per plant the second year than the first (Table 3.1). Cosmos were cut as soon as the bud began to open and before petals unfurled. Cosmos's reputation for having a short vase life holds true for 'Versailles.' It lasted an average of only 5.7 d and performed similarly across treatments (Table 3.2).

Dianthus 'Amazon Neon Duo'. 'Amazon Neon Duo' has neon purple and pink flowers atop strong, long stems. The first season, it produced five, 35 cm stems per plant. Because of wet conditions, all plants died in 2013 (Table 3.1). Dianthus was cut when more than three florets were open per flower head. Flowers were terminated when more than 50% of flowers were desiccated or had fallen off. 'Amazon Neon Duo' was among the longest lasting cut flowers in our trial. The flowers lasted an average of 15 d in the vase and was unaffected by treatments (Table 3.2).

Helianthus 'Sonja'. 'Sonja' is a miniature sunflower perfect for smaller arrangements and bouquets. It has small heads with black disc flowers and yellow rays. It can be cut as short, single flowers or as a spray of flowers. We harvested it as a spray and therefore obtained one stem per plant (Table 3.1). 'Sonja' lasted on average 8.5 d after harvest and performed similarly across treatments (Table 3.2).

Lilium 'Concad'or'. This lily has very large white flowers with butter yellow centers. Strong stems bear three to five flowers per stalk. Lilies were field grown in 2012 only. The emerging stems of these lilies were particularly attractive to Canada geese and some of the bulbs were pulled up out of the ground. In 2013, lilies were grown in crates that were set on the ground outside. The stems were cut when buds began to color up, but were not yet open. Blooms were terminated when most petals were abscised. The flowers lasted about 12 d (Table 3.2). 'Concad'or' was unaffected by treatments, probably due to the fact that we used general floral preservatives. In other tests, lilies respond very well to flower foods specifically designed for lilies, which keep the foliage green and allow the buds to open up (Amjad and Ahmad, 2011).

Lilium 'Merostar'. 'Merostar' had smaller flowers than 'Concad'or' and four to six flowers per stalk. Its flowers were deep pink with white tips and darker pink spots in the throat similar to 'Stargazer.' Stems were cut when buds began to color up, but were not yet open. Blooms were terminated when most petals were abscised. 'Merostar' flowers lasted about 13.6 d after harvesting (Table 3.2). The flowers were unaffected by the floral preservatives used in this study.

Nigella 'Miss Jekyll Blue'. These sky blue flowers are very quick to shatter in the vase. It may be advisable to grow the variety for its green and purple striped dried pods rather than as a cut flower. The pods last indefinitely and their distinctive purple stripes stay true after drying. 'Miss Jekyll Blue' harvested at pod stage from a different experiment is still looking great nine months later (personal observation). No data was gathered in 2013 because all plants died in the field (Table 3.1). In postharvest, the opened flowers shattered almost immediately, but the buds in the spray still opened and that helped extend vase life to 6.3 d. Performance was the same across all four treatments (Table 3.2).

Phlox 'David'. 'David' is common in the garden due to its powdery mildew resistance, and it makes a great cut flower as well. No powdery mildew was observed the first year and only a little was noted during 2013. Its large, white, fragrant, cloudlike panicles perch atop long sturdy stems. No marketable stems were harvested until the second year (Table 3.1).

Vase life was, on average, 10.6 d. Hydrating and holding treatments had no significant effects (Table 3.2).

Salvia 'Caradonna'. This perennial salvia produced many spikes of vivid purple spires its second year in the field. Stems averaged just over 37 cm in length (Table 3.1). Most flowering occurred in spring and fall. A vase life of 8.1 d was observed in deionized water and the holding solution increased vase life around 1.5 d (Table 3.2).

Scabiosa 'Black Knight'. 'Black Knight' is not a large flowered scabiosa cultivar like those in the 'Fama' series, yet it makes a large impact on arrangements 'Black Knight' was prolific in the first growing season, but many died in 2013 (Table 3.1). Stems averaged about 38 cm long. It fared well with an average 8.1 d vase life. Performance was the same across all four treatments (Table 3.2).

Scabiosa 'Olympia Mix'. 'Olympia Mix' has blooms that are slightly larger than 'Black Knight', with colors that range from white to pale pink to lavender to a deep purple. Seed was discontinued the second year, so we only have one year of production data (Table 3.1). 'Olympia Mix' averaged 6.8 d in the vase and there was no difference among treatments (Table 3.2).

Solidago 'Fireworks'. 'Fireworks' is a common garden flower in North Carolina. This is a tall, rugged goldenrod with an open, vase-like shape and deep yellow flowers. Its open habit and hardy disposition make it an easy choice for growers. The large inflorescence can be used as a filler flower. It produced nine marketable stems per plant in its first year in the field, and fifty stems per plant the second year (Table 3.1). Using a combination of hydrating and holding solutions, vase life increased from 6.7 d in DI water to 9.1 d (Table 3.2).

Solidago 'Little Lemon'. 'Little Lemon' is a compact, mounding goldenrod with shorter, fuller sprays than 'Fireworks.' Its flowers are a lemon yellow and have an ombre effect, lightening as they age. 'Little Lemon' bloomed well the first year although many stems were too short to count (Table 3.1). They most likely would have been taller the second year, but all of the plants died. This cultivar is promising for cut flower production and would benefit from further trials.

Zinnia Benary's 'Blue Point Golden Yellow'. 'Blue Point Golden Yellow' is a large flowered, long stemmed zinnia with clear yellow flowers. Flowers were harvested when disk flowers opened and terminated when more than 50% of ray petals shriveled or if the neck bent to less than a 90° angle. 'Blue Point Golden Yellow' outlasted the other zinnias with an average vase life of 7.2 d and performed best when treated with a holding solution (Table 3.2).

Zinnia Benary's 'Blue Point Lilac'. 'Blue Point Lilac' has large flowers and long stems. Colors varied slightly in intensity, but all would be considered lilac. Flowers were harvested when disk flowers opened and terminated when more than 50% of ray petals shriveled or if the neck bent to less than a 90° angle. 'Blue Point Lilac' had an average 6.7 d vase life and performed best when treated with a holding solution (Table 3.2).

Zinnia Benary's Blue Point Salmon Rose'. 'Blue Point Salmon Rose' is a tall, large flowered zinnia with dusty pink or salmon heads. Flowers were harvested when disk flowers opened and terminated when more than 50% of ray petals shriveled or if the neck bent to less than a 90° angle. It lasted an average of 6.5 d in the vase and performed best when treated with a holding solution (Table 3.2).

Zinnia Benary's 'Giant Deep Red'. 'Giant Deep Red' has large, uniform heads of a crimson color. Flowers were harvested when disk flowers opened and terminated when more than 50% of ray petals shriveled or if the neck bent to less than a 90° angle. 'Giant Deep Red' lasted 5.6 d in the vase and performed best when treated with a holding solution (Table 3.2).

Mountain Horticultural Crops Research and Extension Center (MHCREC) Trials.

Of the 14 annuals planted at MHCREC in 2013, three produced no marketable stems (Table 3.1). The remaining 11 varieties had stem lengths similar to those grown at HFL, with the exception of Amaranthus 'Green Flowered', which were shorter. However, because of the wet and cooler weather in Mills River throughout the growing season, the varieties produced low numbers of stems per plant. According to the National Oceanic and Atmospheric Association (NOAA), the MHCREC plot received 40.47 inches of precipitation between planting in May and terminating the study in September. Average daily temperatures in July and August were 73.5°F and 71.5°F, respectively.

Conclusions

Production and postharvest trials benefit cut flower growers by saving them time and money, two of the most valuable factors in any business. Rather than learning from trial and error, growers can access trial results and use them to make decisions about what crops to grow and how to treat these crops after harvest. New introductions are commonly trialed before or soon after introduction to the marketplace, but old favorites are often overlooked. Some of the most commonly produced cut flowers listed in the 2012 production and marketing survey of NC cut flower growers (Granitz, 2014) had never been evaluated for productivity or postharvest performance. Production, marketability, and postharvest evaluations benefit cut flower growers by helping them select the most productive, longest lasting cut flower varieties for their farms.

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Table 3.1. Mean stem length and number of stems per plant of varieties included in 2012-2013 cut flower production and postharvest evaluations at HFL, Raleigh and MHCREC, Mills River, NC

		Raleigh 2012	Raleigh 2013	Mills River 2013	Raleigh 2012	Raleigh 2013	Mills River 2013
Genus 'Variety'	Propagule	Mean stem length (cm)[1]			Mean no. stems/plant		
Achillea 'Fireland'	Plugs	38.05	55.63	NP	13	39	NP
Achillea 'Strawberry Seduction'	Plugs	32.48	42.93	NP	7	26	NP
Ageratum 'Blue Horizon'	Seed	37.33	36.83	34.80	21	31	2
Agrostemma 'Purple Queen'	Seed	43.46	43.94	-	13	6	-
Amaranthus 'Green Flowered'	Seed	64.69	61.72	40.89	10	5	<1
Amaranthus 'Hot Biscuits'	Seed	58.40	75.95	-	1	1	-
Ammi majus (species)	Seed	37.57	36.83	NP	5	-	NP
Asclepias 'Silky Formula Mix'	Seed	48.34	56.64	43.70	13	4	3
Aster 'Lady in Black'	Plugs	48.28	78.99	NP	20	24	NP
Aster 'Vibrant Dome'	Plugs	34.02	-	NP	1	-	NP
Astilbe 'August Light'	Bare root	38.50	52.32	NP	2	3	NP
Astilbe 'Bridal Veil'	Bare root	42.65	61.47	NP	2	5	NP
Astilbe 'Fanal'	Bare root	-	51.82	NP	-	5	NP
Cosmos 'Double Click'	Seed	36.53	35.31	37.08	62	47	9
Cosmos 'Sonata Mix'	Seed	33.86	35.56	34.29	21	8	2
Cosmos 'Versailles'	Seed	38.95	38.61	37.59	21	73	11
Dianthus 'Amazon Neon Duo'	Seed	36.45	-	-	5	-	-
Helianthus 'Sonja'	Seed	57.90	46.74	NP	1	1	NP
Lilium 'Concad'or'	Bulbs	47.45	45.72	NP	1	1	NP
Lilium 'Merostar'	Bulbs	42.70	62.23	NP	1	1	NP
Nigella 'Miss Jekyll Blue'	Seed	34.01	-	NP	4	-	NP
Phlox 'David'	Plugs	-	40.64	NP	-	1	NP
Salvia 'Caradonna'	Plugs	36.41	38.10	NP	2	23	NP
Scabiosa 'Black Knight'	Seed	37.90	37.34	40.13	27	3	<1
Scabiosa 'Olympia Mix'	Seed	37.38	NP	NP	19	NP	NP
Solidago 'Fireworks'	Plugs	55.46	68.33	NP	9	50	NP
Solidago 'Little Lemon'	Plugs	-	-	NP	-	-	NP
Zinnia 'Benary's Blue Point Golden Yellow'	Seed	39.03	37.08	38.86	30	24	7
Zinnia 'Benary's Blue Point Lilac'	Seed	40.49	38.10	37.34	22	20	4
Zinnia 'Benary's Blue Point Salmon Rose'	Seed	38.63	37.34	37.85	24	20	5
Zinnia 'Benary's Giant Deep Red'	Seed	39.31	38.10	36.83	18	16	3

- Plants did not produce marketable stems

Table 3.2. Mean vase life of cut flower varieties from the 2012-2013 HFL cut flower production HFL with four postharvest treatments

