EFFECTS OF COLORED PLASTIC FILM ON SEVERAL FIELD GROWN AND GREENHOUSE GROWN CUT FLOWER SPECIES

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THESIS ABSTRACT

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The affects of colored plastic film or paints on morphological features of several cut flower species were tested either in the greenhouse or in the field. A Chapter II experiment was performed in a greenhouse using plywood covered in either red, blue, black, or white plastic film. 'Maryland Appleblossom' snapdragon (*Antirrhinum majus*), 'Blue Horizon' ageratum (*Ageratum houstonianum*), 'Bombay Fire Apricot' celosia (*Celosia argentia* var. *cristata*), 'Majestic Deep Blue with Blotch' pansy (*Viola ×wittrockiana*), and 'Oklahoma Pink' zinnia (*Zinnia elegans*) were used. Ageratum was tallest and had fewest days to flower on red and black films and shortest with more days to flower on blue film and the control. No differences in shoot height were found at 4 wks after treatment for celosia or snapdragon, but at 8 wks shoot height was tallest on red and black film and shortest in the control for celosia and blue film for snapdragon. Shoot dry weight of pansy was largest on red film and smallest on black and blue film and the control. In a repeat experiment, shoot heights of celosia were not different, but shoot dry weight was largest on red film and smallest on white film. Shoot heights of zinnia were tallest on black film and shortest on blue and white film and the control. Zinnia was harvestable 3 days earlier on red film than on blue film or the control.

A Chapter III experiment was conducted in the greenhouse involving painted Styrofoam plates. In celosia, black, blue, and red paints produced the tallest shoot height and the largest growth index while white plates produced the smallest in both experiments. Pansy had the largest growth index on red and black paints and white plates and the smallest on blue paint. In snapdragon, black and red paints and white plates produced the tallest shoot height and largest growth index while blue plates produced the smallest in the first experiment but no differences were found in the second experiment. No differences among treatments were found for ageratum.

A Chapter IV experiment was performed outdoors in two locations to test colored plastic films along with pine bark and bare soil. In Auburn, black film had tallest stems for yarrow and dianthus. Red film had tallest stems for snapdragon. Blue film produced larger stem diameter and fewer DTF for dianthus. White film had highest stem number for dianthus. In Cullman, white film had longest stems for all species while blue film had largest flower diameters for yarrow and dianthus.

Overall, when climate and season have been taken into account along with plant species, colored plastic films show a promising future in field production. However, when used in the greenhouse, colored films were not useful.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction to Cut Flower Production

Around 1993, 75% of cut flowers sold in the United States were imported from other countries, mainly Latin America (1). However, several factors have evolved to make it more feasible for U.S. growers to capitalize on possible benefits of producing cut flowers. Breeding and the introduction of new cultivars, advanced refrigeration, improvements in post-harvest handling, and new floral preservatives on the market are examples of developments that now make it easier to grow and preserve cut flowers (1, 16). A significant challenge facing domestic growers was competition from foreign growers that produced high quality flowers at lower cost throughout the year (1). Likewise, the Andean Trade Preference Act offered countries like Ecuador and Columbia an opportunity to export flowers to the U.S. duty free, helping to keep the competitive price lower (31). In terms of domestic competition, Florida and California had higher production rates because they had extended growing seasons that put them at an advantage over other states (16). However, North Dakota, Mississippi, and other states have tested cut flower production with optimistic results (13, 17). The assumption was that florists would be willing to buy cut flowers from local growers if they were presented a healthy, high quality, consistent product at competitive costs. With new production and harvest techniques available, locally grown cut flowers of the same quality could last longer than imported flowers because they had shorter travel times to their destinations.

One key to understanding the advantage of cut flower production in Alabama is to understand the reasons why farmers have not been involved in cut flower production in the past. With increased competition among farmers, and an exceptional growing season of a single product forcing prices and revenue down, it would be beneficial to have an additional revenue source to create income during low income periods. Discussions with several Alabama extension agents revealed that most farmers were not aware of alternative products or new markets other than those they currently produce (personal communications.) More importantly, most farmers did not know the components for successful cut flower production or which species to grow. For instance, a small grower can use 1 to 2 acres for cut flower production, using only himself or one employee to manage that area. That is enough area to compete if selling directly to consumers via farmer's markets, roadside stands, or pick-your-own operations (18). Cut flower production also offers farmers a chance to work with other area farmers to produce multiple types of cut flowers, sharing land and resources to multiply profits for each. It also provides opportunities for community supported agriculture programs.

In 2004, there were only a small number of cut flower growers operating in Alabama. These growers mainly produced chrysanthemums, iris, lilies, and snapdragons (33), but there were so few growers they were not included in the statistics for USDA Agricultural Statistics Service reports for Alabama. California ranked the highest in number of growers and income from cut flower sales. Income from domestically-grown cut flower sales totaled $422 million in 2004, with California making up the majority of the wholesale value. However, sales value decreased to $397 million in 2005 probably as a result of several growers getting out of the business. The major crops were tulips, roses and lilies. In 2004, there were 536 cut flower growers in the U.S., five more than were present in 2003. However, the USDA report only included data from 36 states (10, 32).

Local cut flower production is a potentially viable niche for farmers and growers that is just beginning to be explored in Alabama. Field grown cut flowers carry the potential for high profit margins if quality flowers are produced and correctly marketed. Profitability depends on the number of weeks of production possible in Alabama, output of quality flowers, the price of equipment and supplies, cost of labor, and the price florists will pay for flowers. If Alabama farmers are able to successfully produce a cut flower product comparable to flowers imported from other countries or states, local florists and wholesalers will likely buy them and keep money in the state. The idea of a successful cut flower market in Alabama would be economically beneficial to both Alabama farmers and the state in general.

It is difficult to refer to the cut flower industry without giving credit to the Netherlands. They have been in the industry for over 400 years, have excelled in marketing strategies, and continue to be a leader in the industry (1, 31). While they are no longer considered leading producers, they are still active in breeding and develop most of the inventive technology for greenhouses. (31)

United States Cut Flower Imports

The majority of cut flowers entering the United States come through the Miami International Airport (MIA). To prevent spread of pests and disease from imported cut flowers, products are inspected on arrival to the U.S. by the Animal and Plant Health Inspection Services (APHIS) Plant Protection and Quarantine (PPQ) officers. Shipments are required to have phytosanitary certificates provided by the purchaser as well as permits indicating no pest or disease problems at the time of exportation. A daily average of the number of cut flowers imported through the MIA is up to 20 million stems (32). To date, the USDA has no standards or regulations regarding imported or domestically grown flowers. The Society of American Florists (SAF) has established voluntary standards as U.S. Blue, Red, Green, or Yellow grades for more common flowers; however, these standards are mainly based on defined aesthetic value and are not mandatory (1, 31). The USDA mainly focuses on pests and diseases based on the flower's country of origin. In her book, *Flower Confidential,* Amy Stewart (31) interviewed Bunny Shreiber, a marketing specialist for the cargo division of MIA, who stated that on a normal day, 10 to 12 flights arrive carrying cut flowers from Columbia, and up to 40 flights a day arrive just before Valentine's Day.

Quality Cut Flowers

Because quality may be the determining factor in the success or failure of locally grown cut flowers, there should be a clear understanding of the meaning of quality related to florists and consumers. Many factors determine quality, including stem length, weight, appearance, and health (27). Post harvest quality applies to the ability of the flower to withstand transportation and handling methods and the longevity of the flower for florists and consumers. After passing into the consumer market, the flower has to measure up to three components linked to consumer quality: appearance (size, shape and color), chemical (fragrance), and anatomically related features such as texture. Consumers usually purchase flowers that are visually appealing to them in color and texture (27).

While quality characteristics were important to selling products, the price florists and consumers will pay for cut flowers depends on the available supply of cut flowers and consumer demand for the flower (1). Prices for cut flowers vary throughout the year, with the highest prices occurring during holidays (16). A study done in Mississippi measuring cut flower market potential found that consumers' decision to purchase flowers was based on occasions, such as weddings, holidays, and funerals, with the occasion rather than the price dictating sales (13).

Specialty Cut Flowers & Marketing

Besides competing on price and quality, local producers can choose from a variety of specialty cut flowers to bring to their local markets. The term "specialty cut flower" refers to one that is considered to be a non-traditional, previously unavailable or rarely available flower. While roses and carnations are examples of traditional cut flowers, *Ageratum houstonianum* and *Achillea millefolium* are examples of species that can be considered specialty cut flowers (1). Specialty cut flower production is not a new concept, which began in the U.S. in the 1940's (1). However, specialty cut flowers can potentially produce the highest profit returns and form a greater niche market for the local cut flower grower. The fact that they can provide “specialty” or difficult to find flowers is appealing to buyers because they are not as widely available as traditional flowers on the market and offer a distinction of expression in floral arrangements.

Several market options exist for specialty cut flowers. The most popular consumer outlets have been retail florists, road-side stands, farmers markets, and supermarkets (13, 16). One obstacle and possible opportunity for local growers is establishing a relationship with local florists. The benefits can include price cuts for florists and a stable customer base for growers. Community supported floral crop production results from local florists agreeing to support Alabama cut flower growers in their efforts to enter the cut flower market (9, 30).

