Effect of Plastic Mulch Color on Cut Flower Production of Snapdragon and Dianthus in a High Tunnel Production System[1]

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Abstract

The objective of these studies was to determine the effects of colored plastic mulch in a high tunnel production system on cut flower production of 'Potomac Appleblossom', 'Potomac Orange', 'Potomac Pink', 'Potomac Yellow', and 'Supreme Gold Yellow' snapdragons (*Antirhinum majus*) in 2007 and 'Cool Bronze', 'Cool Rose', and 'Cool White' snapdragons and 'Amazon Neon Purple' dianthus (*Dianthus barbatus*) in 2008. In 2007, snapdragons were evaluated on blue (BM), red (RM), or white plastic mulch (WM) at the Auburn University, E.V. Smith Research Center (Shorter, AL). Over all cultivars, total stem length, inflorescence length, and stem diameter values were highest on BM and lowest on RM, though inflorescence lengths and stem diameters were not different on BM and WM. 'Potomac Orange' and 'Supreme Gold Yellow' had the longest total stem lengths and 'Potomac Yellow' the shortest while 'Potomac Pink' and 'Potomac Yellow' had the highest stem diameters and 'Potomac Appleblossom' had the lowest over all mulch colors. In 2008, 'Cool Bronze', 'Cool Rose', and 'Cool White' snapdragons and 'Amazon Neon Purple' dianthus were evaluated on black (BkM), blue, red, or white mulch or bare ground (BG) at the Auburn University, Wiregrass Experiment Station (Headland, AL). Total stem lengths were highest on BkM and lowest on BG over all cultivars, however the second highest total stem length was on BM, which is in agreement with the 2007 study where BkM was not included. Inflorescence lengths and stem diameters were highest on BkM, BM, and RM in 2008, which agrees with results for 2007 for BM, but not for RM. The same pattern of differences was found for stem diameters. 'Cool Bronze' had the highest total stem lengths, inflorescence lengths, and stem diameters while 'Cool Rose' had the lowest over all mulch colors. For 'Amazon Neon Purple' dianthus, BkM and BM resulted in the highest stem numbers and stem lengths. These studies were conducted at two different locations and at two different times of the year. Though there were inconsistencies in response to mulch color, BkM and BM generally resulted in longer and thicker stems in snapdragons and the highest stem numbers and stem lengths in dianthus.

Index words: plastic film, Sweet William.

Species used in this study: 'Cool Bronze', 'Cool Rose', 'Cool White', 'Potomac Appleblossom', 'Potomac Orange', 'Potomac Pink', 'Potomac Yellow', and 'Supreme Gold Yellow' snapdragon (*Antirrhinum majus* L.); 'Amazon Neon Purple' dianthus (*Dianthus barbatus* interspecific).

Significance to the Nursery Industry

High tunnels have become popular agricultural structures for frost protection and for growing season extension in the spring and fall for a variety of vegetables and cut flowers. When used for season extension, crops can be planted earlier and harvested sooner allowing them to be sent to market sooner than crops in an outdoor cropping system. Plastic mulches for field production of vegetables have become widely used because it suppress weeds, reduce fertilizer leaching, retains soil moisture, and increases soil temperature, thus increasing growth and resulting in earlier harvests. Studies with colored plastic mulches have shown increased yields of vegetables with certain combinations of season, mulch color, and vegetable type. The objective of these studies was to determine the effects of colored plastic mulch in a high tunnel production system on cut flower yield of snapdragon and dianthus. When 'Potomac Appleblossom', 'Potomac Orange', 'Potomac Pink', 'Potomac Yellow', and 'Supreme Gold Yellow' snapdragons were grown on blue (BM), red (RM), or white mulch (WM) in 2007, total stem length, inflorescence length, and stem diameter values were highest on BM and lowest on RM, though inflorescence lengths and stem diameters were not different on BM and WM over all cultivars. 'Potomac Orange' and 'Supreme Gold Yellow' had the longest total stem lengths and 'Potomac Yellow' the shortest while 'Potomac Pink' and 'Potomac Yellow' had the highest stem diameters and 'Potomac Appleblossom' had the lowest over all mulch colors. In 2008, 'Cool Bronze', 'Cool Rose', and 'Cool White' snapdragons and 'Amazon Neon Purple' dianthus were evaluated black (BkM), blue, red, or white mulch or bare ground (BG). Total stem lengths were highest on BkM and lowest on BG over all cultivars, however the second highest total stem length was on BM, which is in agreement with the 2007 study where BkM was not included. Inflorescence lengths and stem diameters were highest on BkM, BM, and RM in 2008, which agrees with results for 2007 for BM, but not for RM. The same pattern of differences was found for stem diameter. 'Cool Bronze' had the highest total stem lengths, inflorescence lengths, and stem diameters while 'Cool Rose' had the lowest over all mulch colors. For 'Amazon Neon Purple' dianthus, BkM and BM resulted in the highest stem numbers and stem lengths. These studies were conducted at two different locations and at two different times of the year. Though there were inconsistences in response to mulch color, BkM and BM generally resulted in longer and thicker stems in snapdragons and the highest stem numbers and stem lengths in dianthus.