	Vase Life (days)			
Genus 'cultivar' or *species*	Deionized water	No hydrator/ holding	Hydrator/ no holding	Hydrator/ holding
Achillea 'Fireland'	6.4bc[2]	8.5a	5.0c	7.4ab
Achillea 'Strawberry Seduction'	8.8c	11.1a	8.5c	10.6ab
Ageratum 'Blue Horizon'	8.9a	9.9a	8.2a	9.2a
Agrostemma 'Purple Queen'	8.2ab	9.2ab	7.9b	9.5a
Amaranthus 'Green Flowered'	6.0b	9.2a	8.6ab	9.5a
Amaranthus 'Hot Biscuits'	6.6c	10.3ab	8.2bc	12.0a
Ammi majus[1]	8.5b	10.6a	9.5ab	10.9a
Asclepias 'Silky Formula Mix'	9.9a	12.2a	10.1a	12.0a
Aster 'Lady in Black'	8.3b	9.7ab	10.2a	9.4ab
Astilbe 'August Light'	4.6b	7.6a	4.6b	8.0a
Astilbe 'Bridal Veil'	4.5bc	6.7a	3.9c	5.6ab
Astilbe 'Fanal'[1]	5.4c	7.7a	5.8bc	7.4ab
Cosmos 'Double Click'	5.0a	5.9a	5.2a	5.6a
Cosmos 'Sonata Mix'	7.4a	8.4a	7.2a	8.6a
Cosmos 'Versailles'	5.2a	6.1a	5.6a	5.8a
Dianthus 'Amazon Neon Duo'[1]	15.4a	15.0a	14.3a	15.2a
Helianthus 'Sonja'	7.6a	8.6a	8.7a	9.1a
Lilium 'Concad'or'	12.0a	12.1a	12.0a	11.9a
Lilium 'Merostar'	13.9a	13.5a	13.6a	13.2a
Nigella 'Miss Jekyll Blue'[1]	6.1a	6.3a	6.5a	6.1a
Phlox 'David'[1]	10.8a	11.1a	9.9a	10.8a
Salvia 'Caradonna'	8.1b	9.7a	8.9ab	9.2a
Scabiosa 'Black Knight'	7.9a	8.6a	8.2a	7.8a
Scabiosa 'Olympia Mix'[1]	5.8a	6.9a	6.8a	7.8a
Solidago 'Fireworks'	6.7b	8.4a	8.5a	9.1a
Zinnia 'Benary's Giant Deep Red'	4.4b	6.5a	4.7b	6.6a
Zinnia 'Blue Point Golden Yellow'	5.2b	9.1a	5.6b	9.2a
Zinnia 'Blue Point Lilac'	5.2b	7.7a	5.2b	8.5a
Zinnia 'Blue Point Salmon Rose'	5.3b	8.0a	5.1b	7.8a

[1]Denotes cultivars with only one year of postharvest data
[2]Mean separation (in rows) by Tukey's test at $P \leq 0.05$

CHAPTER 4

PREEMERGENCE HERBICIDE AND MULCH EVALUATIONS ON COMMONLY GROWN NORTH CAROLINA SPECIALTY CUT FLOWERS

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Abstract

North Carolina has a thriving floriculture industry with sales that are fifth in the United States. In 2012, cut flower sales (from farms with $10,000 or more in sales) were valued at $6.8 million, up 70 percent from 2011. The objectives of this research were to expand the weed control options for cut flower growers by 1) increasing the number of preemergence herbicides labeled for cut flower species; 2) documenting the effects of weed competition on cut flower production, and 3) comparing the safety and efficacy of a herbicide-impregnated mulch with other weed control treatments. Weed competition in weedy check plots greatly impacted plant quality and marketable stem production. Weed control provided by hardwood mulch was comparable to that of the least effective herbicide tested. Herbicide-impregnated mulch, Preen Mulch Plus, provided over 90% weed control and was among the top performing treatments in the study. Pendulum 2 GR, Snapshot 2.5 G, Preen Southern Gardens 0.27 GR, Barricade 4 L, and Preen Mulch Plus (trifluralin 0.0032% and isoxaben 0.0008%) did not injure Ammi, Platycodon and Eryngium. Freehand 1.75 G and Pennant Magnum 7.62 EC were safe on Ammi and Platycodon but caused injury to Eryngium and Amaranthus. Amaranthus was also injured by Barricade 4 L. Nigella was injured by Snapshot 2.5 G, Freehand 1.75 G, and Barricade 4 L. All treatments appeared safe on Solidago.

Introduction

North Carolina has a thriving floriculture industry with sales that are fifth in the United States (USDA, 2013). The cut flower industry represents a small, but growing, segment of the state's floriculture industry. North Carolina cut flower sales (from farms with $10,000 or more in sales) were valued at $6.8 million in 2012, up 70 percent from 2011 (USDA, 2012; 2013). Thirty years ago, more than 80% of domestic cut flower production consisted of just four species: carnations, chrysanthemums, roses and gladiolus. As these four species began to be imported at competitive prices, local growers began to seek alternative, specialty crops (Bonarriva et al., 2003). At first, a specialty cut flower was defined as anything other than these four species (Armitage and Laushman, 2003) As the industry grew and cut flower products diversified, the definition of specialty cut flowers changed to mean flowers that are only available seasonally or for a short time period during the year (Armitage and Laushman, 2003). Many specialty cut flowers are field grown, and thus, only available for a few months per year during the growing season. Today, specialty cut flowers account for over 80% of domestic cut flower production (Bachmann, 2006).

Varieties of cut flowers commonly grown in NC are diverse and change quickly from year to year to keep up with trends and consumer demand. The top ten cut flowers grown in NC are zinnia, sunflower, celosia, lily, snapdragon, Dutch iris, larkspur, gomphrena, dianthus, and cosmos. Some NC producers will field grow more than 40 cut flower varieties each season (Granitz, 2014).

Whether farms employ conventional or organic systems, weed management is time consuming and contributes greatly to labor costs (Weddington, 2003; Rutgers, 2013). Physical barriers such as plastic or organic mulch help control weeds across a wide variety of species. Mulches shade the soil and help prevent weed seed germination, plus they have the added benefit of also preventing water evaporation from the soil surface (Kumar and Las, 2012). However, little research has been published to compare the effectiveness of mulch as a weed control treatment in field grown cut flowers. Mulched field grown wild flowers have been shown to have quicker growth and canopy establishment than plants in non-mulched soil (Harkess and Lyons, 1997). In some cases, mulches applied on top of preemergence herbicides have resulted in taller plants overall (Kuhns, 1992), which is desirable in cut flower production. Among all weed control practices (organic and conventional), 74% of NC cut flower growers use organic mulches such as bark, straw, leaf mold or hardwood mulch, and 95% pull weeds by hand (Granitz, 2014).

Because NC producers typically grow a wide variety of different cut flower species, determining an appropriate chemical weed control plan can be problematic. Until recently, the fumigant methyl bromide was widely used in conventional systems as a pre-plant soil sterilant to control weed seeds and other soil-borne pests (Klose et al., 2007). However, because of environmental concerns, the use of methyl bromide is highly restricted (Kolbe, 2013). Other soil fumigants are expensive and not as versatile or effective, and are thus not widely used in cut flower production. From the NC cut flower industry survey (Granitz

2014), only 3% of NC cut flower growers use any soil fumigants to control soil-borne pests before planting.

Traditional approaches to weed management in annual and perennial crops include the use of preemergence and postemergence herbicides. Many herbicides are labeled for use on woody and herbaceous ornamentals in nursery and landscape sites. However, the response of many cut flower species to herbicides is not well known (Senesac and Neal, 2012). Because herbicides can cause stunting, epinasty, and yellowing in some species (Smith and Taylor, 1997; Neal, 1997), growers must be careful selecting appropriate herbicides for the crops they plan to cultivate. Even minor stunting or physical blemishes from herbicide injury can render an entire cut flower crop unmarketable. Because of these concerns, it is difficult for growers to find an effective herbicide that is also safe on the majority of their cut flower crops. Of the cut flower species commonly grown in NC, several have preemergence herbicide options available. For example, zinnia is listed on the labels of Dacthal, Devrinol, Freehand, Pendulum 2G, Pennant Magnum, Snapshot, Surflan, Preen Southern Gardens, and Treflan (Senesac and Neal, 2012). However, few or no herbicides are labeled for use on many important specialty cut flower species including love lies bleeding *(Amaranthus caudatus*), false Queen Anne's lace *(Ammi majus*), sea holly (*Eryngium planum*), love in a puff *(Nigella damascena*), balloon flower *(Platycodon grandiflorus*), and goldenrod *(Solidago rugosa*). The cut flower species used in this study were chosen based on two main criteria; first, they are commonly grown in NC, and second, there are currently few or no preemergence herbicides labeled for use on these crops (Appendix A).

For growers to utilize herbicides in cut flower production, it is essential to determine the safety of herbicides on these species. Several factors were taken into consideration to determine which preemergence herbicides to include in this study. First, those with efficacy across a broad range of weeds and already labeled for other cut flower crops were selected. These include Pendulum 2G (pendimethalin), Snapshot TG (isoxaben + trifluralin), Preen Southern Gardens (dithiopyr GR), and Barricade 4L (prodiamine) (Appendix A). Each of these herbicides is labeled for use in ornamental landscape plantings, including several herbaceous ornamentals. Pendulum 2G and Preen Southern Gardens are both granular herbicides that list a greater number of cut flower species on their labels than Snapshot or Barricade (Appendix A). Barricade is a spray-applied formulation that is widely used in landscape plantings but is not currently labeled for common cut flower species. Snapshot TG provides a broader spectrum of weed control compared to Pendulum, Preen Southern Gardens or Barricade, but is labeled for use on few annual cut flower species.

Yellow nutsedge (*Cyperus esculentus*) is a common weed in North Carolina with limited management options (Rutgers, 2013), and a production constraint for some cut flower growers (Granitz, 2014). Freehand (dimethanamid-p + pendimethalin) and Pennant Magnum (s-metolachlor) have been shown to suppress yellow nutsedge (Patton and Daniel, 2012). These herbicides are labeled for use on many woody ornamental plant species but their safety to cut flower species is not well studied.

Broad spectrum weed control is desirable but, in general, herbicides that provide a broader spectrum of weed control will also tend to cause injury on a greater number of herbaceous ornamentals. For example: Snapshot TG applied at the labeled rates has been shown to injure some herbaceous perennials (Derr, 1994). Samtani et al. (2007) reported that using organic matter as a carrier for preemergence herbicides can alleviate phytotoxic effects of preemergence herbicides in some cases. Preen Mulch Plus is a commercially available wood chip mulch impregnated with trifluralin and isoxaben, the same active ingredients as Snapshot TG. However, no research reports are published on the safety of this herbicide impregnated mulch on herbaceous ornamental plants or its efficacy on common weeds.

The objectives of this research were to expand the weed control options for cut flower growers by increasing the number of preemergence herbicides labeled for cut flower species; to document the effects of weed competition on cut flower production, and to compare the safety and efficacy of a herbicide-impregnated mulch.

Materials and methods

Field Trials 2012

Greenhouse grown, 48 cell plug flats of Ammi ‘Green Mist,’ Nigella ‘Miss Jekyll Blue,’ Eryngium ‘Blue Glitter,’ Agrostemma ‘Purple Queen,’ Platycodon ‘Sentimental Blue,’ and Solidago ‘Little Lemon’ were transplanted into freshly tilled soil at the Horticultural Field Lab (HFL) in Raleigh, NC on May 21, 2012. Prior to planting, a soil test was performed and composted leaves were incorporated to increase the organic matter content in the soil. Planting beds were raked smooth and all large plant material and rocks were removed to ensure even weed control treatment application. Treatments were arranged in a randomized complete block design with 13 treatments and 4 replications. Each experimental unit contained four plants of each of the six species. Plants were spaced 30 cm apart and were hand watered after planting.

Herbicide treatments included Pendulum 2 GR, Snapshot 2.5 G, and Freehand 1.75 GR, each applied at the manufacturer’s labeled dose and twice that dose. Preen Southern Gardens, Barricade, and Pennant Magnum were applied only at the labeled rate. The herbicide active ingredients, formulations and doses are listed in Table 4.1.   All herbicides were applied after foliaged had dried. Granular treatments were applied in pre-weighed aliquots using a hand-held shaker jar. Spray-applied herbicides were applied using a CO2 pressurized sprayer equipped with flat fan nozzles and calibrated to deliver 30 GPA at 40 PSI. Treatments also included bagged hardwood mulch applied to a 1-inch layer (approximately 1 cu ft per sq meter), and Preen Mulch Plus, a hardwood mulch impregnated with isoxaben + trifluralin, the same active ingredients in Snapshot TG.

Weed control was evaluated 4 weeks after treatment (WAT) using a rating scale of 0 to 10, where 0 = no control and 10 = complete control. Approximately 4 WAT, the weeds were pulled and weighed; subsequently all plots except for the weedy check were hand weeded bi-weekly.

Cut flower plant quality ratings (CFQ) using a 0 to 5 rating system similar to the one used by judges in the All-America Selections trials (All-America, 2014), where 0 = dead plants and 5 = the healthiest plants, were recorded at approximately 4 and 6 WAT. Percent leaf area showing necrosis was recorded 1 WAT on Eryngium 'Blue Glitter', the only species to exhibit treatment-related leaf necrosis.