The Effects of Light and Color

Light has obvious effects on plant growth and is required for plants to complete their life cycle. Photosynthesis is a physical and chemical process that provides food for the plant by taking radiant energy from the sun and converting it to chemical energy. The presence of light provides the necessary ingredient for biomass production, but it also provides the plant with information about its environment such as time of year and location (12). Photomorphogenesis is defined as “the non-photosynthetic influence of light on germination, growth, development, and reproduction.” Wavelengths (λ) of light that are usable by plants are within the range of 300-1000 nm. That spectrum generally includes colors perceived by humans ranging from ultra-violet to infra-red. To put those numbers into perspective, the visible wavelengths are 400-700 nm. Therefore, plants use some wavelengths undetectable to the human eye for their biological processes. The energy level provided by each color is specific to the wavelength associated with it. For example, violet at 400 nm has an energy level of 0.299 joules (J) per µmole, while red at 700 nm has an energy level of 0.171 J/µmole (12). According to Grotthus and Draper (12) in the first law of photochemistry in 1818, photochemical changes are only produced when light is absorbed. To absorb as much of the available spectrum as possible, plants rely on carotenoids and chlorophylls for gathering the correct quality and quantity of light. Phytochrome isomers are responsible for the quality of light absorbed in the red (P_r) and far-red (P_{fr}) wavelengths that change configuration back and forth depending on the type of radiant energy to which it is exposed, and this process is referred to as photoreversibility (12, 28). The following diagram illustrates how red (R) and far-red (FR) wavelengths change in configuration (26):

$$P_r \underset{FR\lambda}{\overset{R\lambda}{\rightleftarrows}} P_{fr}$$

Wavelengths R and FR light enter the plant and are absorbed into the interchangeable forms of P_r and P_{fr}, with P_{fr} wavelengths activate the biological processes in the plant (6, 12). The following diagram illustrates how radiant energy activates photomorphogenic responses (23):

$$P_r \xrightarrow{R\lambda} P_{fr} \rightarrow \text{altered gene expression} \rightarrow \text{morphogenesis}$$

Perception transduction response

P_{fr} wavelengths alter the plant's genes leading to a morphological response. Phytochrome pigments initiate tasks such as flower induction and development of chloroplasts. High FR:R ratios cause a high root to shoot ratio (15). The blue-light photoreceptors cryptochromes and phototropins are responsible for blue light responses that typically produce shorter plants and influence the stomatal opening. Phototropins also give the plant the ability to grow toward light, known as phototropism. (12) Therefore, the rationale behind use of colored film in plant production is to manipulate wavelengths of light to optimize the growth habit of plants.

Colored Film Studies

Plastic film covering soil as a mulch has been used since the 1960's, mainly in vegetable production. Eggplant, squash, cucumbers and tomatoes are examples of the many vegetables that have produced better quality fruit and a greater yield when grown on plastic by changing the microclimate (2, 7). Purposes of applying mulch include preserving moisture, increasing or decreasing soil temperature, and suppressing weeds. Colored plastic mulch offers the possibility for an extended growing season, thus increasing yield compared with results from plain black plastic film, organic mulch, or no mulch beds. However, research results fluctuated from year to year and have yet to produce consistent affects (29). One theory is that film can have different effects on plants growth and yield because of light intensity fluctuations from seasonal changes during the year (7). Field production using both older and newer plastic film colors is an area being explored to test which color produces the desired benefits in cut flower production.

Plastic films come in a variety of thicknesses, opacities, and colors that should be chosen based on climate (22). Recent research has explored the possible effects of different colored plastic films on plant biomass, fruit yield, pest control, and even taste. Most work in this area has been performed in vegetable production. Generally, the effects of colored films were species specific and depended on film properties and application method. It was hypothesized that the distance between the plant material and the colored film itself could influence the color's effect on the plant (14).

An Auburn University experiment evaluated the effects of colored films on tomatoes, using several colors painted onto black film, but this study showed no consistent differences in yield (3). A Kansas State University study on light and temperature effects of film color showed higher soil temperatures under black films, and lower temperatures under white film, followed by bare soil (11). To obtain the best results in raising soil temperature, proper film application was crucial. If the plastic did not make direct contact with the soil, temperatures were inconsistent and not raised to potential. Colored film affected plant material by absorbing, reflecting, or transmitting wavelengths of light (11, 21).

Black plastic film was used for many years for its ability to absorb light, raise soil temperatures which extended the production season in cooler climates, and block light from reaching weed seeds below the surface by absorbing light. The soil underneath was as high as 2.8C (5F) higher at 5.1 cm (2 in) of depth (2). Black film is able to absorb wavelengths from all colors (14). Black plastic film is also the color that all other color films were compared to in terms of their effects on soil temperature and yield, and is best used in winter and spring (7).

White plastic film is used to decrease soil temperature. A combination of white plastic on top and black underneath provides weed control and soil cooling. It is widely used in warmer climates during the summer and fall (7). White plastic on top of black plastic was also shown to lower soil temperatures when compared to bare soil (11). White plastic film also resulted in a higher, more marketable yield than black film in bell peppers (5).

Red plastic film raises soil temperatures and controls weeds. It was shown to improve tomato, eggplant, onion, strawberry, and potato yield when compared to black film, and works by reflecting red and far-red light back into the plant canopy from underneath creating more leaf and fruit growth on the lower half of the plant (2, 14, 21, 29). Red film acts by absorbing short wavelengths of light and reflecting FR and R wavelengths into the plant canopy, and can be beneficial when applied during the spring (7, 14). Research has shown that red plastic film does not reflect blue wavelengths (7). Colored film performance also varies based on the manufacturer. M.D Orzolek and L. Otjen (21) found differences in the performance of several red films from different manufacturers. Differences in yield in cantaloupe and pepper, they concluded, were the result of the films ability to hold its color, appearance, and longevity.

Kasperbauer (14) at Clemson University evaluated the effects of red versus black plastic film on yield of strawberry, *Fragaria ×ananassa* Duch. 'Chandler.' Plants grown on red film produced more fruit, and heavier fruit than plants grown on black film. Soil temperatures under the films were similar, leaving the author to conclude that film color was responsible for differences in plant yields, and the red film reflected the necessary wavelengths of light that stimulated the plants' morphogenesis. Therefore, the plant was able to direct photoassimilates to the berries during production on red film.

A study conducted at North Carolina State University concluded that the use of blue film on tomatoes caused a higher incidence of tomato spotted wilt virus (19). Csizinszky et al. (7) found that soil temperature and tomato yield under plastic film painted blue was higher in September and early November than temperatures under yellow or aluminum film, however plants were shorter. Orzolek et al, (20) also conducted a study on tomato plants grown on several plastic film colors. Blue film produced the highest yield, but was not higher than gray or red films; however, they performed better than bare-ground grown plants. Fruit harvested from blue film treatments was larger than from the other colors. Soil temperatures were higher under blue film and black or gray films produced the coolest temperatures. In their experiments, Orzokek et al. determined that blue film reflects wavelengths in the 510 to 720nm range (20).

Decoteau et al. (8) performed a two-year study with tomatoes and film color at Clemson University. The objective of this study was to determine the effects that different film colors had on yield and the light environment. Black polyethylene film was applied to all beds then painted with exterior enamel paints in black, red, white, silver, or no paint. Results showed that the film colors affected the light environment, marketable yield, soil temperatures, and foliage yield. More photosynthetically active radiation was reflected by the white and silver film than the other colors and produced more foliage. Red and black films produced higher fruit yields and higher soil temperatures while white film had the lowest soil temperatures. Red film had high early yields, but that was probably due to the "spectral distribution of reflected light" rather than soil temperatures, meaning that the effects were due to reflected light. Overall, the study showed that film color did, in fact, have an effect on the plant's microclimate.

Ham et al. (11) performed a study using eight types of film from different manufacturers to determine how each affected soil temperature. Highest temperatures, both soil and surface, were recorded for black embossed film and black photodegradable films. Black film showed daily maximum surface temperatures of 17C (31F) higher than white film. White plastic film had the lowest surface temperatures. Their research indicated that the films caused different effects in their test plants because of the varied optical properties used in plastics production and that these characteristics affected soil temperatures.

Colored Film in the Greenhouse

There have been several experiments related to the use of photoselective films in the greenhouse; however, these experiments studied effects on plants when exposed to film overhead as opposed to light reflected from underneath. In the greenhouse, polyethelyne film was studied as a possible non chemical method to regulate plant height (25). Rajapakse et al. (25) determined through their experiments with bedding plants that light quality can be altered by a material and could have the potential to change the way the plant grows. Most of the plants used in this study reacted to the filters, which made plants taller under the red intercepting films and shorter under the far-red intercepting films. Since far red light activates growth, research in this area concentrates on excluding those wavelengths, to keep the plant more compact (24).

Cerny et al. (4) constructed growth chambers wrapped in films manufactured with red and far red absorbing dyes to demonstrate the effect filtered light could have on plants growing underneath them. In snapdragon (*Antirrhinum majus* L.), the film that transmitted R light did not affect stem length, but shoot dry weight was reduced compared to the control. With FR transmitting film anthesis and shoot dry weight did not change much from the control plants. Zinnia (*Zinnia elegans* Jacq.) showed no effect on stem elongation or flowering from exposure to R transmitting film, and but had a reduced shoot dry weight compared to the control plants. Under FR transmitting film, zinnia showed lower shoot dry weight and a slight delay in anthesis.

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CHAPTER II

EFFECTS OF COLORED PLASTIC FILM ON FIVE CUT FLOWER SPECIES

Abstract

The effects of colored plastic films were evaluated for growth and flowering of *Ageratum houstonianum* 'Blue Horizon', *Antirrhinum majus* 'Maryland Appleblossom', *Celosia argentia* var. *cristata* 'Bombay Fire Apricot', *Viola ×wittrockiana* 'Majestic Giant Deep Blue with Blotch', and *Zinnia elegans* 'Oklahoma Pink'. Treatments consisted of light reflected from below into the plant canopy from black, blue, red, or white plastic film or a no film control. Treatment began when cotyledons unfolded on the seedlings. In the first experiment begun December, 2006, ageratum was tallest after 4 wks and 8 wks of growth on red and black film and shortest after being grown on blue film and the control. Fewest days to harvest were also found for ageratum on red and black film and the greatest on blue film. No differences in shoot height were found at 4 wks after treatment for celosia or snapdragon, but at 8 wks shoot height was tallest on red and black film and shortest in the control for celosia and blue film for snapdragon. Plant size was not affected in pansy, but shoot dry weight was largest on red film and smallest on black and blue film and the control. In the second experiment begun March, 2006, ageratum was again tallest after 7 wks of treatment on red and black film and shortest on blue film and the control. Unlike the first experiment, shoot heights of celosia were not different, but shoot dry weight was largest on red film and smallest on white film. Shoot heights of zinnia were tallest on black film and shortest on blue and white film and the control. There were no differences in days to harvest except zinnia was harvestable 3 days earlier on red film than on blue film or the control. Results indicate a possible change in plant response to different color films with season.