Introduction

Demand by florists for spike flowers, a wide range of colors, and high stem strength found in modern snapdragon cultivars reserves their spot in the U.S. cut flower markets

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(1). According to the USDA, over 46 million snapdragon stems were sold at wholesale in 2006 at a total value of over $12 million (15). Cultivars of cut snapdragons are placed in four response groups based on optimum response to growing conditions (7). Cultivars grown in winter and early spring are in Group I, cultivars grown in late winter and spring are in Group II, cultivars grown in late spring and fall are in Group III, and cultivars grown in summer are in Group IV. Group I cultivars should not be grown in the southeastern United States. due to insufficient cold. Group II cultivars flower from December 15 to April 1 in the southeast, while Group III cultivars flower from April 1 to June 1, and from November 1 to December 15. Group IV cultivars flower from June 1 to November 1 (7, 13). *Dianthus barbatus* is available in a wide range of colors and cultivars that are well suited for the U.S. cut flower market (1). No additional information about this plant as a cut flower was found.

High tunnels are nonpermanent, infield structures, lacking electrical service, automated ventilation, or permanent heating systems, though temporary heaters may be used during frosts, that resemble traditional polyethylene-covered greenhouses (8, 16, 17). They consist of a pipe or other materials framework covered in a single layer of greenhouse-grade polyethylene plastic (8, 16). High tunnels are ventilated manually by rolling the side walls up and down with a roll bar that runs the length of the tunnel and depends on cross winds to provide ventilation (17, 18). High tunnels are used for growing season extension in the spring and fall. When used for season extension, crops can be planted earlier and harvested sooner allowing them to be sent to market sooner than crops in an outdoor cropping system.

Colored plastic mulches have been used in field production of vegetable crops for several decades (2, 4, 6). The Penn State Center for Plasticulture has done extensive studies on the effects of mulch color on yield of vegetable crops in field studies (10). The mulch colors tested were black, white, silver, red, blue, brown, dark blue, green infrared thermal, and yellow. Eggplants and tomatoes responded more to red mulch when compared to black with a 20 and 12%, respectively, increase in marketable fruit yield. Peppers responded more to silver mulch when compared to black with a 20% increase in marketable fruit yield and fruit size. Cantaloupes responded more to green infrared thermal or dark blue mulch when compared to black with a 35% increase in marketable fruit yield. Cucumbers and summer squash responded more to dark blue mulch when compared to black with a 30% increase in marketable fruit yield. Onions and potatoes responded to red, metalized silver, or black mulch when compared to bare ground with a 24% increase in marketable bulb or tuber yield.

However, other results have been variable and have depended on location, climate, and plastic mulch application method (5, 12, 14). For example, Decoteau et al. (5) found that tomato yields were higher early in the season on red mulch, while Csizinszky et al. (4) found that plastic film painted blue increased late season tomato yields. In addition, Orzolek et al. (11) found that tomato yields were higher early in the season on blue and gray mulch.

Crowley and Kessler (3) grew *Antirhinum majus* 'Sonnet Mix' and *Dianthus barbatus* 'Bouquet Purple' as cut flowers on red, white, black, or blue plastic mulches, pine bark, or bare ground outdoors in Auburn or Cullman, AL. Snapdragon stem length was highest on black, blue, red, and white mulch in Auburn and highest on black, red, and white mulch in Cullman. Dianthus stem lengths was highest on black mulch and stem numbers was highest on black and white mulch in Auburn while stem lengths was highest on white mulch and stem numbers was highest on black, blue, red, and white mulch in Cullman.

High tunnels benefit cut flower production by offering more production options ranging from herbaceous perennials being over-wintered for spring cut flower production to summer annuals, and natural fall-season chrysanthemums (9). The objective of these studies was to determine cut flower production of snapdragons and dianthus grown on colored plastic mulches in a high tunnel system.