When the flowers were ready to harvest, each marketable stem of Ammi, Nigella, Eryngium, and Solidago was cut and measured. Marketable stems were those equal to or greater than 30 cm in length. Platycodon 'Sentimental Blue' was not tall enough to meet this criteria for marketable stems. Plant height was measured throughout the season, and blooms were counted as they opened and then removed.

Field Trial 2013

In 2013, Eryngium 'Blue Glitter,' Platycodon 'Fuji Pink,' and Nigella 'Miss Jekyll Blue' were planted into freshly tilled soil at HFL on May 29, 2013 following the same planting method and experimental design as in 2012. Solidago 'Fireworks' and Ammi 'Green Mist' were planted on July 18, 2013 using the same planting method and experimental design.

Treatments were the same as in 2012 except Freehand and Pennant Magnum treatments were not applied to Eryngium because of severe injury to these species from these treatments in 2012 (Table 4.1). Also, the weedy check was omitted. Evaluations of foliar necrosis, plant quality and marketable stems were recorded as previously described. In 2012, visual evaluations for weed control and above ground fresh weights of weeds were negatively correlated (R = -0.99); therefore, in 2013 only visual evaluations of weed control were recorded.

Amaranthus Container Trial 2012

Amaranthus 'Green Flowered' plugs were planted into 3.8 L (trade #1) pots on June 5, 2012 at the Horticulture Field Lab in Raleigh, NC. The potting substrate was hammer milled pine bark amended with Osmocote Pro 17N-5P-11K slow release fertilizer at 12 lbs/yd^3 (7.1 kg/m^3). Plants were hand watered after planting then received about 1.6 cm a day of overhead irrigation, applied in three equal increments morning, mid-day and afternoon.

Herbicide treatments were applied after transplanting using a randomized complete block design with 4 replications (Table 4.1). Because there was no existing weed seed bank in the potting substrate, there was very little weed infestation in the containers. CFQ ratings were taken approximately 2, 3, and 6 weeks after treatment using a 0 to 5 rating system, where 0 = dead plants and 5 = the healthiest plants. When flowers were ready to harvest, each marketable stem of Amaranthus was cut, measured, and recorded.

Statistical analysis

Data were subjected to analysis of variance using the ARM 7 statistical analysis program by species and year. Means were separated using least significant difference (LSD) at $P \leq 0.05$. The effects of weed competition on marketable stems was analyzed separately. Data for hand weeded and weedy check plots were compared using Proc GLM (SAS 9.2) using species and weed control treatment as the main effects.

Results and discussion

Efficacy of weed control treatments in 2012 and 2013 field trials

The dominant weed in the field trials for both years was redroot pigweed (*Amaranthus retroflexus* L.). In 2012, there was a strongly negative correlation (R = -0.99) between visual ratings and weed fresh weights; therefore weed fresh weights were not recorded in 2013. Pigweed control across all treatments, except hardwood mulch, was lower the second season than the first (Table 4.3). In the 2013 growing season (May through August), the prevailing weather was an average of 3^{o} F cooler and over 7 inches more rainfall than in 2012, according to the National Oceanic and Atmospheric Association (NOAA). It is likely that cooler, moister conditions resulted in more pigweed germination and growth. Of the herbicide treatments, Preen Southern Gardens had the lowest pigweed control, 70% and 45% in 2012 and 2013, respectively (Table 4.3). Labeled rates of Pendulum, Snapshot TG, Freehand, Barricade, Pennant Magnum, and Preen Mulch Plus provided equivalent pigweed control both years. Hardwood mulch provided only 75% pigweed control in 2012, but 93% control in 2013.

Effects of weed competition on cut flower marketable stems, 2012

Weeds, predominately redroot pigweed, grew more rapidly and taller than all of the cut flower plants tested, yet cut flower species responded differently to weed competition. Ammi plants produced over 13 marketable stems per plant in the hand-weeded plots, but less than 1 stem per plant in the weedy checks (Table 4.2). In contrast, the numbers of Nigella and Solidago stems longer than 30 cm were not significantly different in weedy and hand weeded plots. However, stem and plant quality were reduced in Solidago. Since Nigella is an early flowering crop, there was not as much time for the pigweed to take over the plants and compete for sunlight, water and nutrients as in later flowering crops such as solidago.

Cut Flower Plant Quality (CFQ) Response to Weed Control Treatments

Amaranthus 'Green Flowered' Container Trial

Freehand and Barricade each reduced Amaranthus 'Green Flowered' CFQ, number of stems, and stem length (Table 4.4). Pennant Magnum, Pendulum at 6 lb ai/a; and Snapshot at 5 lb ai/a each reduced CGQ, but not stem numbers or stem length. Lower, labeled doses of Pendulum and Snapshot TG did not affect CGQ or stem counts or length.

Ammi 'Green Mist' Field Trial

Ammi 'Green Mist' CFQ was unaffected by herbicide or mulch treatments (Table 4.5). However, plants treated with Preen Southern Gardens had fewer and shorter stems in 2012. No other treatment reduced stem length or number compared to the hand weeded plots. In 2013, several herbicide treatments increased stem length compared to the hand-weeded plots. These data support registration of Pendulum 2 GR, Snapshot 2.5 G, Freehand 1.75 GR, Barricade 4 L, Pennant Magnum 7.62 EC and Preen Mulch Plus (trifluralin 0.0032% and isoxaben 0.0008%) for use on Ammi 'Green Mist' (Table 4.10). These data also demonstrate that although hardwood mulch did not control weeds as well as herbicide treatments, Ammi stem number and length in mulched plots were similar to those in all other treatments except Preen Mulch Plus. This despite the fact that Ammi appears to be more sensitive to weed competition than other species included in the trial (Table 4.4)

Eryngium 'Blue Glitter' Field Trial

In 2012, Eryngium 'Blue Glitter' was particularly sensitive to Freehand and Pennant Magnum. Both caused malformed leaves and stunting of Eryngium plants. Pennant Magnum treated plants had necrotic lesions on 10% of leaves 1 WAT and continued to have lower CFQ ratings throughout the growing season (Table 4.6). Injury from Freehand treatments was not immediately noticeable, but CFQ decreased over time and with increased Freehand dose Due to this observed injury, Freehand and Pennant Magnum treatments were omitted from the treatment list in 2013 (Table 4.6). In 2012, plants in hardwood mulch had higher CFQ ratings compared to most herbicide treatments. This trend was not observed in 2013, potentially due to the moister and cooler weather. Less than half of the plants in the trial produced stems, thus no cut stem data were recorded. These data would support registration of Pendulum 2G, Snapshot TG, Preen Southern Gardens, Barricade 4L, and Preen Mulch Plus for use with Eryngium 'Blue Glitter' (Table 4.10), yet additional research is needed to determine if treatments affect marketable stems.

Nigella 'Miss Jekyll Blue' Field Trial

In 2013, Nigella 'Miss Jekyll Blue' had poor survival, likely due to the cooler and moist weather conditions resulting in crown or root rot. Therefore, data are available for the 2012 season only. In 2012, plants in hardwood mulch had higher marketable stems per plant compared to hand weeded plots. This is thought to be due to the fact that Nigella is an early spring, cool season ornamental, and the mulch shaded the roots and lowered soil temperatures. Preen Mulch Plus plots averaged 11 marketable stems per plant compared to 16 in the hardwood mulch. Data trends suggest that higher doses of some herbicides could reduce plant quality and stem numbers but plant responses were too variable to allow for statistical separation of treatments. These results should be confirmed with an additional testing.

Platycodon 'Sentimental Blue' and 'Fuji Pink' Field Trial

Two platycodon cultivars were evaluated. 'Sentimental Blue' is a dwarf variety that was planted as plugs in 2012. Pennant Magnum caused necrotic lesions on 'Sentimental Blue' within 3 days of application; however, it did not have long term effects on CFQ or on the number of flowers (Table 4.8). In 2013, 'Fuji Pink' was selected for its longer stems and better cut flower attributes. No damage from Pennant Magnum was observed on Platycodon 'Fuji Pink'. In 2012, the Platycodon 'Sentimental Blue' plugs were greenhouse-grown and had active growth at the time of treatment. In 2013, Platycodon 'Fuji Pink' was planted as bare-root liners and not actively growing at the time of treatment. The differences in acute injury following treatment are likely due to the presence or absence of tender new growth at the time of application, rather than cultivar differences. Calkins (1996) showed that dormant plants suffer less herbicide toxicity than actively growing ones. In 2012, plants treated with the high rates of Pendulum and Freehand had lower CFQ ratings compared to the hand weeded and mulched checks, but this effect was not observed in 2013, nor did Pendulum decrease the number of marketable stems in either year (Table 4.8). Pendulum 2 GR, Snapshot 2.5 G, Freehand 1.75 GR, Preen Southern Gardens 0.27 GR, Barricade 4 L, and Preen Mulch Plus (trifluralin 0.0032% and isoxaben 0.0008%) appear to be safe for use on Platycodon 'Sentimental Blue' and 'Fuji Pink.' Pennant Magnum 7.62 EC appears safe on Platycodon when applied before leaves emerge (Table 4.10).

Solidago 'Little Lemon' and 'Fireworks' Field Trial

Two cultivars of solidago were evaluated. In 2012, Solidago 'Little Lemon' was planted. Overall CFQ ratings of Solidago 'Little Lemon' was slightly impacted by the high rate of Freehand, but the plants recovered (Appendix H) and there were no significant differences between the number of stems per plant or stem length among any of the treatments. In 2013, Solidago 'Fireworks' was selected for planting because this variety has longer stems and is more appropriate for use in cut flower production. However, because of wet conditions early in the 2013 growing season, planting was delayed and was too late to obtain data other than initial phytotoxicity, which showed no injury in any treatment. Previous trials at other universities have shown no injury to solidago when Freehand, Snapshot TG, Pendulum, and Pennant Magnum were applied at recommended and double rates (Rutgers, 2014). However, these trials did not evaluate the potential impacts on marketable stems; thus solidago would benefit from additional research, specifically on potential impacts to cut stem number and quality, prior to registration.

Conclusions

While hardwood mulch does provide significant weed control compared to no weed control at all, its control rate is comparable to that of Preen Southern Gardens, the least effective herbicide tested. However, Preen Mulch Plus provided over 90% weed control both years and was among the top performing treatments in the study (Table 4.3). For growers, the cost of purchasing and applying a herbicide impregnated mulch such as Preen Mulch Plus can be prohibitive. Also, many cut flower growers in North Carolina employ organic practices so standard, unimpregnated mulches provide a non-chemical weed barrier that also enriches the soil over time (Granitz, 2014).

There are several species with potential for herbicide registrations (Table 4.10). Pendulum 2 GR, Snapshot 2.5 G, Freehand 1.75 GR, Preen Southern Gardens 0.27 GR, Barricade 4 L, Pennant Magnum 7.62 EC, and Preen Mulch Plus (trifluralin 0.0032% and isoxaben 0.0008%) appear to be safe for use on Ammi ‘Green Mist.’ Pendulum, Snapshot, Preen Southern Gardens (dithiopyr GR), Barricade, and Preen Mulch Plus appear to be safe for use with Eryngium ‘Blue Glitter.’ Pendulum 2 GR, Snapshot 2.5 G, Freehand 1.75 GR, Preen Southern Gardens 0.27 GR, Barricade 4 L, Pennant Magnum 7.62 EC, and Preen Mulch Plus (trifluralin 0.0032% and isoxaben 0.0008%) appear to be safe for use on Platycodon ‘Sentimental Blue’ and ‘Fuji Pink’ (Table 4.10).

Both ammi and platycodon appear to be tolerant of Pennant Magnum and Freehand applications (Tables 4.5 and 4.8), and would give cut flower growers viable options for nutsedge control. First year data and previous research suggest that Pennant Magnum and Freehand are also safe on solidago, but further trials are needed to confirm potential effects on marketable stem production.

Because of unfavorable conditions the second year, three species would benefit from further study. Solidago ‘Fireworks,’ Nigella ‘Miss Jekyll Blue,’ and Agrostemma ‘Purple Queen’ show potential for herbicide registrations and should be trialed for a second season.