Index words: cut flower production, colored plastic film

Species used in this study: ‘Blue Horizon’ ageratum (*Ageratum houstonianum* Mill.), ‘Maryland Appleblossom’ snapdragon (*Antirrhinum majus* L.), ‘Bombay Fire Apricot’ celosia (*Celosia argentia* var. *cristata* L.), ‘Majestic Deep Blue with Blotch’ pansy (*Viola* ×*wittrockiana* Gams), and ‘Oklahoma Pink’ zinnia (*Zinnia elegans* Jacq.).

Significance to the Cut Flower Industry:

Competition is challenging for domestic growers because most foreign growers have advantages such as warmer climates, longer production seasons, and lower production costs which enable them to offer lower prices for their products. Furthermore, other countries consistently produce high quality flowers. Specialty cut flower production allows domestic growers to compete by offering flowers that are not available through importing. Currently, specialty cut flower production is an unfilled niche for farmers seeking alternative income sources in Alabama, with only a few growers attempting to offer a high quality selection. This study evaluated the effects of four

colors of plastic film used in conjunction with cut flower greenhouse production on the time to flower and shoot length of several cut flower species. ‘Blue Horizon’ ageratum was tallest on red and black films and shortest on blue film or when no film was used. ‘Bombay Fire Apricot’ celosia also grew tallest on red and black films and shortest on the control in the first experiment, but not the second. ‘Oklahoma Pink’ zinnia shoots were tallest on black film and shortest on blue and white films and the control. While ‘Maryland Appleblossom’ snapdragon showed no changes due to film colors in the second experiment, plants were tallest on red and black films and shortest on blue film in the first experiment that began in December. There needs to be further work using different species, and testing species in different seasons to determine all seasonal effects and best colors for use in each season.

Introduction:

The majority of cut flowers sold in the U.S. are imported from other countries, mainly Latin America (1). These countries have warmer climates that allow longer production periods, have lower labor costs, and can produce a more consistent product than is generally found in the U.S. To compete, U.S. growers use greenhouses in production to extend growing seasons and achieve environmental control.

Colored plastic films have been used as mulch in agriculture on vegetable crops for several decades (2, 4). However, results have been variable and have depended on location, climate, and film application method (6, 9, 11). For example, in areas with a warmer climate, soil temperatures may be excessive, and therefore white mulch could be an option because of its ability to lower soil temperatures (6). Black plastic film was used to raise soil temperatures up to 2.8C (5F), 5.1 cm (2 in) deep in the soil (2). Red plastic film also increased soil temperatures, so these have been more successfully used in cooler regions.

Several studies have been performed in field trials to study the effects of color on plant growth (3, 5, 6, 7, 8, 9). Kasperbauer (7) compared strawberries grown on black and red plastic films. Soil temperatures under both plastics were similar but larger, heavier fruit were harvested from plants grown on red film. These results led to the conclusion that differences in yield were due to wavelengths of light reflected from each film back into the plant canopy. Decoteau et al. (5) obtained similar results using tomatoes. Early tomato yields were higher early in the season on red film. Csizinszky et al. (4) found that plastic film painted blue increased late season tomato yields.

Previous experiments showed variable results from year to year and indicated that climate and season may influence film performance (3, 11). For example, Brown et al. (3) showed no consistent changes in tomato yield when plants were grown on black painted film. Effects appear to be influenced by seasonal temperature and light intensity, application method, and film properties, both optical and physical (4, 6, 7, 9, 10).

Another way to modify plant growth might be the application of colored plastic films under greenhouse conditions. Through manipulating light wavelengths, there could be an effect on growth, flowering time, and yield of plants. The objective of these studies was to determine the effects that reflected light from colored plastic films may have on growth and flowering of several greenhouse grown cut flower species.

Materials and Methods:

Experiment 1

On December 23, 2006, 12 sheets of 1.2 m × 2.4 m (4 × 8 ft), 0.1 cm (0.375 in) thick plywood were purchased and cut into 1.6 m (5.3 ft) by 1.14 m (3.8 ft) units to fit greenhouse benches. Benches were 1.9 m (6.1 ft) wide and 6.5 m (21.3 ft) long. Each unit of plywood had 24, 11 cm (4.3 in) circular holes cut into them to accommodate 11.4 cm (4.5 in) top diameter plastic pots. Circles were cut 22.9 cm (9 in) on center, forming a rectangular grid of four columns and six rows. The plywood units were held above the bench tops with four pieces of 30.5 cm × 5.1 cm × 10.2 cm (12 in × 2 in × 4 in) wood laid on their 10.2 cm (4 in) sides under each corner and one placed under the center of each plywood unit. Low density polyethylene film in red, blue, white, or black (Pliant Corp, Schaumburg, IL) were stapled to cover the plywood units. All films were 0.038 mm (0.0015 in) thick and each film color was applied to three plywood units. Additionally, there were three control plots where pots sat on the bench tops and had neither plywood nor film underneath. The bench tops were constructed of #13 expanded metal. The plywood units were placed on benches inside a non-shaded, polycarbonate-covered greenhouse with a heat set point of 18C (65F) and ventilation set point of 26C (78F).

On December 21, 2006, seeds were sown in 11.4 cm (4.5 in) diameter plastic pots containing Fafard Lightweight Mix #2 (Fafard, Inc., Anderson, SC). Plant species used were *Celosia argentea* var. *cristata* ‘Bombay Fire Apricot’ (celosia), *Viola ×wittrockiana* ‘Majestic Deep Blue with Blotch’ (pansy), *Antirrhinum majus* L. ‘Maryland Appleblossom’ (snapdragon), and *Ageratum houstonianum* ‘Blue Horizon’ (ageratum)

(Germania Seed Company, Chicago, IL). Pots were placed into the plywood unit holes, after cutting the film in an x-pattern, at seedling emergence and inserted into each hole up to the rim. Each film color replication had 24 plants, six of each species. Plants were watered by hand as needed, and fertilized three out of four waterings, using 75 ppm N of a 20-10-20 (Pro-Sol, Ozark, AL) fertilizer.

Shoot height of snapdragons, celosia, and ageratum and growth index [GI=(height + widest width + width 90°)/3] of pansy were measured at 4 wks (January 18, 2007) and 8 wks (February 14, 2007) after treatments began. Plants were harvested at a harvestable stage: snapdragons were harvested when the inflorescence was 50% open, ageratum was harvested when the first flower was fully open, pansies were harvested the first day the flower was completely open, and celosia was harvested when the crest reached 3 cm (1.2 in) in width at the top of the inflorescence. The date was recorded at harvest to determine days to harvest (DTH). Harvested plants were placed in paper bags, labeled, and placed into a drying oven set at 70C (158F). After at least 24 hrs, plants were removed and measured for dry weight (g).

Experiment 2

On March 23, 2006, C*elosia argentea* var. *cristata* ‘Bombay Fire Apricot,’ *Zinnia elegans* ‘Oklahoma Pink’ (zinnia), *Antirrhinum majus* ‘Maryland Appleblossom,' and *Ageratum houstonianum* ‘Blue Horizon’ seeds were sown. All procedures in the second experiment were the same as the first experiment except as follows. All plants were measured for height at 7 wks after treatment began (May 7, 2007). ‘Oklahoma Pink’ zinnia plants were harvested when the first flower was 50% open.

The experimental design was a split plot with film color as the main plot and plant species as the subplot. However, each plant species was analyzed separately. The PROC-MIXED procedure in PC-SAS (SAS Institute, Cary, NC) was used to determine the significance of the main effect, *P*= 0.05. Treatment differences were determined using the Tukey's test, *P*= 0.05.

Results and Discussion

Experiment 1

The tallest ageratum plants were found on red film that was 67% and 56% taller than on blue film or the control, respectively, after 4 wks of treatment (Table 1). However, shoot heights of plants on red film were not different from black or white film. The shortest plants were found on blue film and the control. The trend for ageratum was the same after 8 wks with red film plant heights 49% and 46% taller than blue film and the control, respectively, and heights of plants on red film were not different from black or white film. The largest DTH occurred on blue film which was 4 days longer than on black or red film. However, blue film was not different from white film or the control. There was no difference in shoot dry weight among the treatments.

There was no difference in shoot heights for celosia at 4 wks. At 8 wks, the tallest plants were recorded on black and red films which were 20% taller than in the control. Blue and white films were not different from red and black film. The shortest plant heights were recorded in the control. There was no difference in DTH. These results were similar to those found for ageratum. Both plants were tallest on red and black films at 8 wks and neither species showed differences in shoot dry weight.

There was no difference in shoot heights for snapdragon at 4 wks. The tallest plants were on red film and were 14% taller than plants on blue film. Black and white films and the control were not different from the red film. Red and black films produced the tallest plants of snapdragon, ageratum, and celosia. Like celosia, snapdragon showed no difference in DTH.

For pansy, greatest shoot dry weight resulted from plants grown on red film. Plants grown on red film had dry weight that was 29% higher than the control, but was not different from those grown on white film. Dry weights of plants grown on black and blue films were similar to the control. There were no differences in shoot height at 4 wks, growth index, or DTH.