Materials and Methods

Two studies were conducted with snapdragon in 2007 and with snapdragon and dianthus in 2007–2008. The first study was conducted at the Auburn University, E.V. Smith Research Center (Shorter, AL; 32.4° north latitude, 85.9° west longitude) in a gothic arch, high tunnel (Ledgewood Farm, Moultonborough, NH) covered with a single layer of 0.15 mm (0.006 in) polyethylene. The high tunnel was positioned on a north/south longitudinal axis with dimensions of 14.6 m (48 ft) long, 6.4 m (21 ft) wide, and 2.7 m (9 ft) high. Wiggle-wire locks were attached 1.2 m (4 ft) above the high tunnel base to allow the sides to be rolled up for passive cooling.

Eighteen raised beds 2.1 m (7 ft) long, 45.7 cm (18 in) wide, and 20.3 cm (8 in) tall were laid on a Marvyn sandy loam (fine-loamy, kaolinitic, thermic typic Kanhapludults) and covered with three colored plastic mulches using a mulch bedder (Reddick Fumigants, Wilmington, NC) resulting in three replications of each mulch color. The mulch colors and replications were completely randomized. The soil was not amended before planting. Blue, red, or white polyethylene plastic mulchs were used (0.025 mm (0.001 in) thick, Pliant Corporation, Schaumburg, IL). Each bed had one line of T-Tape (T-Systems International, San Diego, CA) in the center and under the plastic that delivered 1.7 liters per min per 30.5 m of row (0.45 g per min per 100 ft of row).

The snapdragon cultivars 'Potomac Appleblossom', 'Potomac Orange', 'Potomac Pink', 'Potomac Yellow', and 'Supreme Gold Yellow' (*Antirrhinum majus*, Group III) from 288 plug flats (Ball Seed, West Chicago, IL) were transplanted into the raised beds in three rows on July 30, 2007, at a spacing of 12.7 cm (5 in) between rows and 10.2 cm (4 in) within rows. Each row consisted of six seedling blocks, one for each cultivar, randomized within a row. Once the seedlings resumed growth, 0.6 m (2 ft) wide MaxiGrid Warning Barrier (Easy Gardener Products Waco, TX) fencing was installed horizontally over the seedlings to provide plant support. Fi-Shock (Woodstream Corporation Lititz, PA) 1.2 m (4 ft) Step-In Fence Posts were set on either side of the beds to support the fencing. The fencing was moved higher as the plants grew taller to provide support for the stems. Plants were watered when the soil appeared dry, but before plants wilted. Fertilizer [20-4.4-16.6 (20-10-20 Peters Professional, The Scotts Company LLC, Marysville, OH)] was applied at a rate of 150 ppm N twice weekly during the study using a fertilizer injector (Dosatron D128R, Dosatron, Clearwater, FL).

The cut flowers were harvested when two-thirds of a plot of plants had open flowers, on September 24 and 29 and on October 2 and 8, 2007. The flower stems were cut as close

to the ground as possible with hand pruners, tied into one bundle for each plot, and put into clean garbage cans with water (no floral preservative). The cut flowers were stored in a walk-in cooler (Kolpak, Brooklyn, NY) at 3.3C (38F) for a maximum of 48 hours before data collection. Data collected were total stem length, stem diameter [30.5 cm (12 in) from the cut base], and inflorescence length (from the lower-most floret on a stem to the tip of the inflorescence).

The second experiment used the same methods as the first except as follows: it was conducted in the fall of 2007 and the winter of 2008. 'Cool Bronze', 'Cool Rose', and 'Cool White' (Group I to early/mid II) snapdragon seedlings in 392 plug flats and 'Amazon Neon Purple' dianthus (*Dianthus barbatus*) seedlings in 200 plug flats (Ball Seed Company, West Chicago, IL) were delivered on October 9, 2007, and were placed in a twin-wall, polycarbonate-covered greenhouse at the Paterson Greenhouse Facility at Auburn University (Auburn, AL; 32.6° north latitude, 85.9° west longitude) with a heating set point of 16.7C (62F) and ventilation at 25.6C (78F). Seedlings were fertilized at 150 ppm N using a 20-4.4-16.6 (20-10-20) water soluble fertilizer every other time the soil appeared dry.