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Table 4.1. Preemergence herbicides, formulations and application rates included in the 2012 and 2013 field and container trials at the Horticultural Field Lab, Raleigh, NC

			Rate	
Treatment	Active Ingredient	Formulation[1]	lb ai/A	kg ai/ha
Hand weeded	none	none	none	none
Weedy check	none	none	none	none
Pendulum	pendimethalin	2 GR	3	3.36
Pendulum	pendimethalin	2 GR	6	6.72
Snapshot TG	trifluralin & isoxaben	2.5 GR	2.5	2.8
Snapshot TG	trifluralin & isoxaben	2.5 GR	5	5.6
Freehand	dimethenamid-P & pendimethalin	1.75 GR	2.62	2.93
Freehand	dimethenamid-P & pendimethalin	1.75 GR	5.25	5.88
Preen Southern Gardens	dithiopyr	0.27 GR	0.5	0.56
Barricade	prodiamine	4 L	0.75	0.84
Pennant Magnum	s-metolachlor	7.62 EC	2.5	2.8
Hardwood mulch	none	none	none	none
Preen Mulch Plus	trifluralin & isoxaben	0.004%	3.12	3.49

[1]GR = granule, EC = emulsifiable concentrate, L = liquid.

Table 4.2. Number of marketable stems produced in hand weeded and weedy check field plots at the Horticultural Field Lab, Raleigh, NC in 2012

Treatment	Ammi	Nigella	Solidago
Hand weeded	13.4 a	7.5 a	6.3 a
Weedy check	0.7 b	4.0 a	3.9 a

[1] Average number of stems ≥30 cm per plant
Means followed by the same letter in the same column do not significantly differ ($P < 0.05$, LSD)

Table 4.3. Preemergence herbicide efficacy on redroot pigweed control at 4 WAT[1] at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

	Rate		Pigweed control²				Pigweed fresh weight (g)	
Treatment	lb ai/A	kg ai/ha	2012		2013		2012	
Hand weeded	none	none	0.0	d	0.0	c	1176.8	a
Weedy check	none	none	0.0	d	-		0[3]	a
Pendulum	3	3.36	9.7	ab	8.3	a	19	d
Pendulum	6	6.72	9.8	ab	9.3	a	18.5	d
Snapshot TG	2.5	2.8	9.4	b	7.8	a	35.5	cd
Snapshot TG	5	5.6	9.9	ab	8.5	a	0	d
Freehand	2.62	2.93	10.0	ab	8.5	a	0	d
Freehand	5.25	5.88	10.0	ab	9.0	a	0	d
Preen Southern Gardens	0.5	0.56	7.0	c	4.5	b	447.5	b
Barricade	0.75	0.84	10.0	ab	9.0	a	0	d
Pennant Magnum	2.5	2.8	10.0	ab	8.3	a	0	d
Hardwood mulch	none	none	7.5	c	9.3	a	350.8	bc
Preen Mulch Plus	3.12	3.49	9.5	ab	9.3	a	12.8	d

¹ WAT = Weeks after treatment

² Rated from 0 to- 10, with 0 being no pigweed control and 10 being complete pigweed control

³All weeds were left in the weedy check plots

Means followed by the same letter do not significantly differ (*P* < 0.05, LSD)

Table 4.4. Response of Amaranthus 'Green Flowered' to preemergence herbicides in containers, Raleigh, NC, 2012

Treatment	Rate lb ai/A	Rate kg ai/ha	CFQ rating[1] 6 WAT		Stems per plant[2] Season long		Stem length (cm) Season long	
Hand weeded	none	none	4.8	a	3.9	a	41.5	a
Pendulum	3	3.36	4.8	a	3.5	abc	42.1	a
Pendulum	6	6.72	4.0	bc	4.2	a	37.9	ab
Snapshot TG	2.5	2.8	4.4	ab	3.3	abc	38.9	ab
Snapshot TG	5	5.6	4.0	bc	3.5	ab	39.5	ab
Freehand	2.62	2.93	3.0	e	2.5	cd	34.5	b
Freehand	5.25	5.88	2.0	f	2.1	d	23.4	c
Preen Southern Gardens	0.5	0.56	4.2	bc	3.9	a	38.1	ab
Barricade	0.75	0.84	3.2	de	2.7	bcd	39.2	ab
Pennant Magnum	2.5	2.8	3.6	cd	3.8	a	36.2	ab

[1] Cut flower quality ratings on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants;
WAT = Weeks after treatment

[2] Average cumulative number of marketable stems (≥30 cm) per plant

Means followed by the same letter in the same column do not significantly differ (*P* < 0.05, LSD)

Table 4.5. Response of Ammi 'Green Mist' to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

	Rate		CFQ rating[1]				Stems/plant[2]				Stem length (cm)			
	lb	kg	2012		2013		2012		2013		2012		2013	
Treatment	ai/A	ai/ha	4 WAT		3 WAT									
Hand weeded	none	none	4.5	a	4.8	a	13.4	ab	6.8	a	47.3	cd	42.2	d
Pendulum	3	3.36	4.8	a	4.5	a	13.8	a	9.0	a	49.2	bcd	49.5	abc
Pendulum	6	6.72	4.8	a	4.3	a	13.5	ab	9.1	a	47.2	cd	47.6	bcd
Snapshot TG	2.5	2.8	4.0	ab	4.3	a	12.9	ab	8.5	a	47.7	cd	48.7	bcd
Snapshot TG	5	5.6	4.5	a	4.5	a	12.6	ab	7.8	a	48.0	cd	51.0	ab
Freehand	2.62	2.93	4.5	a	4.3	a	13.6	ab	7.9	a	46.9	d	50.1	abc
Freehand	5.25	5.88	4.0	ab	4.0	a	14.8	a	9.3	a	49.0	bcd	48.1	bcd
Preen Southern Gardens	0.5	0.56	4.3	a	4.8	a	11.4	b	6.6	a	45.6	d	44.4	cd
Barricade	0.75	0.84	4.5	a	4.5	a	12.8	ab	9.4	a	49.5	bcd	51.9	ab
Pennant Magnum	2.5	2.8	4.8	a	4.8	a	14.4	a	8.5	a	46.3	d	53.0	ab
Hardwood mulch	none	none	4.8	a	3.8	a	14.1	a	8.4	a	56.4	ab	47.6	bcd
Preen Mulch Plus	3.12	3.49	4.8	a	5.0	a	13.9	a	11.6	a	54.8	abc	54.7	a

[1] Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = weeks after treatment

[2] Average cumulative number of marketable stems (≥30 cm) per plant

Means followed by the same letter in the same column do not significantly differ ($P < 0.05$, LSD)

Table 4.6. Response of Eryngium 'Blue Glitter' to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

Treatment	Rate		% Foliar Necrosis[1]		CFQ rating[2]				% Foliar Necrosis[1]		CFQ rating[2]	
			2012		2012		2012		2013		2013	
	lb ai/A	kg ai/ha	1 WAT		4 WAT		6 WAT		1 WAT		4 WAT	
Hand weeded	none	none	0	b	4.3	abc	4.5	ab	0	a	4.3	a
Pendulum	3	3.36	0	b	3.8	bcd	4.3	ab	0	a	3.5	a
Pendulum	6	6.72	0	b	4.3	abc	4.5	ab	0	a	3.0	a
Snapshot TG	2.5	2.8	0	b	4.3	abc	4.3	ab	0	a	3.5	a
Snapshot TG	5	5.6	0	b	3.8	bcd	4.3	ab	0	a	3.8	a
Freehand[3]	2.62	2.93	0	b	2.3	ef	2.0	cd	-		-	
Freehand[3]	5.25	5.88	0	b	2.0	f	1.0	e	-		-	
Preen Southern Gardens	0.5	0.56	0	b	3.5	cd	4.0	b	0	a	3.5	a
Barricade	0.75	0.84	3	b	3.3	cde	4.0	b	0	a	4.0	a
Pennant Magnum[3]	2.5	2.8	18	a	2.0	f	1.3	de	-		-	
Hardwood mulch	none	none	3	b	5.0	a	5.0	a	0	a	4.5	a
Preen Mulch Plus	18	20.16	0	b	4.8	ab	5.0	a	0	a	3.8	a

[1] WAT = Week after treatment

[2] Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants

[3] Not included in 2013 trials

Means followed by the same letter do not significantly differ (*P* < 0.05, LSD)

Table 4.7. Response of Nigella 'Miss Jekyll Blue' to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012

	Rate		CFQ rating[1]		Stems/plant[2]		Stem length (cm)	
Treatment	lb ai/A	kg ai/ha	4 WAT					
Hand weeded	none	none	3.3	cde	7.2	b-e	31.6	bcd
Weedy check	none	none	3.5	bcd	3.3	de	38.9	a
Pendulum	3	3.36	3.5	bcd	8.3	b-e	32.6	bcd
Pendulum	6	6.72	3.3	cde	2.3	e	27.1	d
Snapshot TG	2.5	2.8	3.3	cde	10.2	abc	29.8	cd
Snapshot TG	5	5.6	2.3	e	4.1	cde	27.7	cd
Freehand	2.62	2.93	3.8	a-d	9.9	abc	31.2	bcd
Freehand	5.25	5.88	2.8	de	3.9	cde	27.2	d
Preen Southern Gardens	0.5	0.56	3.8	a-d	9.5	bcd	31.1	bcd
Barricade	0.75	0.84	3.3	cde	7.6	b-e	30.1	cd
Pennant Magnum	2.5	2.8	4.3	abc	7.4	b-e	28.3	cd
Hardwood mulch	none	none	4.5	ab	16.1	a	35.9	ab
Preen Mulch Plus	3.12	3.49	4.8	a	10.7	ab	35.6	ab

[1] Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = weeks after treatment

[2] Average cumulative number of marketable stems (≥30 cm) per plant

Means followed by the same letter do not significantly differ ($P < 0.05$, LSD)

Table 4.8. Response of two cultivars of Platycodon to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

	Rate		% Foliar necrosis		CFQ rating [2]				Flowers/plant		Stems/ plant[3]		Stem length (cm)	
			2012 'Sentimental Blue'		2012 'Sentimental Blue'		2013 'Fuji Pink'		2012 'Sentimental Blue'		2013 'Fuji Pink'		2013 'Fuji Pink'	
Treatment	lb ai/A	kg ai/ha	3 DAT[1]		4 WAT		4 WAT		Season long		Season long		Season long	
Hand weeded	none	none	0.0	b	5.0	a	3.8	a	31.8	ab	4.9	a	39.8	d
Weedy check	none	none	0.3	b	4.0	cd	-		0.0	c	-		-	
Pendulum	3	3.36	0.0	b	4.0	cd	3.5	a	25.7	b	4.4	a	40.2	d
Pendulum	6	6.72	0.0	b	3.5	de	4.3	a	36.8	b	6.5	a	44.9	bc
Snapshot TG	2.5	2.8	0.0	b	4.5	abc	4.0	a	31.9	ab	5.4	a	41.3	cd
Snapshot TG	5	5.6	0.0	b	4.8	ab	3.5	a	33.1	ab	4.6	a	40.7	cd
Freehand	2.62	2.93	0.0	b	4.3	bc	3.8	a	30.0	ab	5.1	a	42.1	bcd
Freehand	5.25	5.88	0.0	b	3.3	e	3.8	a	34.1	ab	5.3	a	40.4	d
Preen Southern Gardens	0.5	0.56	0.0	b	3.5	de	3.8	a	28.6	b	6.6	a	43.2	bcd
Barricade	0.75	0.84	0.5	b	4.3	bc	3.3	a	33.6	ab	5.4	a	40.5	d
Pennant Magnum	2.5	2.8	8.8	a	4.5	abc	4.5	a	41.1	a	6.0	a	40.0	d
Hardwood mulch	none	none	0.0	b	5.0	a	4.8	a	27.9	b	7.5	a	46.1	bcd
Preen Mulch Plus	18	20.16	0.3	b	5.0	a	5.0	a	24.9	b	5.5	a	49.4	a

[1] DAT = Days after treatment
[2]Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = weeks after treatment
[3]Average cumulative number of marketable stems (≥30 cm) per plant
- Treatment not included in this year
Means followed by the same letter do not significantly differ *(P* < 0.05, LSD)

Table 4.9. Response of Solidago 'Little Lemon' to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012