Overall, red film produced the tallest shoot heights in snapdragon, celosia, and ageratum and the highest plant dry weight for pansy. Previous studies in vegetable production showed that the best results for products such as eggplant, strawberries, and tomatoes were on red films, based on its ability to reflect red and far-red light back into the plant canopy (2, 7, 9, 11). Blue films produced the shortest plants of ageratum and snapdragon, with heights shorter than the control while blue film was not different from the control for celosia. It also resulted in the longest DTH for ageratum. Csizinszky, et al. (4) grew shorter tomato plants on film painted blue than on yellow, orange, red, white, black, or aluminum films in September and early November 1988 and 1989, but in a spring planting, plant heights on blue film were not different from the other films indicating that the response to blue film colors may be season specific in its effects.

Experiment 2

Ageratum at 7 wks after treatments began was tallest on red film but was not different from black or white film (Table 2). Plants grown on blue film and the control plants were shortest and results were similar to each other. Control plants and those grown on blue film were 18% and 17% shorter than plants on red film, respectively. There was no difference in shoot dry weight or DTH.

There was no difference in shoot height or DTH for celosia. Shoot dry weight was highest in plants grown on blue film and 23% higher than the lowest dry weight found in plants grown on white film. There were no differences in blue, black, red, or the control.

Zinnia was tallest on black film and 40% taller than the shortest plants found on white film, but plants grown on black film was not different from red film or the control. There was no difference in white and blue films. Black film produced plants 34% taller than blue film. The longest DTH was 60 days found for the control and blue film, both of which were 3 days longer than red film. Shoot dry weight was not different. Snapdragon showed no differences in shoot height, DTH, or shoot dry weight.

Results among all species were different. Red and black film produced the tallest plants of ageratum, black film produced tallest plants for zinnia, and shoot height was not different for celosia. Blue film produced the greatest plant biomass for celosia. Orzolek et al. (8) grew larger tomatoes on blue film. This supports the effect of blue wavelengths on plant biomass, yield in particular, and can help explain the difference in plant biomass for celosia.

Temperature data from treatments showed no differences in air or soil temperatures and supports the idea that results were due to light quality effects rather than soil temperature (Table 3). The exception is blue film that produced shortest plants of ageratum at 4 wks and 8 wks and the greatest DTH, shortest plants of snapdragon at 8 wks, and the least dry weight of pansy in the first experiment. Blue film produced shortest plants of ageratum and zinnia and the greatest DTH for zinnia, but the largest dry weight in celosia in the second experiment. Temperature for blue film was the lowest of all treatments. Temperature readings on red and black films were not different from the control, but plants were taller on the films.

In both experiments, ageratum was tallest on red and black films and shortest on blue film and the control. Plants grown on red and black films also showed the fewest DTH and greatest DTH was on blue film in the first experiment. Red and black films also produced tallest plants for snapdragon and celosia in the first experiment and shortest celosia plants in the control and shortest snapdragons on blue film. The largest shoot dry weight for pansy was on red film and smallest on blue and black films and the control. In the second experiment, the tallest zinnia plants were on black film and the shortest on blue and white film and the control. Overall, the tallest plants occurred on black and red films.

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Table 1. Effects of colored plastic film on growth and flowering of pansy (*Viola ×wittrockiana* ‘Majestic Deep Blue with Blotch’), snapdragon (*Antirrhinum majus* ‘Maryland Appleblossom’), ageratum (*Ageratum houstonianum* ‘Blue Horizon’), and celosia (*Celosia argentia* var. *cristata* ‘Bombay Fire Apricot’). Experiment 1.

Film color	‘Blue Horizon’ ageratum			‘Bombay Fire Apricot’ celosia	‘Maryland Appleblossom’ snapdragon	‘Majestic Deep Blue with Blotch’ pansy
	Height (cm) 4 wks[z]	Height (cm) 8 wks	Days to harvest	Height (cm) 8 wks	Height (cm) 8 wks	Shoot dry weight (g)[y]
Black	4.7ab[x]	20.1ab	66b	22.1a	35.1a	1.33b
Blue	3.3b	15.4b	70a	20.9ab	31.9b	1.30b
Red	5.5a	22.9a	66b	22.1a	36.4a	1.66a
White	4.3ab	19.3ab	68ab	20.5ab	34.8a	1.50ab
Control	3.5b	15.7b	69ab	18.4b	32.1a	1.29b

[z] Weeks after treatments began when heights were recorded.

[y] Recorded at the time of harvest.

[x] Mean separation in columns using Tukey’s test, $P = 0.05$.

Table 2. Effects of colored plastic film on growth and flowering of zinnia (*Zinnia elegans* ‘Oklahoma Pink’), ageratum (*Ageratum houstonianum* ‘Blue Horizon’), and celosia (*Celosia argentia* var. *cristata* ‘Bombay Fire Apricot’). Experiment 2.

	‘Blue Horizon’ ageratum	‘Bombay Fire Apricot’ celosia	‘Oklahoma Pink’ zinnia	
Film color	Height (cm)^z	Shoot dry weight (g)^x	Height (cm)^z	Days to Harvest
Black	32.6ab^y	8.0ab	31.0a	59ab
Blue	29.2b	9.2a	23.1b	60ab
Red	34.2a	7.8ab	25.0ab	57b
White	31.4ab	7.5b	22.2b	58ab
Control	28.9b	8.1ab	26.5ab	60a

^{z}Heights recorded 7 weeks after treatments began.
^{y}Mean separation in columns using Tukey’s test, $P = 0.05$.
^{x}Recorded at the time of harvest.

Table 3. Effect of colored plastic film on air temperature one-inch above the plastic surface and potting mix temperature[z].

Mulch type	Air (C)	Soil (C)
Red	27.9[ns y]	27.7a
White	28.0	27.7a
Black	27.9	27.6a
Blue	28.0	27.3b
None	27.9	28.1a

[z] Data recorded from July 23 to August 1, 2007.

[y] Mean separations in columns using the Bonferroni Multiple Range test, $P = 0.05$, ns = not significant.

CHAPTER III

THE EFFECTS OF PLASTIC PLATES PAINTED DIFFERENT COLORS ON GREENHOUSE GROWN CUT FLOWERS

Abstract

The effects of light from several paint colors reflected into the plant canopy on plant growth and flowering were evaluated in two experiments on *Viola ×wittrockiana* ‘Majestic Giant Deep Blue with Blotch’, *Zinnia elegans* ‘Oklahoma Pink’, *Antirrhinum majus* ‘Maryland Appleblossom’, *Celosia argentia* var. *cristata* ‘Bombay Fire Apricot’, and *Ageratum houstonianum* ‘Blue Horizon’. Each species received treatments with white Styrofoam plates painted blue, red, black, or no paint. Plants were measured for growth index, shoot height, and dry weight. In celosia, black, blue, and red paints produced the tallest shoot height and the largest growth indexes while white plates produced the smallest in both experiments. Pansy had the largest growth index on red and black paints and white plates and the smallest on blue paint. In snapdragon, black and red paints and white plates produced the tallest shoot height and largest growth index while blue plates produced the smallest in the first experiment but no differences were found in the second experiment. Pansy was largest on black and red paints and white plates and smallest on blue paint. Shoot dry weight was not affected by the treatments in any species indicating that there was a different distribution of biomass in plants under different color treatments. No differences in treatments for ageratum were found.

Index words: Greenhouse, cut flowers, light color effects, paint

Species used in this study: 'Blue Horizon' ageratum (*Ageratum houstonianum* Mill.), 'Maryland Appleblossom' snapdragon (*Antirrhinum majus* L.), 'Bombay Fire Apricot' celosia (*Celosia argentia* var. *cristata* L.), 'Majestic Deep Blue with Blotch' (*Viola ×wittrockiana* Gams), and 'Oklahoma Pink' zinnia (*Zinnia elegans* Jacq.).

Significance to the Cut Flower industry:

American cut flower producers are constantly trying to find ways to be more competitive with foreign growers. One way to create a favorable climate and longer growing season is using colored plastic mulches to raise or lower soil temperatures and alter the light quality reflected in the plant canopy to produce higher yields and higher quality plants. Altering light quality can be used to produce taller plants that benefit to cut flower growers. But the question is whether the colored medium providing wavelengths of light affects the influence on the plant. Several cut flower species were grown over Styrofoam plates painted red, black, blue, or white non-painted to test the effects of the colors on the growth of the plants. 'Bombay Fire Apricot' celosia had taller shoot height and larger growth index on black, blue, and red painted plates, but 'Blue Horizon' ageratum showed no effects. 'Maryland Appleblossom' snapdragons were taller and larger on black and red paints and white plates in an experiment begun in December, but no differences were found in an experiment begun in March. 'Majestic Deep Blue with Blotch' pansy was largest on black and red paint and white plates.

Introduction

Competition with foreign cut flower growers is a problem for domestic growers. The most stringent competition comes from countries that have longer growing seasons yielding more flowers over a longer period of time and producing consistently high quality flowers to export to the U.S at a low cost (1). Colored plastic mulch has been used in vegetable production for decades to suppress weeds and warm soil temperatures that extended the growing season (2). In the past, the colored mulches used were mainly black and white, but there are now a multitude of other colors being tested for their effects on plant growth, yield, and ability to extend the growing season.

Light quality manipulation is the principle behind the use of most of the newer colored films on the market. The effects produced are due to photomorphogenesis, which accounts for changes in plant growth considered separate from photosynthetic activity. Far red light activates plant growth, so in a red light environment where far red light is not dominant, the plant grows more compact (9, 13). Blue light affects stem elongation through cryptochrome pigments that are among of several types of blue light receptors (7).

Kasperbauer et al. (8) evaluated strawberries grown on black and red films. Plants grown on red film produced more fruit than those plants grown on black film, and fruit was heavier on red film. Soil temperatures underneath the films were similar, so the authors attributed differences in yield to the reflection of wavelengths of light altering the plants' morphogenesis. Red film absorbed short wavelengths of light and reflected red and far red wavelengths into the plant canopy to produce differences in yield (4, 8).