The seedlings were transplanted into a 29.3 m (96 ft) long, 8.5 m (28 ft) wide, and 3.7 m (12 ft) high (Atlas, Alapaha, GA) high tunnel at the Auburn University, Wiregrass Experiment Station (Headland, AL; 31.4° north latitude, 85.3° west longitude) on October 19, 2007. The soil type was a Dothan sandy loam (fine-loamy, kaolinitic, thermic Plinthic Kandiudults). Black, blue, red, or white polyethylene plastic mulch or bare ground were randomly assigned to three replications of each treatment. The mulch plots were divided into four equal sections, and the four cultivars were randomly assigned to the sections. Snapdragon seedlings were spaced 10.2 cm (4 in) by 10.2 cm (4 in), and dianthus seedlings were spaced 25.4 cm (10 in) by 25.4 cm (10 in) with 12 plants per plot.

Snapdragons were harvested from January 3 to February 29, 2008, and dianthus was harvested from February 16 to February 29, 2008. All except for one harvest of dianthus were processed within 24 hours of harvest without refrigeration. The number of stems per plant and the length of each stem were recorded for dianthus.

In both experiments, data was analyzed using PROC GLIMMIX in SAS version 9.2 (SAS Institute, Cary, NC) to determine significances of the main effects and the interaction. The experimental design was a split-plot with the colored mulch treatments completely randomized in the main plot and cultivars in the sub-plots; stems within sub-plots were sub-samples. Where residual plots and a significant COVTEST statement with the HOMOGENEITY option indicated heterogeneous variance, a RANDOM statement with the GROUP option was used to correct heterogeneity. Mean comparisons among main effects treatments were determined using the Simulation test. All significances were at $\alpha = 0.05$.

Results and Discussion

In the first study, only the cultivar and mulch color main effects were significant for total stem length and stem diameter, and only the mulch color main effect was significant for inflorescence length (Table 1). Over all mulch colors, 'Potomac Orange' (PO) and 'Supreme Gold Yellow' (SG) had the longest total stem lengths followed by 'Potomac Appleblossom' (PA) and 'Potomac Pink' (PP) while 'Potomac Yellow' (PY) had the shortest. PO and SG had 13.8 cm (5.4 in) longer stems than PY while PA and PP were shorter by 9.9 and 6.8 cm (3.9 and 2.7 in), respectively. Over all mulch colors, PP and PY had the highest stem diameters followed by PO and SG while PA had the lowest. PP and PY had 37–42% thicker stems while SG and PO had 26–34% thicker stems than PA.

Over all cultivars, blue mulch (BM) had the longest total stem length followed by white mulch (WM) while red mulch (RM) had the shortest. BM had 5.0 cm (2.0 in) longer stems than WM and 8.8 cm (3.5 in) longer stems than RM. Over all cultivars, BM and WM had longer inflorescence lengths than RM. BM and WM had 2.9 and 2.7 cm (1.1 and 1.1 in) longer inflorescence lengths than RM. Likewise, BM and WM had higher stem diameters then RM over all cultivars. BM and WM had 6% higher stem diameters than RM.

In the second study, only the cultivar and mulch color main effects were significant for total stem length, inflorescence length, and stem diameter (Table 2). Over all mulch colors,'Cool Bronze' (CB) had the longest total stem lengths followed by 'Cool White' (CW) and 'Cool Rose' (CR) that had the shortest. CB had 5.9 cm (2.2 in) longer stems than CW and 19.4 (7.6 in) longer stems than CR. Over all mulch colors, CB and CW had the longer inflorescence lengths and CR had the shortest. CB and CW had 3.6 and 4.6 cm (1.4 in and 1.8 in), respectively, longer inflorescence lengths than CR. Likewise, CB and CW had the highest stem diameters and CR had the lowest over all mulch colors. CB and CW had 22 and 20%, respectively, higher stem diameters then CR.

Over all cultivars, black mulch (BkM) resulted in the longest total stem lengths followed by BM, RM and WM while bare ground (BG) resulted in the shortest. BkM resulted in 6.8–9.0 cm (2.7–3.5 in) longer stems than BM, RM, and WM,

Table 1. Effects of plastic mulch color on cut flower production of snapdragons at the Auburn University, E.V. Smith Research Center (Shorter, AL) in 2007.[z]

Cultivar	Total stem length (cm)	Stem diameter (mm)	Mulch color	Total stem length (cm)	Stem diameter (mm)	Inflorescence length (cm)
'Potomac Appleblossom'	82.0bc[y]	3.8d	Blue	90.4a	5.0a	16.5a
'Potomac Orange'	91.9a	5.1bc	Red	81.6c	4.7b	13.6b
'Potomac Pink'	85.1b	5.2ab	White	85.4b	5.0a	16.3a
'Potomac Yellow'	78.1c	5.4a				
'Supreme Gold Yellow'	91.9a	4.8c				

[z]Only the cultivar and mulch color main effects were significant for total stem length and stem diameter, and only the mulch color main effect was significant for inflorescence length at $\alpha = 0.05$.