Treatment	Rate lb ai/A	Rate kg ai/ha	Plant Quality[1] 4 WAT		Stems/plant[2]		Stem Length (cm)
Hand weeded	none	none	4.8	ab	6.3	a	35.2 a
Weedy check	none	none	4.3	b	3.9	a	38.5 a
Pendulum	3	3.36	5.0	a	7.5	a	34.5 a
Pendulum	6	6.72	4.8	ab	5.3	a	33.7 a
Snapshot TG	2.5	2.8	5.0	a	5.9	a	35.5 a
Snapshot TG	5	5.6	5.0	a	4.7	a	32.2 a
Freehand	2.62	2.93	5.0	a	4.4	a	35.0 a
Freehand	5.25	5.88	4.3	b	5.8	a	32.9 a
Preen Southern Gardens	0.5	0.56	5.0	a	6.4	a	32.9 a
Barricade	0.75	0.84	5.0	a	7.0	a	35.2 a
Pennant Magnum	2.5	2.8	5.0	a	6.3	a	35.7 a
Hardwood mulch	none	none	4.8	ab	5.3	a	35.0 a
Preen Mulch Plus	3.12	3.49	5.0	a	4.3	a	35.1 a

[1] Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = weeks after treatment

[2] Average cumulative number of flower stems (≥30 cm) per plant

Means followed by the same letter do not significantly differ ($P < 0.05$, LSD)

Table 4.10. Safety of preemergence herbicides on selected cut flowers at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

Species	Pendulum (pendimethalin)	Snapshot TG (trifluralin & isoxaben)	Pennant Magnum (s-metolachlor)	Preen Southern Gardens (dithiopyr)	Barricade (prodiamine)	Freehand (dimethenamid-P & pendimethalin)	Barricade (prodiamine)	Pennant Magnum (S-metolachlor)	Preen Mulch Plus (trifluralin & isoxaben)
Amaranthus	OK 2012	OK 2012	OK 2012	OK 2012	OK 2012	X 2012	X 2012	X 2012	Not tested
Ammi	OK	OK	OK	OK	OK	OK	OK	OK	OK
Eryngium	OK	OK	X	OK	OK	X	OK	X	OK
Nigella	OK 2012	X 2012	OK 2012	OK 2012	OK 2012	X 2012	X 2012	OK 2012	OK 2012
Platycodon	OK	OK	X 2012 OK 2013	OK	OK	OK	OK	OK	OK
Solidago	OK	OK	OK	OK	OK	OK	OK	OK	OK

OK = safe for use

X = not safe for use at the labeled dose

APPENDICES

Appendix A. Preemergence herbicides registered for use on herbaceous cut flowers[1]

Genus	Common Name	Barricade	Corral	Dacthal	Devrinol	Dimension	Preen Southern	Freehand	Gallery	Jewel	Pendulum EC,ACS	Pendulum 2G	Pennant Magnum	Ronstar G	Snapshot	Surflan	PREEN Garden	Treflan 5G	XL
Achillea	Yarrow	y	y	y		d	e	y	y	e		e	y		e	e	y	e	e
Agapanthus	Lily-of-the-Nile	y	y		y	d	e	y	y	e	e	e	y	e	e	e	y	e	e
Ageratum	Blue flossflower			y	y					e		e	y				y	e	
Alcea	Hollyhock																y		
Allium	Ornamental Onion	y											y						
Alstroemeria	Peruvian Lily				y										e				
Amaranthus	Love-Lies-bleeding																		
Anemone	Wind Flower	y						y				e							
Antirrhinum	Snapdragon			y		d	e					e	y	e	e	e	y	e	e
Arisaema	Jack-in-the-Pulpit																		
Artemesia	Wormwood	y		y						e		e	y		e		y		
Asclepias	Butterfly weed		y					x				e	y						
Aster	Aster	y	y	y	y		e		y	e		e	y		e	e	y	e	
Astilbe	Astilbe					d		y		e		e			e	e		e	e
Athyrium	Lady Fern	y			y		e									e		e	
Brassica	Ornamental cabbage								x			e			x	e			
Callistephus	China aster					d			y			e			e	e			
Campanula	Bellflower	y		y	y							e	y			e	y	e	e
Celosia	Cockscomb					d	e					e							
Centaurea	Cornflower					d	e										y	e	
Chasmanthium	Sea Oats																y		
Chrysanthemum	Chrysanthemum			y	y			y				e	y	e	e	e	y	e	e
Cirsium	Thistle																		
Consolida	Larkspur																		
Cosmos	Cosmos			y													y	e	
Crocosmia	Montbretia	y									e	e							
Dahlia	Dahlia			y	y				y			e		e	e		y	e	
Daucus	Queen Anne's Lace												y						
Delphinium	Delphinium	y				d	e						y						
Dennstaedtia	Fern, Hay-				y		e												

Genus	Common Name	Barricade	Corral	Dacthal	Devrinol	Dimension	Preen Southern	Freehand	Gallery	Jewel	Pendulum EC,ACS	Pendulum 2G	Pennant Magnum	Ronstar G	Snapshot	Surflan	PREEN Garden	Treflan 5G	XL
	scented																		
Dianthus	Carnation	y		x			e	y	y					y			y	e	
Dianthus	Pink	y		x			e	y	y						e	e		e	
Dianthus	Sweet William			x		d	e	y	y	e		e	y	e		e	y	e	e
Digitalis	Foxglove			y						e		e		e	x	e	y		
Dryopteris	Fern, Log (Shaggy Shield)				y		e		y										
Echinacea	Coneflower	y		y	y	y		y	x			e			x	e	y		e
Euphorbia	Snow-on-the-Mountain								x						x		y	e	
Eustoma	Lisianthus								y						e				
Freesia	Freesia										e	e							
Gaillardia	Blanketflower	y		y	y	d	e		y	e		e	y	y	e	e	y	e	
Gerbera	Gerbera Daisy																		
Gladiolus	Gladiolus	y		y	y			y	y	e		e	y	e		e	y	e	e
Gomphrena	Globe Amaranth							x											
Goniolimon	Statice, German																		
Gypsophila	Baby's Breath	y		y					y	e		e		e	x	e	y	e	e
Helianthus	Sunflower											e					y	e	
Helichrysum	Strawflower								y						e				
Hyacinthus	Hyacinth								y				y			y	y	y	y
Hypericum	St. Johnswort		y		y				y			e	y		e	e	y		e
Iris	Iris, Bulbous	y		y	y	d	e	y	y				y		e	y	y	y	y
Iris	Iris, Rhizomatous	y		y	y	d	e	y	y				y		e	e		e	e
Laurentia	Laurentia																		
Lavandula	Lavender	y						y		e	e	e				e	y	e	
Leucanthemum	Daisy, Shasta											e					y		e
Liatris	Blazing Star (Gayfeather)								y	e		e		e	e	e	y		e
Lilium	Lily	y		y	y				y	e	e	e	y						
Limonium	Statice								y			e	y	e	e	e	y	e	
Lobelia	Cardinal	y	y					y							e	e		e	

Genus	Common Name	Barricade	Corral	Dacthal	Devrinol	Dimension	Preen Southern	Freehand	Gallery	Jewel	Pendulum EC,ACS	Pendulum 2G	Pennant Magnum	Ronstar G	Snapshot	Surflan	PREEN Garden	Treflan 5G	XL
	Flower																		
Lupinus	Lupine			y								e	y				y	e	
Lysimachia	Moneywort								y			e			e				
Lythrum	Loosestrife, Purple	y	y									e	y						
Matthiola	Stock								y						e		y	e	
Molucella	Bells of Ireland																		
Monarda	Beebalm					d	e								e		y		
Myosotis	Forget-Me-Not			y													y	e	
Narcissus	Daffodil	y			y	d	e		y			e	y			y	y	y	y
Nephrolepis	Fern, Boston (Sword)						e					e							
Nigella	Love-in-a-Mist																		
Nipponanthemum	Daisy, Montauk	y															y		
Osmunda	Fern, Royal (Cinnamon)				y		e		y										
Paeonia	Peony	y		y						e	e	e		e					
Papaver	Poppy																	e	
Penstemon	Beardtongue		y		y				y	e		e			e		y		
Perovskia	Sage, Russian	y			y				y	e		e			e		y		
Phlox	Phlox			x				y	y			e	y	e	x		y	e	
Physostegia	Obedient Plant	y										e	y						
Platycodon	Balloon Flower											e							
Polianthes	Tuberose																		
Polystichum	Fern, Tassel (Christmas)				y		e		y									e	
Ranunculus	Ranunculus															e			e
Ratibida	Coneflower, Prairie								y						e				
Rosa	Rose	y		y	y	d				e		e	y	e		e		e	e
Rosmarinus	Rosemary	y	y			d						e				e	y	e	e
Rudbeckia	Black-Eyed Susan	y				d	e	x	y	e		e			e	e	y	e	e
Rumohra	Fern, Leatherleaf	y					e				e	e	y						
Salvia	Salvia (Sage, ann.)			y			e	y	y			e				e	y	e	e

Genus	Common Name	Barricade	Corral	Dacthal	Devrinol	Dimension	Preen Southern	Freehand	Gallery	Jewel	Pendulum EC,ACS	Pendulum 2G	Pennant Magnum	Ronstar G	Snapshot	Surflan	PREEN Garden	Treflan 5G	XL
Salvia	Salvia (Sage, per.)					d	e	y	y	e					e	e	y	e	e
Saponaria	Soapwort																	e	
Scabiosa	Pincushion Flower	y		y	y			x		e							y	e	
Scilla	Squill												y						
Stokesia	Stokes' Aster		y									e				e		e	e
Strelitzia	Bird of Paradise				y											e			e
Tagetes	Marigold			y		d	e	y	y			e	y		e	e	y	e	e
Tulipa	Tulip	y			y	d	e		y			e	y			y	y	y	y
Verbena	Verbena (Vervain)		y			d	e	y	y			e			e	e	y	e	
Veronica	Speedwell	y			y			x			e	e	y			e	y	e	
Zantedeschia	Calla lily										e	e							
Zinnia	Zinnia			y	y			y				e	y		e	e	y	e	e

y = registered for some species of this genus
e = registered for some species of this genus, apply only after established
d = registered for some species of this genus, directed application only
x = NOT registered/prohibited from use on some species
[1] Excerpt from Senesac, A. and J. Neal. 2012. Preemergence Herbicides for Herbaceous Ornamentals. Cornell Cooperative Extension, Riverhead, NY.

Appendix B. Preemergence herbicide efficacy on redroot pigweed control at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

	Rate		Pigweed control[2]										Weed fresh weight (g)	
			2012						2013				2012	
Treatment	lb ai/A	kg ai/ha	2.5 WAT[1]		3 WAT		4 WAT		2 WAT		4 WAT		4 WAT	
Hand weeded	none	none	0	e	0	d	0.0	d	0.0	c	0.0	c	1176.8	a
Weedy check	none	none	0	e	0	d	0.0	d	-		-		0	d
Pendulum	3	3.36	8.8	c	9.1	b	9.7	ab	9.0	a	8.3	a	19	d
Pendulum	6	6.72	9.4	abc	9.6	ab	9.8	ab	9.5	a	9.3	a	18.5	d
Snapshot TG	2.5	2.8	9.5	abc	9.4	ab	9.4	b	9.3	a	7.8	a	35.5	cd
Snapshot TG	5	5.6	10	a	9.8	ab	9.9	ab	8.8	a	8.5	a	0	d
Freehand	2.62	2.93	10	a	10	a	10.0	ab	9.8	a	8.5	a	0	d
Freehand	5.25	5.88	10	a	10	a	10.0	ab	10.0	a	9.0	a	0	d
Preen Southern Gardens	0.5	0.56	6.8	d	7.5	c	7.0	c	4.0	b	4.5	b	447.5	b
Barricade	0.75	0.84	9	bc	9.1	b	10.0	ab	9.5	a	9.0	a	0	d
Pennant Magnum	2.5	2.8	10	a	10	a	10.0	ab	9.5	a	8.3	a	0	d
Hardwood mulch	none	none	7.3	d	7.8	c	7.5	c	8.5	a	9.3	a	350.8	bc
Preen Mulch Plus	18	20.16	9.7	ab	9.6	ab	9.5	ab	8.8	a	9.3	a	12.8	d

[1] WAT = Weeks after treatment

[2] Rated from 0 to 10, with 0 being no pigweed control and 10 being complete pigweed control

[3]All weeds were left in the weedy check plots

Means followed by the same letter do not significantly differ (*P* < 0.05, LSD)