Decoteau et al. (5) grew tomatoes on black film painted with exterior enamel paints in black, red, white, silver, or non painted. Differences were observed in marketable fruit yield, soil temperature, and foliage yield. Red and black films produced higher yields and soil temperatures. White film showed the lowest soil temperatures and reflected the most photosynthetically active radiation. Overall, they determined that the color of the film did have an effect on the microclimate.

Studies using colored films with vegetables have shown variable results. Brown et al. (3) evaluated yield of tomatoes grown in black film over which various colors were applied. No consistent differences in yield were observed. Ham et al. (6) evaluated eight plastic film types from different manufacturers including black, clear, silver on black, and white on black, and determined that the individual properties of the film, film application method, and the spacing of plant material, and the colored film itself could all contribute to differences in yields and other effects on plant biomass. Some of these factors have also been reported by other researchers (4, 8, 11, 12). Orzolek and Otjen (11) also studied several red films from different manufacturers used on cantaloupe and pepper and concluded that differences in films were the result of the film's ability to hold its color, appearance, and longevity.

The objective of these studies was to evaluate the differences in plant growth resulting from blue, red, black, or no paint on plants grown on white Styrofoam plates in a greenhouse environment.

Materials and Methods:

Experiment 1

On December 21, 2006, 360 seeds were sown in 11.4 cm (4.5 in) diameter plastic pots containing Fafard Lightweight Mix #2 (Fafard, Inc., Anderson, SC). Plant species used were *Celosia argentea* var. *cristata* ‘Bombay Fire Apricot’ (celosia), *Viola ×wittrockiana* ‘Majestic Deep Blue with Blotch’ (pansy), and *Antirrhinum majus* L. ‘Maryland Appleblossom’(snapdragon) (Germania Seed Company, Chicago, IL).

White Styrofoam plates, 26 cm (10.25 in) in diameter, were painted with Krylon Fusion for Plastic colors 2421 Satin Black, 2328 Safety Red, or 2329 Safety Blue (Krylon Products Group, Cleveland, OH). A hole, approximately 3.8 cm (1.5 in), cut into the center of each plate to allow the seedlings to grow through the center of the plate. The top edges of the pots were lined with DAP Kwik Seal Kitchen & Bath Adhesive Caulk (DAP, Inc. Baltimore, MD) to hold the plates to the pot rims. The pots and plates were placed on benches with #13 expanded metal surfaces inside a non-shaded, twin-wall polycarbonate-covered greenhouse with a heat set point of 18C (65F) and ventilation set point of 26C (78F). The painted plates were attached to the pot when seedlings within a species had cotyledon leaves unfolding. Plastic trays were placed under each pot to allow sub-irrigation. Plants were watered by hand as needed, and fertilized every three out of four waterings, using 75 ppm nitrogen of a 20-10-20 fertilizer (Pro-Sol, Ozark, AL).

Growth index [GI=(height + widest width + width 90°)/3] of snapdragons, celosia, and pansy were measured at 5 wks (January 24, 2006) after treatment began. At 8 wks after treatment began (February 12, 2007), shoot height was measured on all plants except pansy that was again measured for growth index.

Shoots of plants were removed at a harvestable stage: snapdragons were harvested when the inflorescence was 50% open, pansies were harvested when petals of the first flower had completely expanded, and celosia was harvested when the crest reached 3 cm (1.2 in) in width at the top of the inflorescence. The date of harvest (DTH) was recorded for each plant. Harvested plant tissue was placed in paper bags and put into a drying oven set at 70C (158F). After at least 24 hours, tissue was removed and measured for dry weight (g).

The experiment was a randomized complete block design with six blocks to account for an anticipated light intensity gradient in the greenhouse. The data were analyzed by plant species using PROC GLM (SAS Institute, Cary, NC) to determine treatment effects, $P = 0.05$. Treatment differences were determined using Tukey's test, $P = 0.05$.

Experiment 2

On March 23, 2006, C*elosia argentea* var. *cristata* 'Bombay Fire Apricot' (celosia), *Zinnia elegans* 'Oklahoma Pink' (zinnia), *Antirrhinum majus* 'Maryland Appleblossom' (snapdragon), and *Ageratum houstonianum* 'Blue Horizon' (ageratum) seeds were sown. All procedures in the second experiment were the same as the first experiment except as follows. All plants were measured for height at 7 wks after treatment began (May 7, 2007). ‘Oklahoma Pink’ zinnia plants were harvested when the first flower was 50% open.

Results and Discussion:

Experiment 1

At 5 wks, GI was largest for celosia when grown on blue paint. Plants grown on white plates were 74% smaller than those on blue paint (Table 1). Black and red paints were not statistically different from blue paint. At 8 wks, plants on black paint were 121% taller than plants on white paint. However, there was no difference in black, red, or blue paint. Differences in DTH were not significant; however, blue paint showed the fewest DTH and white plates showed the greatest DTH at 7 days longer.

For pansy, GI was different at 8 wks but not at 5 wks. Plants were largest on red paint and white plates. Blue paint plants were smallest, 21% smaller than plants on red paint and black paint was not different from blue paint. DTH were not different, but white plate plants flowered 6 days earlier than plants on blue paint. Shoot dry weight was not different for any of the three plant species.

Snapdragon GI at 5 wks was 43% larger on black paint than blue paint. Height of plants grown on black paint were similar to those grown on red paint and white plates. At 8 wks, black paint continued the trend by producing plants 45% taller than plants grown on blue paint. Shoot heights of plants grown on red paint and white plate were not different from those grown on black paint. Plants grown on black and red paints and white plates all averaged the same DTH, but blue plate plants flowered 4 days later.

Black film has been used in vegetable production for its ability to absorb wavelengths of all colors and warm soil (2, 8). In this experiment, red and black paints produced the tallest and largest plants of celosia and snapdragon. White film decreases soil temperature but also was shown to reflect more photosynthetically active radiation than other colors, which could have been the reason plants were smaller when grown white plates or blue plates (5).

Experiment 2

Celosia was the only species to show differences in the second experiment (Table 2). Red paint produced plants that were 52% taller than the shortest plants on white plates. Shoot heights of plants grown on black and blue paints were not different from those of plants grown on red paint. DTH and shoot dry weight were not different.

In celosia, black, blue, and red paints produced the tallest shoot height and the largest growth index while white plates produced the smallest in both experiments. Pansy had the largest growth index on red and black paints and white plates and the smallest on blue paint. In snapdragon, black and red paints and white plates produced the tallest shoot height and largest growth index while blue plates produced the smallest in the first experiment but no differences were found in the second experiment. Pansy was largest on black and red paints and white plates and smallest on blue paint. Shoot dry weight was not affected by the treatments in any species indicating that there was a different distribution of biomass in plants under different color treatments. No differences in treatments for ageratum were found. It has been hypothesized that the effects of colored film on plant biomass were seasonal (4, 10). This could account for the differences in celosia and snapdragon in the first experiment that were not continued in the second. In the case of blue light, responses have been shown to be affected by the amount of radiant energy the plant receives, so blue paint could have a different effect on plants in a higher or lower light season (7).

Analysis using PROC TTEST and the Bonferroni Multiple Range test showed that substrate and air temperatures under black plates were 16% cooler than temperature under blue plates, which were the highest temperatures measured (Table 3). Temperature recorded from temperature loggers showed no difference in air and soil temperatures under red, white, and blue plates.

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Table 1. Effects of Styrofoam plates painted different colors on growth and flowering of celosia (*Celosia argentia* var. *cristata* ‘Bombay Fire Apricot’), pansy (*Viola ×wittrockiana* ‘Majestic Giant Deep Blue with Blotch’), and snapdragon (*Antirrhinum majus* ‘Maryland Appleblossom’). Experiment 1.

	‘Bombay Fire Apricot’ celosia		
Plate Color	Shoot height (cm) 8 wks WAT[z]	Growth index 5 wks WAT	Days to harvest
Black	11.7a[y]	6.6ab	85^{ns}
Blue	11.0a	7.3a	82
Red	10.8a	6.9ab	84
White	5.3b	4.2b	89

	‘Majestic Deep Blue with Blotch’ pansy		
Plate Color		Growth index 8 wks WAT	Days to harvest
Black		4.6ab	60^{ns}
Blue		4.2b	62
Red		5.1a	58
White		5.0a	56

	Maryland Appleblossom’ snapdragon		
Plate Color	Shoot height (cm) 8 wks WAT	Growth index 5 wks WAT	Days to harvest
Black	15.7a	6.7a	73b
Blue	10.8b	4.2b	77a
Red	15.4a	5.6a	73b
White	13.8ab	4.8ab	73b

[z] WAT = weeks after treatment began.

[y] Mean separation within columns using Tukey’s test, $P = 0.05$, ns = not significant.

Table 2. Effects of Styrofoam plates painted different colors on growth or celosia (*Celosia argentia* var. *cristata* 'Bombay Fire Apricot'). Experiment 2.

	Celosia
Plate color	Shoot height (cm) 7 wks WAT[z]
Black	17.2ab[y]
Blue	17.2ab
Red	19.0a
White	12.5b

[z] WAT = weeks after treatment began.

[y] Mean separation within columns using Tukey's test, $P = 0.05$, ns = not significant.

Table 3. Effect of Styrofoam plates painted different colors on air temperature and potting mix temperature[z].

Mulch type	Air (C)	Substrate (C)
Black	27.9b [y]	28.4b
Blue	32.6a	33.0a
Red	32.7a	32.7a
White	32.9a	32.6a

[z] Data recorded from July 23 to August 1, 2007.

[y] Mean separations in columns using the Bonferroni Multiple Range test, *P* = 0.05, ns = not significant.