[y]Least squares means comparisons within columns (lower case) using the Simulation test at $\alpha = 0.05$.

Table 2. Effects of plastic mulch color on cut flowers production in snapdragons at the Auburn University, Wiregrass Experiment Station (Headland, AL) in 2008.[z]

Cultivar	Total stem length (cm)	Inflorescence length (cm)	Stem diameter (mm)	Mulch color	Total stem length (cm)	Inflorescence length (cm)	Stem diameter (mm)
'Cool Bronze'	95.5a[y]	20.8a	5.5a	Bare[x]	80.0c	17.3b	4.6b
'Cool Rose'	76.1c	17.2b	4.5b	Black	94.8a	19.7a	5.9a
'Cool White'	89.6b	21.8a	5.4a	Blue	88.0b	21.7a	5.3a
				Red	85.8b	22.1a	5.5a
				White	87.0b	18.9b	4.4b

[z]Only the cultivar and mulch color main effects were significant for total stem length, inflorescence length, and stem diameter at $\alpha = 0.05$.

[y]Least squares means comparisons within columns (lower case) using the Simulation test at $\alpha = 0.05$.

[x]Bare ground.

Table 3. Effects of plastic mulch color on cut flower production in 'Amazon Neon Purple' dianthus at the Auburn University, Wiregrass Experiment Station (Headland, AL) in 2008.

		Mulch color			
	Bare ground	Black	Blue	Red	White
Stem number per plant	5c[z]	10a	9ab	7bc	7b
Stem length (cm)	57.4b	63.3a	61.2ab	59.9ab	59.9ab

[z]Least squares means comparisons within rows (lower case) using the Simulation test at $\alpha = 0.05$.

and 14.6 cm (5.8 in) longer stems than BG. BkM, BM, and RM had the highest inflorescence lengths and stem diameters while BG and WM had the lowest. Inflorescence lengths were 2.4–4.8 cm (1.0–1.9 in) longer on BkM, BM, and RM than on BG and WM, and stem diameter was 21–34% higher.

BkM and BM resulted in the highest stem number per plant in 'Amazon Neon Purple' dianthus followed by WM and RM, but BM was not different from WM or RM (Table 3). BG had the lowest stem number per plant, but it was not different from RM. BkM, and BM had 3 and 2 more stems than RM and WM, respectively, while BkM and BM had 5 and 4 more stems than BG. BkM, BM, RM, and WM had the highest stem lengths and BG the lowest, but BM, RM, and WM were not different from BG. BkM, BM, RM, and WM had 5.9, 3.8, 2.5, and 2.5 cm (2.3, 1.5, 1.0, and 1.0 in), respectively, longer stems than BG.

In 2007 and 2008, cultivar and colored mulch influenced the responses of snapdragon independently. In 2007, PO and SG had the longest total stem lengths and PY the shortest while PP and PY had the highest stem diameters and PA had the lowest over all mulch colors. In 2008, CB had the highest total stem length, inflorescence length, and stem diameter while CR had the lowest over all mulch colors.

In 2007, total stem length, inflorescence length, and stem diameter values were highest on BM and lowest on RM, though inflorescence length and stem diameter were not different on BM and WM. In contrast in 2008, total stem lengths were highest on BkM and lowest on BG over all cultivars; however, the second highest total stem length was on BM, which is in agreement with the 2007 study where BkM was not included. Inflorescence lengths and stem diameters were highest on BkM, BM, and RM in 2008 over all cultivars, which agrees with results for 2007 for BM, but not for RM. The same pattern of difference was found for stem diameters. In addition, BkM and BM resulted in the highest stem numbers and lengths in 'Amazon Neon Purple' dianthus. These results are generally in agreement with Crowley and Kessler (3).

Several researchers have reported variable results with colored plastic mulches in outdoor studies with vegetables depended on location, climate, and film application method (5, 12, 14). Our studies were conducted at two different locations, one in the central part of Alabama and the other in the southern part of the state, and they were conducted at two different times of the year, one with harvests in September/October and the other with harvests in January/February. Though there were inconsistences in response to mulch color, BkM and BM generally resulted in longer and thicker stems in the cut snapdragons tested here, and the highest stem numbers and stem lengths in 'Amazon Neon Purple' dianthus.

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