Appendix C. Response of Amaranthus 'Green Flowered' to preemergence herbicides in containers, Raleigh, NC, 2012

	Rate		CFQ rating[1]						Stems/plant[2]		Stem Length (cm)	
			2012		2012		2012		2012		2012	
Treatment	lb ai/A	kg ai/ha	3 WAT		4 WAT		6 WAT		Season long		Season long	
Hand weeded	none	none	4.8	a	4.8	a	4.8	a	3.9	a	41.5	a
Pendulum	3	3.36	4.8	a	5.0	a	4.8	a	3.5	abc	42.1	a
Pendulum	6	6.72	4.0	b	4.6	a	4.0	bc	4.2	a	37.9	ab
Snapshot TG	2.5	2.8	4.2	ab	4.4	a	4.4	ab	3.3	abc	38.9	ab
Snapshot TG	5	5.6	4.6	ab	4.4	a	4.0	bc	3.5	ab	39.5	ab
Freehand	2.62	2.93	3.0	c	3.2	b	3.0	e	2.5	cd	34.5	b
Freehand	5.25	5.88	3.0	c	2.2	c	2.0	f	2.1	d	23.4	c
Preen Southern Gardens	0.5	0.56	4.8	a	4.8	a	4.2	bc	3.9	a	38.1	ab
Barricade	0.75	0.84	2.8	c	3.4	b	3.2	de	2.7	bcd	39.2	ab
Pennant Magnum	2.5	2.8	4.6	ab	4.4	a	3.6	cd	3.8	a	36.2	ab

[1] Cut flower quality ratings on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = Weeks after treatment

[2] Average cumulative number of marketable stems (≥30 cm) per plant

Means followed by the same letter in the same column do not significantly differ (*P* < 0.05, LSD)

Appendix D. Response of Ammi 'Green Mist' to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

	Rate		CFQ rating[1]								Stems/plant[2]				Stem Length (cm)			
	lb	Kg	2012		2012		2012		2013		2012		2013		2012		2013	
Treatment	ai/A	ai/ha	2 WAT		4 WAT		6 WAT		3 WAT		Season long				Season long			
Hand weeded	none	none	4.3	ab	4.5	a	4.5	a	4.8	a	13.4	ab	6.8	a	47.3	cd	42.2	d
Weedy check	none	none	4.0	b	3.3	b	3.3	b	-		0.7	c	-		57.7	a	-	
Pendulum	3	3.36	4.3	ab	4.8	a	4.8	a	4.5	a	13.8	a	9.0	a	49.2	bcd	49.5	abc
Pendulum	6	6.72	4.5	ab	4.8	a	4.8	a	4.3	a	13.5	ab	9.1	a	47.2	cd	47.6	bcd
Snapshot TG	2.5	2.8	4.3	ab	4.0	ab	4.0	ab	4.3	a	12.9	ab	8.5	a	47.7	cd	48.7	bcd
Snapshot TG	5	5.6	3.8	b	4.5	a	4.5	a	4.5	a	12.6	ab	7.8	a	48.0	cd	51.0	ab
Freehand	2.62	2.93	4.3	ab	4.5	a	4.5	a	4.3	a	13.6	ab	7.9	a	46.9	d	50.1	abc
Freehand	5.25	5.88	3.8	b	4.0	ab	4.0	ab	4.0	a	14.8	a	9.3	a	49.0	bcd	48.1	bcd
Preen Southern Gardens	0.5	0.56	3.8	b	4.3	a	4.3	a	4.8	a	11.4	b	6.6	a	45.6	d	44.4	cd
Barricade	0.75	0.84	4.3	ab	4.5	a	4.5	a	4.5	a	12.8	ab	9.4	a	49.5	bcd	51.9	ab
Pennant Magnum	2.5	2.8	4.5	ab	4.8	a	4.8	a	4.8	a	14.4	a	8.5	a	46.3	d	53.0	ab
Hardwood mulch	none	none	5.0	a	4.8	a	4.8	a	3.8	a	14.1	a	8.4	a	56.4	ab	47.6	bcd
Preen Mulch Plus	18	20.16	5.0	a	4.8	a	4.8	a	5.0	a	13.9	a	11.6	a	54.8	abc	54.7	a

[1] Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = weeks after treatment

[2] Average cumulative number of marketable stems (≥30 cm) per plant

Means followed by the same letter in the same column do not significantly differ (*P* < 0.05, LSD)

Appendix E. Response of Eryngium 'Blue Glitter' to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

	Rate		% Foliar necrosis[1]				CFQ rating[2]											
			2012		2013		2012		2012		2012		2013		2013		2013	
Treatment	lb ai/A	kg ai/ha	1 WAT		1 WAT		2 WAT		4 WAT		6 WAT		4 WAT		6 WAT		7 WAT	
Hand weeded	none	none	0	b	0	a	4.5	ab	4.3	abc	4.5	ab	4.3	a	4.3	a	4.8	ab
Weedy check[3]	none	none	0	b	-		2.5	c	3.0	def	2.5	c	-		-		-	
Pendulum	3	3.36	0	b	0	a	4.3	ab	3.8	bcd	4.3	ab	3.5	a	4.3	a	4.5	abc
Pendulum	6	6.72	0	b	0	a	4.5	ab	4.3	abc	4.5	ab	3.0	a	4.0	a	3.5	cd
Snapshot TG	2.5	2.8	0	b	0	a	4.3	ab	4.3	abc	4.3	ab	3.5	a	4.8	a	4.0	a-d
Snapshot TG	5	5.6	0	b	0	a	4.3	ab	3.8	bcd	4.3	ab	3.8	a	4.3	a	3.8	bcd
Freehand[3]	2.62	2.93	0	b	-		2.0	cd	2.3	ef	2.0	cd	-		-		-	
Freehand[3]	5.25	5.88	0	b	-		1.0	e	2.0	f	1.0	e	-		-		-	
Preen Southern Gardens	0.5	0.56	0	b	0	a	4.0	b	3.5	cd	4.0	b	3.5	a	4.0	a	3.3	d
Barricade	0.75	0.84	3	b	0	a	4.0	b	3.3	cde	4.0	b	4.0	a	4.5	a	4.3	a-d
Pennant Magnum[3]	2.5	2.8	18	a	-		1.3	de	2.0	f	1.3	de	-		-		-	
Hardwood mulch	none	none	3	b	0	a	5.0	a	5.0	a	5.0	a	4.5	a	5.0	a	5.0	a
Preen Mulch Plus	18	20.16	0	b	0	a	5.0	a	4.8	ab	5.0	a	3.8	a	3.8	a	4.0	a-d

[1] WAT = Week after treatment

[2] Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants

[3] Not included in 2013 trials

Means followed by the same letter do not significantly differ (*P* < 0.05, LSD)

Appendix F. Response of Nigella 'Miss Jekyll Blue' to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012

	Rate		CFQ rating[1]				Stems/plant[2]		Stem Length (cm)	
Treatment	lb ai/A	kg ai/ha	2 WAT		5 WAT		Season long		Season long	
Hand weeded	none	none	3.5	c	3.3	cde	7.2	b-e	31.6	bcd
Weedy check	none	none	3.8	bc	3.5	bcd	3.3	de	38.9	a
Pendulum	3	3.36	3.8	bc	3.5	bcd	8.3	b-e	32.6	bcd
Pendulum	6	6.72	3.5	c	3.3	cde	2.3	e	27.1	d
Snapshot TG	2.5	2.8	3.3	c	3.3	cde	10.2	abc	29.8	cd
Snapshot TG	5	5.6	3.8	bc	2.3	e	4.1	cde	27.7	cd
Freehand	2.62	2.93	3.8	bc	3.8	a-d	9.9	abc	31.2	bcd
Freehand	5.25	5.88	3.0	c	2.8	de	3.9	cde	27.2	d
Preen Southern Gardens	0.5	0.56	3.8	bc	3.8	a-d	9.5	bcd	31.1	bcd
Barricade	0.75	0.84	3.3	c	3.3	cde	7.6	b-e	30.1	cd
Pennant Magnum	2.5	2.8	3.5	c	4.3	abc	7.4	b-e	28.3	cd
Hardwood mulch	none	none	4.5	ab	4.5	ab	16.1	a	35.9	ab
Preen Mulch Plus	18	20.16	5.0	a	4.8	a	10.7	ab	35.6	ab

[1] Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = weeks after treatment

[2] Average cumulative number of marketable stems (≥30 cm) per plant

Means followed by the same letter do not significantly differ (*P* < 0.05, LSD)

Appendix G. Response of two cultivars of Platycodon to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012 and 2013

	Rate		% Foliar Necrosis		CFQ rating²								Flowers/plant		Stems/plant		Stem Length (cm)	
			2012		2012				2013				2012		2013		2013	
	lb	kg	Sent. Blue'		Sentimental Blue'				Fuji Pink'				Sent. Blue'		Fuji Pink'		Fuji Pink'	
Treatment	ai/A	ai/ha	3 DAT¹		4 WAT		6 WAT		4 WAT		6 WAT							
Hand weeded	none	none	0.0	b	5.0	a	5.0	a	3.8	a	3.0	a	31.8	ab	4.9	a	39.8	d
Weedy check	none	none	0.3	b	4.0	cd	4.0	cd	-		-		0.0	c	-		-	
Pendulum	3	3.36	0.0	b	4.0	cd	4.0	cd	3.5	a	3.3	a	25.7	b	4.4	a	40.2	d
Pendulum	6	6.72	0.0	b	3.5	de	3.5	de	4.3	a	4.0	a	36.8	b	6.5	a	44.9	bc
Snapshot TG	2.5	2.8	0.0	b	4.5	abc	4.5	abc	4.0	a	3.8	a	31.9	ab	5.4	a	41.3	cd
Snapshot TG	5	5.6	0.0	b	4.8	ab	4.8	ab	3.5	a	3.8	a	33.1	ab	4.6	a	40.7	cd
Freehand	2.62	2.93	0.0	b	4.3	bc	4.3	bc	3.8	a	3.3	a	30.0	ab	5.1	a	42.1	bcd
Freehand	5.25	5.88	0.0	b	3.3	e	3.3	e	3.8	a	3.5	a	34.1	ab	5.3	a	40.4	d
Preen Southern Gardens	0.5	0.56	0.0	b	3.5	de	3.5	de	3.8	a	4.0	a	28.6	b	6.6	a	43.2	bcd
Barricade	0.75	0.84	0.5	b	4.3	bc	4.3	bc	3.3	a	3.3	a	33.6	ab	5.4	a	40.5	d
Pennant Magnum	2.5	2.8	8.8	a	4.5	abc	4.5	abc	4.5	a	3.5	a	41.1	a	6.0	a	40.0	d
Hardwood mulch	none	none	0.0	b	5.0	a	5.0	a	4.8	a	4.8	a	27.9	b	7.5	a	46.1	bcd
Preen Mulch Plus	18	20.16	0.3	b	5.0	a	5.0	a	5.0	a	4.5	a	24.9	b	5.5	a	49.4	a

¹ DAT = Days after treatment

² Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = weeks after treatment

³ - Treatment not included in this year

⁴ Average cumulative number of flower stems (≥30 cm) per plant

⁵ Means followed by the same letter do not significantly differ (*P* < 0.05, LSD)

Appendix H. Response of Solidago 'Little Lemon' to preemergence herbicides at the Horticultural Field Lab, Raleigh, NC, 2012

	Rate		CFQ rating[1]						Stems/plant[2]		Stem length (cm)	
			2012						2012		2012	
Treatment	lb ai/A	kg ai/ha	2 WAT		4 WAT		6 WAT					
Hand weeded	none	none	4.8	a	4.8	ab	5.0	a	6.3	a	35.2	a
Weedy check	none	none	4.8	a	4.3	b	2.8	c	3.9	a	38.5	a
Pendulum	3	3.36	4.8	a	5.0	a	5.0	a	7.5	a	34.5	a
Pendulum	6	6.72	4.5	a	4.8	ab	4.8	a	5.3	a	33.7	a
Snapshot TG	2.5	2.8	4.8	a	5.0	a	5.0	a	5.9	a	35.5	a
Snapshot TG	5	5.6	4.5	a	5.0	a	4.8	a	4.7	a	32.2	a
Freehand	2.62	2.93	4.3	a	5.0	a	5.0	a	4.4	a	35.0	a
Freehand	5.25	5.88	4.5	a	4.3	b	4.3	b	5.8	a	32.9	a
Preen Southern Gardens	0.5	0.56	4.8	a	5.0	a	5.0	a	6.4	a	32.9	a
Barricade	0.75	0.84	4.8	a	5.0	a	5.0	a	7.0	a	35.2	a
Pennant Magnum	2.5	2.8	4.5	a	5.0	a	4.8	a	6.3	a	35.7	a
Hardwood mulch	none	none	4.8	a	4.8	ab	4.8	a	5.3	a	35.0	a
Preen Mulch Plus	18	20.16	4.8	a	5.0	a	5.0	a	4.3	a	35.1	a

[1] Cut flower quality rating on a scale of 0 to 5 where 0 = dead and 5 = the healthiest plants; WAT = weeks after treatment

[2] Average cumulative number of marketable stems (≥30 cm) per plant

Means followed by the same letter do not significantly differ ($P < 0.05$, LSD)

Appendix I

ASCFG Cut Flower Quarterly Publication

December 2012

Postharvest Treatment of Specialty Cut Flowers

North Carolina State University Report for 2012

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As part of our yearly ASCFG cut flower trials, we conduct vase life studies on cultivars and varieties that show potential as future mainstays on growers' lists. This year, thanks to a joint NCDA and USDA grant, we also had the opportunity to evaluate some cultivars that are already widely grown in North Carolina. A total of 38 annual and perennial cut flowers from 20 different genera were evaluated for postharvest vase life.