CHAPTER IV

THE EFFECTS OF COLORED MULCHES ON FOUR FIELD GROWN CUT FLOWER SPECIES

Abstract

The effects of colored plastic films on cut flower size and yield of *Antirhinum majus* ‘Sonnet Mix’, *Penstemon digitalis* ‘Husker’s Red’, *Achillea* ×’Coronation Gold’, and *Dianthus barbatus* ‘Bouquet Purple’ were evaluated at two locations, Auburn or Cullman, Alabama, U.S. Species were grown outdoors on six rows mulched with red, white, black, or blue plastic films, pine bark, or bare ground. All plants were harvested, date of harvest recorded, and cut flowers were measured for shoot height, stem count, and stem diameter. Additionally, dianthus and penstemon were measured for node count, and inflorescence length was recorded for penstemon and snapdragons. Results for yarrow, snapdragon and dianthus grown in two different locations were variable and support the idea that response to colored plastic films is related to climate differences. Effects from colored films on penstemon were few and small. Red film produced snapdragon stems 28% longer than stems grown on pine bark in Auburn, but in Cullman plants grown on red film performed well, but longest stems were grown on white film, 12% longer than on pine bark. In Auburn, black film produced 50 more stems per plot than bare ground or white film. In Dianthus, plants grown in Auburn produced the longest stems on black film, 14% longer than plants grown on bare ground, and white film produced eight stems more per plot than bare ground. Dianthus plants grown in Cullman had longest stems on white film and were 21% longer than stems grown on pine bark. The highest stem count was produced on red film, 13 more stems per plot than pine bark which had the lowest. Blue and black films produced the longest yarrow stems in Auburn, 8% longer than pine bark plants. In Cullman these two treatments effects were reversed. Yarrow grown on blue and white films had the largest flower diameters in Cullman, 17% larger than flowers grown on pine bark. Plants grown on red film were 22% larger in diameter than plants grown on pine bark in Auburn.

Index words: field grown cut flowers, plastic film, colored film

Species used in this study: ‘Coronation Gold’ yarrow (*Achillea* ×’Coronation Gold’), ‘Sonnet Mix’ snapdragon (*Antirrhinum majus* L.), ‘Bouquet Purple’ dianthus (*Dianthus barbatus* interspecific ‘Bouquet Purple’), and ‘Husker’s Red’ penstemon (*Penstemon digitalis* Nutt. ex Sims).

Significance to the Industry:

Field grown cut flower production in the U.S. has greater potential than is being realized. Foreign growers dominate the market because of more favorable climates with longer growing seasons, lower labor costs, and the high quality flowers they consistently produce. One way to create a favorable climate and longer growing season in the U.S. is using colored plastic mulches to raise or lower soil temperatures and alter the light

quality reflected into the plant canopy. Altering light quality can be used to increase stem length and possibly produce higher yield and quality that could benefit cut flower growers. Four cut flower species were grown outdoors at Auburn and Cullman, Alabama to test the effects of red, white, blue, or black plastic film, pine bark mulch, and bare soil. Yarrow, snapdragon, and dianthus results indicated that colored film usage was location specific. In Auburn, dianthus grew longest stems on black film and had the highest stem count on white film. Snapdragons produced the highest stem count on black film and the longest stems on red film. Yarrow stems grew longest on black and blue films and flower diameter was largest on red film. In Cullman, Alabama, dianthus stems grew longest on white film and stem count was highest on red film. Snapdragon stems were longest on white film, but yarrow plants yielded longest stems on pine bark, with the largest flower diameters on blue and white films. Penstemon had few and small response to the use of colored films. Generally, black film increased stem number and length while red increased stem diameter, node number, flower diameter, and inflorescence length. White film decreased DTH for all species tested. Further experiments are needed to test species in all seasons.

Introduction:

Most of the cut flowers sold in the U.S. are imported from foreign countries (1). Foreign growers have been successful because they have favorable climates for a longer growing season, lower labor costs so they can sell flowers at lower prices, and consistently high quality products. For these reasons, domestic growers have had a hard time competing in field production. However, colored plastic films used as mulch on raised beds could make domestic growers more competitive. Colored polyethylene films can extend the growing season, and possibly produce higher quality flowers than in the past through open field production.

There have been several studies using colored plastic films in vegetable production with either successful or inconsistent results (2, 5, 7, 8). Kasperbauer (7) evaluated red and black plastic film on yield of strawberry. Fruit yield on plants grown on red film was heavier and higher in number than on plants grown on black film. Soil temperatures were similar leading to the conclusion that film color was the factor responsible for differences in plant yields. It was proposed that red film reflected the necessary wavelengths of light that stimulated the plants' morphogenic response. Generally, many of the effects of colored plastic films were due to application method and physical and optical properties that can vary based on the plastic film manufacturer (5, 8). Ham et al. (5) studied eight types of film from different manufacturers to determine how each affected soil temperatures. Highest temperatures were found under black embossed film and black photodegradable films while lowest temperatures were recorded under white plastic film. Their research indicated that the films caused different effects based on the varied optical properties used in plastics production. Orzolek and Otjen (8) tested several red plastic films from different manufacturers for differences in yield of cantaloupe and pepper plants and found that differences were the result of the film's ability to hold its color, appearance, and longevity.

Other research has indicated that variations in results from repeated experiments could be due to changes in season or variations in weather for a duplicated season (2, 3).

Brown et al. (2) used several colors painted on black film to study the effects of colored films on tomatoes, but this study showed no consistent differences in yield due to colored paint. Csizinsky et al, (3) studied soil temperature and yield of tomatoes grown on blue plastic film and showed that both parameters were higher in September and early November than tomatoes grown on yellow or aluminum film, but plants were shorter.

The object of this experiment was to test the effects of four colored plastic films in comparison with bare soil and pine bark mulch in southern and northern locations in Alabama, U.S. on four field grown cut flower species.

Materials & Methods:

Auburn

Six raised beds 0.5 m (1.5 ft) wide, 15.2 m (50 ft) long, and 6 in (0.5 ft) tall were prepared with a commercial bed-layer (Reddick Inc., Williamston, NC) on the campus of Auburn University (Auburn, AL U.S.A.) in full sun. Soil type is a sandy loam. Four beds were covered with one of the randomly assigned red, white, blue, or black low density polyethylene film colors (Pliant Corp., Schaumburg, IL). All films were 0.038 mm (0.0015 in) thick. The two remaining beds were covered with fine grade pine bark mulch or left bare as a control. Pine bark was applied to a depth of 7.6 cm (3 in). While the commercial bed-layer applied film to each row, one strip of 1.7 lpm (0.45 gpm) drip-tape (T-Systems Int., San Diego, CA) was laid under the plastic and down the center of each bed for irrigation. Drip-tape was also applied under the pine bark and on top of the bare ground.

On October 11, 2006, *Dianthus barbatus* 'Bouquet Purple', *Achillea* ×'Coronation Gold', *Penstemon digitalis* 'Husker's Red', and *Antirrhinum majus* 'Sonnet Mix' plugs (Ball Seed Co., West Chicago, IL) were planted in three randomly assigned replications per bed. Plants were planted in a zig-zag pattern with 10 plants per replication of dianthus, three plants per replication of yarrow, and six plants per replication of penstemon, all of which were planted 45.7 cm (18 in) apart. Snapdragon was planted in 12 plants per replication, 15.2 cm (6 in) apart. A knife was used to make an X-shaped cut in the films to accommodate planting each plant.

Temperature loggers (HOBO model H08-031-08, Onset, Bourne, MA) were placed in each bed to a depth of 15.2 cm (6 in) to record air and soil temperatures every 30 minutes during the experiment at Auburn. Loggers were placed in Styrofoam cups with holes punched in the bottom to protect them from moisture and direct sunlight. Tensiometers (Model SR, 45.7 cm (18 in), Irrometer Co., Riverside, CA) were placed in the bare ground and the black film beds in random locations to monitor soil moisture and determine when watering was needed. When tensiometer readings were between 10 and 20 kPa, irrigation was turned on for at least 2 hrs.

At harvest, data was recorded according to species, and measurements taken were to indicate quality of each cut flower. Stems were cut as close to the ground as possible. Penstemon, yarrow, and snapdragons were harvested when the inflorescence was 50% opened. Dianthus stems were usually harvested in one or two harvests per week for stems that were blooming from January to July. Up to three harvests of each species were made, depending on how early in the season plants started blooming. Days to harvest (DTH), stem length, and stem diameter, were recorded at harvest. Stem diameter measurements were taken midway between the top of the inflorescence and the cut end of the stem. In addition, node number was counted on dianthus stems, inflorescence length was measured in snapdragons, node number and inflorescence length were determined on penstemon stems, and yarrow was measured for flower diameter using two width measurements taken 90° to each other.

On nights that the temperature was predicted to drop below 30F (17C), a row cover was used to cover all beds. This resulted in broken stems in some dianthus plants. Several snapdragon plants were lost in all treatment beds due to freezing temperatures, even with the row cover in place. Other species were not affected. A second problem involved red film which allowed weed growth underneath to poke holes in and stretch the film. In Kasperbauer's research a similar problem was reported (7).

Cullman

The experiment was duplicated at the North Alabama Horticultural Substation (NAHS) in Cullman, AL U.S.A., which has a clay loam soil type. The methods were the same as those used at Auburn except as follows. There were three beds divided in half to accommodate the six treatments. Data taken at harvest for yarrow was stem length, flower diameter, stem count per plant, and a flower color rating that was on a scale based on the percentage of florets showing color on each stem (1 = none; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%). Dianthus was measured for stem length, stem count per plant, flower diameter, color rating, and node number. Penstemon was measured for stem length, stem count per plant, inflorescence length, and node number. Snapdragons were measured for stem length, stem count per plant, and color rating on the same scale used for yarrow. Days to harvest was not recorded because stems were mass harvested rather than cut when plants flowered.

The experimental design was a split plot at each location with mulch type as the main plot and species as the sub-plot, however species was analyzed separately. Analysis was done using PC-SAS (SAS Institute, Cary, NC). PROC-MIXED procedure was used to determine significance of the main effect, and Bonferroni's Multiple Range test was used to determine treatment differences, *P*= 0.05, for stem length, inflorescence length, stem diameter and days to harvest. PROC GENMOD was used to determine significance of the main effect for stem count and node number, and the Wald chi-square test was used to determine treatment differences, *P*=0.05.