What we did

Trial varieties were planted sixteen plants per plot, four plots per variety. All marketable flowers were cut, measured, and recorded in the field three days per week. Up to 60 stems per variety were sorted into four uniform groups and bundled for postharvest vase life evaluation.

Bundles were placed into their first solution, hydrator (Floralife Hydraflor 100 Pretreatment at 1 ounce per gallon) or no hydrator (de-ionized water) for four hours. Then, they were transferred to a second solution, holding solution (Floralife Professional Fresh Flower Food at 1.3 ounces per gallon) or no holding solution (de-ionized water), for 48 hours. Hydrators are intended to promote rapid water uptake and do not include sugar, while the holding solutions have sugar to promote long vase life. The four resulting treatments were:

1. Hydrator only (no preservative)
2. Holding preservative only (no hydrator)
3. Hydrator, then holding preservative
4. De-ionized water only (control)

Once pretreatments were done, each stem was placed in its own mason jar with 300 mL of de-ionized water to simulate conditions in consumers' homes. Temperature was kept steady at 68 ± 4° F with 200 fc light for twelve hours per day. Stems were checked daily and terminated once they reach an agreed-upon stage of expiration, usually when greater than 50 percent of petals were desiccated or heads bent over to less than a 90° angle. Vase life was recorded for all stems.

What we found

Ageratum 'Blue Horizon'

‘Blue Horizon’ was cut when more than half of flowers in the head were fuzzy and terminated when more than half of the florets were brown or wilted. The average vase life was 8.7 days and vase life was unaffected by preservatives.

Agrostemma 'Purple Queen'

‘Purple Queen,’ the most commonly grown agrostemma for cuts in North Carolina, produced an average vase life of 9.2 days when cut just after buds showed color (but before they opened). A hydrator plus a holding solution increased vase life by an average of two days over just water.

Amaranthus 'Green Flowered' and 'Hot Biscuits'

These two amaranthus varieties were from opposite ends of the spectrum, both fared comparably in postharvest evaluations. Pendulous, spring green ‘Green Flowered’ averaged 9.9 days and upright ‘Hot Biscuits’ clocked in at 10.6 days. Both lasted longer with a combination of hydrator and holding solution, which added an average of almost six days of vase life.

Ammi majus

The false Queen Anne's lace we tested lasted an average of ten days in the vase. Using a holding solution added two days over untreated stems. This old favorite is a great standby as frothy, lacy filler, but growers beware! The sap causes skin to become photosensitive and blister in the sun. Make *Ammi* the last thing you cut before coming in from the field to minimize sun on exposed skin.

Asclepias 'Silky Formula Mix'

'Silky Formula Mix,' with its tall, sturdy stems and enthusiastic production throughout the season, happily provided stems long into fall. The mix of oranges, deep reds, and yellows looked right at home in hot, summer bouquets and bountiful autumn harvest arrangements alike. Overall, average vase life was over ten days, and neither hydrating nor holding solution provided any significant increase.

Astilbe 'August Light' and 'Bridal Veil'

Our first year astilbes got off to a difficult start this year; Canada geese just couldn't resist a taste of the succulent new leaves as they emerged from the soil, pulling up the plugs along the way. Needless to say, the bare root plants were each planted several times before they could take root. Despite the circumstances, they bloomed quite well and we were able to obtain an average vase life of 6.2 days for 'Bridal Veil' and 5.9 days for 'August Light.' Although 'Bridal Veil' performed similarly across all treatments, 'August Light' lasted an average of 3 days longer with a holding treatment.

Celosia 'Dark Rose,' 'Sunday Orange,' and 'Sunday Wine Red'

'Dark Rose' was the only comb-type celosia in vase life trials this year, and at an average of 16.5 days in the vase, it did not disappoint. Treatments did not show any advantage with 'Dark Rose.' The two 'Sunday' cultivars both lasted over 10.5 days and did better with a holding solution. Their flowers were terminated when more than 50% of the head was either blackened or wilted.

Cosmos 'Double Click,' 'Sonata Mix,' and 'Versailles'

Cosmos were cut as soon as the bud began to open and before petals unfurled. 'Double Click's mix of frilly, sometimes variegated blossoms was a favorite among our growers. However, cosmos's reputation of a short vase life holds true for 'Double Click' and 'Versailles.' Both lasted an average of only 5.3 and 5.8 days respectively. 'Sonata Mix' held on for a few more days and averaged 7.8 days in the vase. All three varieties performed best when a holding solution was used.

Dianthus 'Amazon Neon Duo' and 'Volcano Mix'

Both cultivars of dianthus were cut when more than three florets were open per flower head. Flowers were terminated when more than 50% of flowers were desiccated or had fallen off. As dianthus are known, 'Amazon Neon Duo' and 'Volcano Mix' were among the longest lasting flowers on our grow list. 'Volcano Mix,' which was planted earlier in the season than 'Amazon Neon Duo,' lived an average of 16.6 days after cutting. 'Amazon Neon Duo' was just behind with 15 days in the vase. Both were unaffected by treatments.

Gomphrena 'QIS Carmine' and 'QIS Red'

The ‘QIS’ Gomphrenas, with their long, slender, easy to strip stems and open growth habit, were this year’s marathon runners. There were a few stems that lasted over a month and still had not rooted out! ‘QIS Carmine’s vase life was 19.3 days, while ‘QIS Red’ averaged 16.7 days. Stems were terminated when their necks bent to less than a 90° angle or the flower fell off. Both were unaffected by treatments.

Lily *(Lillium)* 'Merostar' and 'Concad'or'

Both lilies were field grown and suffered some abuse at the beaks of Canada geese. However, of the remaining plants, each lasted right at 13 days after harvesting. Stems were cut when buds began to ‘color up’, but were not yet open. ‘Concad’or’ had three to four very large, heavy creamy butter yellow and white trumpets per stem. ‘Merostar’s stems were a bit more petite, with four to five smaller white and magenta flowers. Blooms were terminated when most petals were abscised. Interestingly both were unaffected by treatments, probably due to the fact that we used general floral preservatives. In other tests we have done, lilies respond very well to flower foods specifically designed for lilies - keeping the foliage green and allowing the buds to open up.

Marigold (*Tagetes)* 'African Jedi Orange'

'African Jedi Orange' was a bountiful bloomer with large, clear flowers that decreased in size over the season. Average vase life was just over 10.5 days, but use of a holding solution bumped the number to over 13 days. Flowers were terminated when they began to blacken in the centers.

Nigella 'Miss Jekyll Blue'

Nigella is known for its dried pods for a reason. Almost as soon as we cut the flowers their beautiful sky blue petals shattered. The other buds in the spray still opened, so that helped extend vase life to 6.3 days. Performance was similar across all four treatments. 'Miss Jekyll Blue' harvested at pod stage from another experiment is still looking great four months later. The pods have distinctive purple stripes that stay true even after drying.

Safflower *(Carthamus)* 'Dark Orange Red,' 'Grenade Orange,' 'Grenade White,' and 'Orange Head'

'Dark Orange Red' was by far the longest lasting *Carthamus* tested this year, lasting an average 8.9 days after harvest. 'Grenade White' followed with 5.9 days, then 'Grenade Orange' and 'Orange Head' with 5 days each. All four cultivars' longest lasting treatment was a combination of hydrator and holding solution.

Scabiosa 'Black Knight' and 'Olympia Mix'

Both *Scabiosa* ‘Black Knight’ and ‘Olympia Mix’ are highly favored for their richly-colored flowers atop long stems. They are not large flowered scabiosas like the ‘Fama’ series, yet their impact on a bouquet is undeniable. We all agree that ‘Black Knight’s consistently deep, velvety, almost black pincushions are a lovely contrast beside almost any other selection from this year’s trials. It fared well with an average 8 day vase life, and ‘Olympia Mix’ averaged 6.8 days. Blooms of the latter are slightly larger, with colors that range from white to the palest pink to lavender to a deep purple that rivals ‘Black Knight.’ Both cultivars lasted the longest with a holding solution.

Snapdragon (*Antirrhinum*) 'Chantilly Purple'

‘Chantilly Purple,’ an open faced snapdragon, had a vase life of 9.7 days. With a holding solution, blooms lived over 1 day longer than untreated stems. Flowers were cut when more than three florets were open and terminated when more than 50% of flowers were desiccated or the stems were bent to less than a 90° angle.

Stock (*Matthiola*) 'Carthago White'

‘Carthago White’ was the first cultivar in this year’s trials to bloom. It is a double flowered stock, but a few plants turned out single as is expected. This stock’s vase life averaged 7.3 fragrant days. It performed similarly regardless of postharvest treatment and was terminated when more than 50% of flowers in the stalk desiccated.

Sunflower (*Helianthus*) 'Goldy Double' and 'Sonja'

'Goldy Double' flower heads appeared after most single type sunflowers have already been harvested atop tall, sturdy, nearly six foot tall stems. It is worth the wait for those large, fluffy golden orbs to begin to unfurl. First is the outer ring of flat petals reminiscent of a classic sunflower, followed by layer upon layer of serrated disc flowers. As these disc flowers open toward the center, the bright green disappears little by little until the entire flower head is one fuzzy, golden ball. On average, their vase life was 8.5 days. 'Sonja' is a miniature sunflower perfect for smaller arangements and bouquets. Its center is a deep, contrasting black. 'Sonja' lasted 9.4 days after harvest. Both lasted the longest with a holding solution.

Yarrow *(Achillea)* 'Fireland' and 'Strawberry Seduction'

We harvested both yarrows when pollen was visible, the recommended cutting stage for optimum vase life. Flowers were terminated at greater than 50% desiccated petals or wilted florets. 'Fireland,' with an average vase life of 6.9 days, had tall, straight stems and muted, rusty red flower heads perfect for fall arrangements. 'Strawberry Seduction' had shorter, but sturdier stems with showier crimson blooms. Its average vase life was 7.7 days. Both showed an average two day increase in vase life with the use of a holding solution versus water.

Zinnia 'Benary's Giant Deep Red,' 'Blue Point Golden Yellow,' 'Blue Point Lilac,' and 'Blue Point Salmon Rose'

All four zinnias grown this year were large, double flowered types. Flowers were harvested when disk flowers opened and terminated once more than 50% of ray petals shriveled or if the neck bent to less than a 90° angle. ‘Blue Point Golden Yellow’ outlasted the rest with an average vase life of 9 days, followed by ‘Blue Point Lilac’ with an 8 day run. At 7.6 days, ‘Blue Point Salmon Rose’ trailed closely behind and ‘Benary’s Giant Deep Red’ came in at 6.3 days. All four performed best when treated with a holding solution.

Genus 'Cultivar' or *species*	No Hydrator, No Holding (water only)	No Hydrator, Holding	Hydrator, No Holding	Hydrator, Holding	Stems Treated	Statistical Significance?
Achillea 'Fireland'	5.9	7.9	6.0	7.9	15	Yes
Achillea 'Strawberry Seduction'	5.4	9.7	5.5	9.9	15	Yes
Ageratum 'Blue Horizon'	7.4	9.8	8.7	9.0	15	No
Agrostemma 'Purple Queen'	8.1	9.7	8.7	10.0	15	Yes
Amaranthus 'Green Flowered'	6.9	11.0	10.5	11.0	15	Yes
Amaranthus 'Hot Biscuits'	7.6	11.4	8.2	15.0	14	Yes
Ammi majus	8.5	10.6	9.5	11.0	15	Yes
Antirrhinum 'Chantilly Purple'	8.5	10.7	9.1	10.0	15	Yes
Asclepias 'Silky Formula Mix'	9.9	11.1	9.3	11.0	15	No
Astilbe 'August Light'	4.2	7.3	4.3	7.8	15	Yes
Astilbe 'Bridal Veil'	6.4	6.7	5.2	6.5	15	Yes
Carthamus 'Dark Orange Red'	8.3	8.4	8.9	9.8	15	No
Carthamus 'Grenade Orange'	5.2	5.2	3.9	6.6	9	Yes
Carthamus 'Grenade White'	6.2	5.1	4.7	7.8	12	Yes
Carthamus 'Orange Head'	3.9	5.3	4.9	6.0	13	Yes
Celosia 'Dark Rose'	17.1	18.3	14.9	16.0	15	No
Celosia 'Sunday Orange'	8.5	12.5	10.7	12.0	15	Yes
Celosia 'Sunday Wine Red'	9.5	11.9	9.5	12.0	15	Yes
Cosmos 'Double Click'	4.7	6.2	4.8	5.6	15	Yes
Cosmos 'Sonata Mix'	6.9	8.3	7.1	8.9	15	Yes
Cosmos 'Versailles'	4.8	6.1	6.3	5.8	15	No
Dianthus 'Amazon Neon Duo'	15.4	15.0	14.3	15.0	15	No
Dianthus 'Volcano Mix'	17.8	16.1	16.1	16.0	15	No
Gomphrena 'QIS Carmine'	24.0	17.3	17.9	18.0	15	No
Gomphrena 'QIS Red'	16.3	18.5	16.7	15.0	15	No
Helianthus 'Goldy Double'	7.5	9.5	7.7	9.5	15	Yes
Helianthus 'Sonja'	8.2	9.1	10.1	10.0	15	Yes
Lilium 'Merostar'	13.7	13.3	13.6	12.0	7	No
Lilium 'Concad'or'	13.3	13.0	12.6	13.0	10	No
Matthiola 'Carthago White'	6.9	7.4	7.4	7.5	12	

Genus 'Cultivar' or *species*	No Hydrator, No Holding (water only)	No Hydrator, Holding	Hydrator, No Holding	Hydrator, Holding	Stems Treated	Statistical Significance?
						No
Nigella 'Miss Jekyll Blue'	6.1	6.3	6.5	6.1	15	No
Scabiosa 'Black Knight'	7.3	8.7	7.5	8.8	15	Yes
Scabiosa 'Olympia Mix'	5.8	6.9	6.8	7.8	15	No
Tagetes 'African Jedi Orange'	8.1	13.9	8.2	13.0	15	Yes
Zinnia 'Benary's Giant Deep Red'	5.5	7.1	5.7	6.9	15	Yes
Zinnia 'Blue Point Golden Yellow'	6.5	11.8	7.2	11.0	15	Yes
Zinnia 'Blue Point Lilac'	7.1	8.7	6.6	9.6	15	Yes
Zinnia 'Blue Point Salmon Rose'	6.9	8.7	6.4	8.5	15	Yes

Appendix J

ASCFG Cut Flower Quarterly Publication

December 2013

Postharvest Treatment of Specialty Cut Flowers

North Carolina State University Report for 2013

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This project was supported by the Association of Specialty Cut Flower Growers Research Foundation, the NCDA Specialty Crop Grant Program, and numerous suppliers. The authors would like to thank Diane Mays, Blair Lane, Luna Gu, and Iftikhar Ahmad for assisting with growing and harvesting the cut flowers.

As part of our yearly ASCFG cut flower trials, we conduct vase life studies on cultivars and varieties that show potential as future mainstays on growers' lists. This year, thanks to a joint NCDA and USDA grant, we also had the opportunity to evaluate some cultivars that are already widely grown in North Carolina. A total of 19 annual and perennial cut flowers from 12 different genera were evaluated for postharvest vase life.

What We Did

Trial varieties were planted sixteen plants per plot, four plots per variety. All marketable flowers were cut, measured, and recorded in the field up to three days per week. Up to 60 stems per variety were sorted into four uniform groups and bundled for postharvest vase life evaluation.

Bundles were placed into their first solution, hydrator (Floralife Hydraflor 100 Pretreatment at 1 ounce per gallon) or no hydrator (deionized water) for four hours. Then they were transferred to a second solution, holding solution (Floralife Professional Fresh Flower Food at 1.3 ounces per gallon) or no holding solution (deionized water) for 48 hours. Hydrators are intended to promote rapid water uptake and do not include sugar, while the holding solutions have sugar to promote long vase life. The four resulting treatments were:

1. Hydrator only (no preservative)
2. Holding preservative only (no hydrator)
3. Hydrator, then holding preservative
4. De-ionized water only (control)

Once pretreatments were done, each stem was placed in its own mason jar with 300 mL of deionized water to simulate conditions in consumers' homes. Temperature was kept steady at 68 ± 4° F with 200 fc light for twelve hours per day. Stems were checked daily and terminated once they reached an agreed-upon stage of expiration, usually when greater than 50 percent of petals were desiccated or heads bent over to less than a 90° angle. Vase life was recorded for all stems.

What We Found

Amaranthus 'Elephant Head'

This beefy, wine-hued amaranthus performed best with a holding solution, lasting an average of almost twelve days. Hydrating solution showed a lesser effect; extending vase life by less than one day.

Aster 'Lady in Black'

This is a large, mounding perennial aster with deep purple foliage and a fine texture. 'Lady in Black' is a nice filler with its dark purple leaves and multitude of tiny pink flowers. Expect it to last around nine days in the vase regardless of treatment.

Astilbe 'Fanal'

All our astilbes were happy with the cool, rainy spring this year and were quite prolific. This was the second year in the field for 'Fanal,' and it put on a beautiful show. 'Fanal' lasted a little over 5 days in water only and an average of 2 days longer with a holding treatment.

Celosia ‘Red Flame’

‘Red Flame’ is a sturdy dark carmine red celosia with leaves fading from purple to green. As expected, it has quite the lengthy vase life, with a vase life of 16 days in water only. Holding solutions, without a hydrator, increased vase life by more than two days.

Dianthus ‘Sweet Black Cherry’

‘Sweet Black Cherry’ struggled with the wet weather this spring, and though it was not as prolific as it might have been in a better year, vase life was as long as we expected. We cut this dianthus when at least three florets were open. Its fragrant, deep purple flowers lasted an average of 15.8 days regardless of treatment.

Eggplant ‘Pumpkin on a Stick’

Talk about bang for your buck! ‘Pumpkin on a Stick’ was worth the season long wait. The unique, orange mini pumpkins just kept going in the vase. With an average vase life of just over 36 days, this Japanese eggplant cultivar is a must grow for fall seasonal sales.

Goldenrod (Solidago) ‘Fireworks’

‘Fireworks’ is a perennial favorite in North Carolina. Its open habit and hardy disposition make it an easy choice for growers. The large inflorescence can be used as a filler flower. Using both hydrating and holding solutions increased vase life from 6.7 in the control to 9.1 days with both hydrator and holding solutions.

Lisianthus ‘Arena II Blue Flash,’ ‘Arena II Light Pink,’ and ‘Arena III Baby Pink’

This year was excellent for lisianthus in North Carolina. They thrived in the cool, wet spring and early summer. ‘Arena II Blue Flash’ flowers have a lilac color fading to white toward the center. ‘Arena II Light Pink’ is a very pale, almost white flowered lisianthus with a deep maroon splotch in the throat. ‘Arena II Baby Pink’ is very similar to the other pink variety, but its petals are a tad bit darker pink. It also has a maroon splotch in the throat. All had similarly long vase lives, with ‘Arena II Baby Pink’ lasting slightly longer at an average of 12 days. ‘Arena II Light Pink’ and ‘Arena II Blue Flash’ averaged 11.2 and 10.6 days, respectively. As expected, holdings treatments increased vase life by up to 3 days.

Pepper 1-159252, 13-441552, 16-441575, and 22-441530-2

These four peppers thrived and produced many sturdy stems. Peppers were harvested in late August when the fruit colored up and terminated when peppers dropped or the stems turned black. They generally lasted a day or two longer with a holding solution, while hydrating solutions were generally deleterious to vase life across all four species. 1-159252 had an average vase life of 14.5 days, 13-441552 lasted 14.5 days, 16-441575 came in at nearly 16 days, and 22-441530-2 was the shortest at 12.2 days on average.

Phlox ‘David’

‘David’ is a familiar favorite to many gardeners due to its higher degree of mildew resistance, and it makes a great cut flower as well. Its large, white, cloudlike panicles perch atop long sturdy stems. Vase life was, on average, 10.6 days. Hydrating and holding treatments had no significant effects.

Salvia ‘Caradonna’

This perennial salvia produces copious spikes of vivid purple spires its second year in the field. Most flowering occurred in spring and fall. A vase life of 8 days was observed in water only, and holding solution increased vase life around a day.

Snapdragon ‘Chantilly Velvet,’ ‘Purple Twist,’ and ‘Pink Trumpet’

We cut snapdragons until August here in North Carolina this year. The cool, rainy weather kept them going strong months past the end of their regular harvest season. ‘Chantilly Velvet’ and ‘Pink Trumpet’ are showy, open faced snapdragon varieties. ‘Chantilly Velvet’ has crimson flowers in the traditional shape and sturdy, tall stems. ‘Pink Trumpet’ is a baby pink hue with an ombre effect, fading to white at the tips of the spikes. ‘Purple Twist’ is a horse of a different color, with white, traditionally shaped snapdragon petals accented by purple zebra stripes. Interestingly, flowers started out with bold purple accents early in the season and were completely white when the weather warmed. In water only, ‘Chantilly Velvet’ had a vase life of 5.0 days and ‘Purple Twist’ and ‘Trumpet Pink’ lasted 7.2

days. Holding solutions were helpful in all cases, increasing vase life a little over a day for ‘Chantilly Velvet” and by 3 days for the other two cultivars.

Genus/Cultivar	No Hydrator, No Holding (water only) (days)	No Hydrator, Holding (days)	Hydrator, No Holding (days)	Hydrator, Holding (days)	Stems per Treatment (no.)	Statistical Significance?
Amaranthus ‘Elephant Head’	8.9	12.0	9.6	11.5	15	No
Aster ‘Lady in Black’	8.3	9.7	10.2	9.4	15	Yes
Astilbe ‘Fanal’	5.4	7.7	5.8	7.4	15	Yes
Celosia ‘Red Flame’	16.0	18.5	13.8	16.5	15	No
Dianthus ‘Sweet Black Cherry’	15.9	16.1	15.5	15.5	15	No
Eggplant ‘Pumpkin on a Stick’	38.0	41.5	33.5	31.6	15	Yes
Goldenrod (Solidago) ‘Fireworks’	6.7	8.4	8.5	9.1	15	Yes
Lisianthus ‘Arena II Blue Flash’	8.8	11.9	10.0	11.9	9	Yes
Lisianthus ‘Arena II Light Pink’	9.3	12.3	11.1	12.0	9	Yes
Lisianthus ‘Arena III Baby Pink’	11.1	12.8	11.0	12.9	11	No
Pepper 1-159252	10.8	12.6	9.1	10.7	15	Yes
Pepper 13-441552	16.7	15.5	11.3	14.3	15	Yes
Pepper 16-441575	15.8	17.5	13.9	16.5	15	No
Pepper 22-441530-2	11.1	13.2	10.1	14.6	15	No
Phlox ‘David’	10.8	11.1	9.9	10.6	15	No
Salvia ‘Caradonna’	8.1	9.7	8.9	9.2	15	Yes
Snapdragon ‘Chantilly Velvet’	5.0	6.3	5.0	6.5	15	Yes
Snapdragon ‘Purple Twist’	7.2	10.0	7.1	10.5	15	Yes
Snapdragon ‘Trumpet Pink’	7.2	10.0	7.1	10.5	15	No