Results & Discussion:

Auburn

In yarrow, DTH was fewest on white and black films, 3 days sooner than on red and blue films and 2 days sooner than on pine bark and bare ground (Table 1). Black and blue films had the longest stems in yarrow. These films produced stems 8% longer than plants grown on pine bark, and 5% longer than plants grown on red film. White film and bare ground were not different. Flower diameter was largest on red film, producing flowers 19% larger than plants grown on pine bark which was not different from plants grown on white film or bare ground. Plants on blue film had flowers 7% smaller than on red film, and plants grown on black film were not different from those on blue or white film. The largest stem diameter was on red film, 22% larger than pine bark. Stem diameters of plants grown on white, black, and blue films and bare ground were not different, but were larger than in plants grown on pine bark. However, pine bark produced five more stems per plant than plants on bare ground or red film. Plants grown on red film were not different from bare ground in respect to stem count. Black and blue films produced the same stem numbers but were not different from stem count on pine bark. Stem counts of plants grown on white film were not different from plants grown on black or blue films or pine bark.

Stem length for dianthus was longest on black film (Table 2). Shortest stems were on bare ground. They were 14% shorter than on black film, and not different from pine bark. White and blue films produced stem lengths 5% and 7% shorter, respectively, than red film, but red film stem lengths were not different from white or blue films. Stem diameters were largest on blue film, and were 27% larger than diameters on pine bark. Diameters of stems of plants grown on white and black films were the same at 9% smaller than those on blue film. Stem number of plants grown on red film and bare ground were not different. Node numbers on red film were 17% higher than on white and black films, or bare ground, which were all the same. Node numbers on blue film and plants grown in pine bark were not different, but pine bark had 8% fewer nodes than those on red film. The highest stem number was produced on white film and was eight stems per plant than bare ground. Stem number of plants grown on black film was not different from those on white film. Stem numbers of plants on blue film and pine bark were the same and two stems fewer than red film. Stem number of plants on red film was not different from those on bare ground.

Penstemon plants showed no differences in stem length, inflorescence length, or stem diameter (Table 3). The fewest DTH was on blue and red films while the largest DTH were on white and black films and pine bark. Red, black, white, and blue films had the same stem number, 130% more than pine bark; however, plants on bare ground did not flower during the course of the experiment.

Snapdragon grown on black and blue films had the fewest DTH, 8 days sooner than pine bark but were not different from those on white or red films (Table 4). Pine bark and bare ground resulted in the largest DTH and were not different from each other. Snapdragons had longest stems when grown on red film. Shortest stems were on pine bark, 28% shorter than stems on red film. Stem length of plants on white, black and blue films were not different. Bare ground resulted in stem lengths similar to those of plants on pine bark at 14% shorter than those on red film. Red film also resulted in the longest inflorescence lengths, 71% longer than plants grown on pine bark. Plants grown on white, black, and blue films were again similar with 39%, 32%, and 33% shorter inflorescences than plants grown on red film. Bare ground plants had inflorescence lengths 31% shorter than red film plants. Plants grown on red film had 43% thicker stems than plants grown on pine bark. Stem diameters of plants grown on white, black, and blue films and bare ground were not different than stem diameter of plants grown on red film. The greatest stem number was found in plants grown on black film. There were 50 more stems on black film than bare ground. Stem number in plants grown on blue and white films were similar to those grown on black film, but those on red film were not different from those on white film. Pine bark and bare ground had the fewest stems and were not different from each other.

Snapdragons had the longest stems, inflorescence length, and stem diameter when grown on red film. White, black, and blue films produced similar results for stem diameter, stem length, inflorescence length, and DTH. Yarrow produced the largest stem and flower diameters on red film and smallest on pine bark, but the largest stem number was on pine bark. Longest stems were found on blue and black films, and plants on black film along with white film had the fewest days to flower. Dianthus plants had the largest stem number on white and black films and fewest on bare ground. Stem length was highest on black film, and stem diameter was largest on blue film. Red film produced the largest node number while plants on white and black films and bare ground had the fewest.

While Csizinszky et al. (3) consistently found the shortest tomato plants on blue film in two fall growing seasons, the spring planting of tomatoes were taller on blue film 66 days after planting than plants on red, orange, or yellow painted films, black, and aluminum films. These findings agree with the yarrow in the Auburn study which, along with black film, had the longest stem lengths and were grown in the spring.

In terms of overall film performance, black film consistently increased stem number in all species, followed by white and blue films. Stem diameters were largest in yarrow and snapdragon grown on red film, but blue film was best for dianthus. Stem lengths for yarrow and dianthus were largest with black film, but red film produced largest stems for snapdragon. Fewest DTH was recorded on white film for yarrow, dianthus, and snapdragon, but blue film for penstemon. Highest node number in dianthus, largest flower diameter in yarrow, and longest inflorescence length in snapdragon was found on red film. Generally, black film increased stem number and length while red increased stem diameter, node number, flower diameter, and inflorescence length. White film decreased DTH for all species tested.

Temperature readings indicated that soil temperature was warmest under red film, but was not different from white, black, or blue films (Table 5). Soil temperature was coolest under pine bark and bare ground. Air temperature was warmest above red and white films, but coolest were above pine bark and bare ground. The DIF was greatest for red and black films. Red film had the highest soil temperatures, second highest air temperatures, and greatest DIF. Black film had third highest soil temperatures, third highest air temperatures, and second highest DIF. White film had third highest soil temperatures, highest air temperatures, lowest DIF. Pine bark and bare ground had lowest air and soil temperatures. Warmer soil and air temperatures from red and black films increased the majority of growth parameters when compared to pine bark and bare ground. However, inconsistencies indicate an interaction with spectral light quality and different responses among species. Decoteau et al. (4) recorded temperatures for their experiments with tomatoes grown on plastic films. They concluded that soil temperatures were highest under red and black films and lowest temperatures were under white film.

Cullman

Stem lengths in yarrow were longest on pine bark but was not different from plants on white film (Table 6). Stems on blue film were 11% shorter than pine bark, and were the shortest stems in the study. Black film and bare soil were similar in their effect on length and producing 8% and 6% shorter stems than on bare ground, respectively. However, they were not different from any of the other treatments. Flower diameters were 17% larger on blue film than those on pine bark. Plants on pine bark had the smallest flowers. Effects of red and black films and bare ground on flower diameter were not different from pine bark while white film was not different from blue film. Best color ratings were reported for red, black, and white films, pine bark, and bare ground while worst ratings were on blue film. There were no differences in stem count.

Dianthus stem lengths were longest on white film, 21% longer than on pine bark which produced plants with the shortest stems (Table 7). Stem lengths of plants on red film were not different from those on bare ground and were 10% and 14% shorter than stems on white film, respectively. Stem lengths on black and blue films were 5% shorter than those on white film and were not different. Plants on red film had 13 and 12 more stems than pine bark and bare ground, respectively, and plants on pine bark and bare ground were not different. Plants on white, black, and blue films showed no differences in stem number and were not different from those on red film. Node number for plants on bare ground was 9% higher than in plants on pine bark and red film but was not different from those on white film. Node numbers of plants on blue and black films were not different. Flower diameters were largest on pine bark. Flowers grown on red film were 24% smaller than those grown on pine bark. White, black, and blue films and pine bark produced flowers the same size.

Longest stems for penstemon were recorded on pine bark but these lengths were not different from plants grown on red, white, black, or blue films (Table 8). Stem lengths of plants on pine bark were 26% longer than those on bare ground. Inflorescence lengths were greatest on plants growing on blue film and produced 27% longer inflorescences than those on red film having the shortest inflorescence. Those on bare ground did not differ from plants grown on red film. Node number was greatest on plants grown on black film but were not different from plants on white or blue films or pine bark. Node number on plants grown on red film had the fewest node number, 35% fewer than black film. There were no differences in stem number for penstemon among treatments.

Snapdragon stem length was greatest on white plastic film, but was not different from black and red films (Table 9). Plants on blue and black films were also similar, as were those on blue film, pine bark, and bare ground. Shortest stems were found on pine bark and were 12% shorter than stems grown on white film. Flowers grown on red plastic received the highest color ratings but were not different from those on black, pine bark, or bare ground. Flowers grown on blue film received the lowest color rating but were not different from those on white film. The highest stem number was recorded on white film. Stem number of plants on red, black and bare ground were not different and produced 62%, 48%, and 31% fewer stems than white film, respectively. The number of stems grown on blue film was 23 fewer than white film. Stem number of plants on blue film and pine bark were not different.

Overall, longest stem lengths in all species were found on white film and produced the highest stem number in dianthus and snapdragon. White film also produced the highest node number for dianthus and penstemon. Color ratings were highest for yarrow and snapdragon on red film. Blue film produced the highest flower diameter for yarrow and dianthus. The majority of growth parameters increased when plants were grown on white film while bare ground yielded the least.

In the Auburn experiment, red film produced the longest snapdragon stem lengths, but in the Cullman experiment, white film produced longest stems. Changes in stem length and longer inflorescence length may be attributed to red light and were due to radiant energy absorbed into the plant by the phytochrome (6). White film produced the lowest stem count in the Auburn experiment, but produced the most stems in the Cullman experiment. Pine bark performed relatively poorly in both locations.

There were few differences in treatments for penstemon. Overall, red film and bare ground produced similar results and white, black, and blue films and pine bark did not produce differences. In both locations stem length was not affected by mulch treatment. The Auburn experiment also showed few penstemon responses to treatment.

Dianthus was different between the locations reacted differently in both experiments. Auburn plants produced the longest stems on black film and the shortest stems on bare ground; however, in Cullman stems were longest on white film and shortest on pine bark. Red film produced the highest stem count in Cullman while white film produced the highest stem count in Auburn. In both locations, bare ground resulted in poor plant responses.

Blue and black films produced the longest achillea stems and pine bark produced the shortest stem lengths in Auburn, but in Cullman these two treatments were reversed. Plants grown on blue and white films had the greatest flower diameters in Cullman while plants grown on red film were greater in diameter in Auburn. Reactions in Dianthus, snapdragon, and achillea plants help support the idea that film performance varies based on climate (2, 3).

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Table 1. Effect of four plastic film colors, pine bark mulch or bare ground on cut flower harvested of ‘Coronation Gold’ Achillea in Auburn, AL.

Mulch type	Days to harvest	Stem length (cm)	Flower diameter (cm)	Stem diameter (mm)	Stem number
Red	208a[z]	52.0b	6.2a	3.9a	11b[y]
White	205b	53.7ab	5.5c	3.6b	16ab
Black	205b	54.6a	5.7bc	3.6b	20a
Blue	208a	54.6a	5.8b	3.6b	20a
Pine bark	207a	50.7b	5.2c	3.2c	23a
Bare ground	207a	52.3ab	5.4c	3.5b	11b

[z] Mean separations in columns using the Bonferroni Multiple Range test, $P = 0.05$.

[y] Mean separation in columns using the Wald chi-square test, $P = 0.05$.

Table 2. Effect of four plastic film colors, pine bark mulch, or bare ground on cut flower harvest from Dianthus in Auburn, AL.

Mulch type	Days to harvest	Stem length (cm)	Stem diameter (mm)	Node number	Stem number
Red	182b[z]	39.0bc	3.3cd	9.0a[y]	9bc
White	176c	39.9b	3.5b	7.7c	16a
Black	183b	41.7a	3.5b	7.7c	14a
Blue	174c	38.9c	3.8a	8.4b	10b
Pine bark	196a	36.9d	3.0d	8.3b	10b
Bare ground	181b	36.5d	3.2cd	7.7c	8c

[z] Mean separations in columns using the Bonferroni Multiple Range test, *P* = 0.05.
[y] Mean separation in columns using the Wald chi-square test, *P* = 0.05.

Table 3. Effect of four plastic film colors, pine bark mulch, or bare ground on cut flower harvest from Penstemon in Auburn, AL.

Mulch type	Days to harvest	Stem number
Red	213b[z]	1.4a[y]
White	215a	0.8a
Black	216a	1.4a
Blue	211b	1.4a
Pine bark	217a	0.1b
Bare ground	–[x]	0.0c

[z] Mean separations in columns using the Bonferroni Multiple Range test, *P* = 0.05.
[y] Mean separation in columns using the Wald chi-square test, *P* = 0.05.
[x] None of the plants flowered.

Table 4. Effect of four plastic film colors, pine bark mulch or bare ground on cut flower harvested of Snapdragon in Auburn, AL.

Mulch type	Days to harvest	Stem length (cm)	Inflorescence length (cm)	Stem diameter (mm)	Stem number
Red	203bc[z]	41.4a	15.7a	4.0a	32bc[y]
White	201c	38.5ab	11.3b	3.7a	44ab
Black	200c	39.0ab	11.9b	3.7a	66a
Blue	200c	39.6ab	11.8b	3.8a	50ab
Pine bark	208a	32.4b	9.2b	2.8b	21c
Bare ground	206ab	36.4b	12.0ab	3.5a	16c

[z] Mean separations in columns using the Bonferroni Multiple Range test, $P = 0.05$.
[y] Mean separation in columns using the Wald chi-square test, $P = 0.05$.

Table 5. Effect of four plastic film colors, pine bark mulch or bare ground on air and soil temperature[z].

Mulch type	Air (C)	Soil (C)	Air – Soil (C)
Red	13.9ab[y]	16.2a	-2.3a
White	14.2a	15.5ab	-1.4c
Black	13.8bc	15.5ab	-1.8ab
Blue	13.5cd	15.6ab	-1.5b
Pine bark	13.3d	14.8b	-1.6b
Bare ground	13.3d	14.9b	-1.6ab

[z] Data recorded from November 1, 2006 to May 14, 2007.

[y] Mean separations in columns using the Bonferroni Multiple Range test, $P = 0.05$.

Table 6. Effect of four plastic film colors, pine bark mulch or bare ground on cut flower harvested of Achillea in Cullman, AL.

Mulch type	Stem length (cm)	Flower diameter (cm)	Color rating[z]
Red	54.2bc[y]	8.1bc	4.8a
White	57.7ab	8.2ab	4.8a
Black	55.8abc	7.7bc	4.7a
Blue	53.9c	8.8a	4.6b
Pine bark	60.0a	7.5c	4.8a
Bare ground	56.7abc	7.7bc	4.8a

[z] Rating of percent florets showing color on a stem: 1 = none; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%.

[y] Mean separations in columns using the Bonferroni Multiple Range test, *P* = 0.05.

Table 7. Effect of four plastic film colors, pine bark mulch, or bare ground on cut flower harvest from Dianthus in Cullman, AL.

Mulch type	Stem length (cm)	Flower diameter (cm)	Node number	Stem number
Red	49.2c[z]	2.1c	11c[y]	26a
White	54.3a	2.4ab	12ab	22ab
Black	51.9b	2.2bc	11bc	22ab
Blue	51.7b	2.4ab	11bc	24ab
Pine bark	44.9d	2.6a	11c	14b
Bare ground	47.8c	2.3bc	12a	13b

[z] Mean separations in columns using the Bonferroni Multiple Range test, *P* = 0.05.
[y] Mean separation in columns using the Wald chi-square test, *P* = 0.05.

Table 8. Effect of four plastic film colors, pine bark mulch, or bare ground on cut flower harvested from Penstemon in Cullman, AL.

Mulch type	Stem length (cm)	Inflorescence length (cm)	Node number
Red	47.0a[z]	18.8b	7.4b[y]
White	48.6a	20.9a	8.2a
Black	52.7a	22.8a	10.0a
Blue	48.5a	23.9a	9.4a
Pine bark	53.6a	21.5a	8.5a
Bare ground	42.7b	19.1b	7.5b

[z] Mean separations in columns using the Bonferroni Multiple Range test, $P = 0.05$.
[y] Mean separation in columns using the Wald chi-square test, $P = 0.05$.

Table 9. Effect of four plastic film colors, pine bark mulch or bare ground on cut flower harvested of Snapdragon in Cullman, AL.

Mulch type	Stem length (cm)	Color rating[z]	Stem number
Red	41.1abc[y]	4.1a	21b[x]
White	43.3a	3.7bc	34a
Black	42.2ab	4.0ab	23b
Blue	40.0bc	3.4c	11c
Pine bark	38.9c	4.0ab	18c
Bare ground	39.6c	3.9ab	26b

[z] Rating of percent florets showing color on a stem: 1 = none; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%.

[y] Mean separations in columns using the Bonferroni Multiple Range test, *P* = 0.05.

[x] Mean separation in columns using the Wald chi-square test, *P* = 0.05.

CHAPTER V

FINAL DISCUSSION

The objective of this research was to determine the effects of colored plastic films or paints on the morphology of cut flowers grown either in a greenhouse and outside in Alabama. Species tested in the greenhouse were *Ageratum houstonianum* 'Blue Horizon', *Antirrhinum majus* 'Maryland Appleblossom', *Celosia argentia* var. *cristata* 'Bombay Fire Apricot', *Viola ×wittrockiana* 'Majestic Giant Deep Blue with Blotch', and *Zinnia elegans* 'Oklahoma Pink', all of which were evaluated on plastic film or painted Styrofoam plates. *Achillea* ×'Coronation Gold', *Antirrhinum majus* 'Sonnet Mix', *Dianthus barbatus* interspecific 'Bouquet Purple', and *Penstemon digitalis* 'Husker's Red' were tested in open field conditions on red, white, blue, or black plastic film, bare ground, or pine bark covered beds.

In the first greenhouse experiment involving film covered plywood units, ageratum produced longest stems when grown on red or black film. Red and black films also produced the tallest celosia and snapdragon plants. When this experiment was repeated, there was no difference among treatments for celosia plant heights, but dry weight was highest on red film. Pansy plant size was not affected in size, however shoot dry weight was largest on red film, indicating a difference in biomass distribution. Shoot heights of zinnia were tallest on black film and shortest on blue and white film and the control. There were no differences in days to harvest except zinnia was harvestable 3 days earlier on red film than on blue film or the control.

A second experiment evaluated the affects of Styrofoam plates painted red, blue, black and no paint (white). Blue and red paints consistently performed best for all species. White plates produced shorter plants of celosia, but did as well as red and black paints in snapdragon and pansy. In these cases, blue paint yielded minimal results. Shoot dry weight was not affected by the treatments in any species. No differences among treatments were found for ageratum.

Chapter III evaluated the effects of red, white, blue, or black plastic films on four cut flower species. While penstemon plants did not respond differently on colored film, pine bark, or bare ground, other species did respond, and not necessarily the same way in both locations tested. The indication is that the varied responses are related to climate differences. In terms of overall film performance in Auburn, black film consistently increased stem number in all species, followed by white and blue films. Stem diameters were largest in yarrow and snapdragon grown on red film, but blue film was best for dianthus. Stem lengths for yarrow and dianthus were largest on black film, but red film produced the largest stems in snapdragon. Fewest DTH was recorded on white film for yarrow, dianthus, and snapdragon, but on blue film for penstemon. Highest node number in dianthus, flower diameter in yarrow, and inflorescence length in snapdragon was best on red film. Generally, black film increased stem number and length while red increased stem diameter, node number, flower diameter, and inflorescence length, and white film decreased DTH for all species tested.

Generally, in Cullman white film produced the longest stem lengths in all species and produced the highest stem number in dianthus and snapdragon. White film also produced the highest node number in dianthus and penstemon. Color ratings were highest for yarrow and snapdragon on red film. Blue film produced the highest flower diameter for yarrow and dianthus. The majority of growth parameters increased when plants were grown on white film while bare ground yielded the least.