Research Reports

Seedling Developmental Stage at Transplanting Affects Growth and Flowering of Medallion Flower and Globe Amaranth[1]

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Abstract

A study was conducted to determine how seedling development stage at transplanting from plug flats into small pots affected growth and flowering of two commonly grown bedding plants. Seeds of Showstar® medallion flower and 'Las Vegas Pink' globe amaranth were sown in 392-cell flats on five dates for each of two experimental runs before transplanting into 8.9 cm (3.5 in) cubic pots. At transplanting of both species, plant height, node count and shoot dry weight increased as days from sowing to transplanting increased and there was no visible cessation in shoot growth due to root restriction. Time to first flower from transplanting decreased linearly with both species in both runs, except with medallion flower in the second run, as time from sowing to transplanting increased. In contrast, time to flower of both species from sowing increased linearly as time from sowing to transplanting increased. However, the magnitude of the increase or decrease in time to flower differed between the two runs indicating that other factors, most likely light intensity and duration, besides node counts were affecting time to flower. Globe amaranth height and growth index and medallion flower growth index at first flower decreased as time from sowing to transplanting increased, whereas medallion flower height was not affected by time from sowing to transplanting.

Index words: greenhouse production, bedding plant production, bulking, crop scheduling.

Species used in this study: Showstar® medallion flower (*Melampodium paludosum* Kunth); 'Las Vegas Pink' globe amaranth (*Gomphrena globosa* L.).

Significance to the Horticulture Industry

Recommendations for the timing of transplanting bedding plants from plug flats into larger containers are usually based on plug age, and are given as a range in days or weeks. However, growth rate of bedding plants vary with seed quality, cultural practices, and environmental conditions, among other factors, making time from sowing to transplanting a poor predictor of shoot and root development and subsequent plant performance. We evaluated how seedling development stage, based on plant node counts, at transplanting from plug flats into small pots affected growth and flowering of two commonly grown bedding plants. Time to first flower from transplanting decreased with both species in two experimental runs, except with medallion flower in the second run, as time from sowing to transplanting increased. In contrast, time to flower of both species from sowing increased linearly as time from sowing to transplanting increased. Practical implications of this response are that for earlier flowering, a grower should transplant seedlings from plug flats to larger pots as soon as they can be handled; however, once transplanted, seedlings will require more bench space for longer than if they were held in plug flats until further development. With both globe amaranth and medallion flower, node counts were strongly correlated with time to flower; however, differences in the magnitude of the effect of node counts in two experimental runs indicated that other factors, most likely light intensity and duration, were also affecting time to flower. The effects of these other factors limit the usefulness of developmental stage as a predictor of flowering.

Introduction

Prior to the introduction of plug production, most seed-propagated bedding plants were germinated in flats and transplanted bare root. Today, the majority of bedding plants grown from seed are germinated in individual cells or plugs and later transplanted with the entire root ball to a finished container (Heins et al. 1992, McDonald and Kwong 2005). Transplants with relatively small root systems, including those transplanted from plug flats prematurely, generally suffer more post-plant shock and thus come into production later than plants with large root systems (Weston and Zandstra 1986). Conversely, root restriction, concomitant with holding plants in plug flats past an optimal period, can have adverse effects on plant growth and development, including reduced growth rates (Latimer 1991), plant leaf area, root and shoot biomass (Cantliffe 1993, Liu and Latimer 1995), branching (van Iersel 1997), photosynthetic rate and leaf chlorophyll content (NeSmith et al. 1992). Root restriction also decreased final plant height and diameter, flower number, and fresh and dry weights of petunia (*Petunia ×hybrida*), vinca (*Catharanthus roseus* (L.) G.Don), pansy (*Viola ×wittrockiana*), and impatiens (*Impatiens walleriana* Hook.f.) (Al-hemaid and Koranski 1990) and plant quality of marigold (*Tagetes erecta* L.), with primary emphasis on flower cover (Latimer 1991). Recommendations for the timing of transplanting bedding plants from plug flats into larger containers are usually based on plug age, and are given as a range in days or weeks (Ernst Benary 2015). However, growth rate of bedding plants vary with seed quality (Cross and Stryer 1996), composed of percent germination, purity, vigor, and pathological condition of a seedlot (Ferguson et al. 1991), cultural practices (Kuehny et

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al. 2001, van Iersel et al. 1998), and environmental conditions (Heins et al. 1992, Kaczperski et al. 1994, Karlsson et al. 1991, Legnani and Miller 1998), among other factors, making time from sowing to transplanting a poor predictor of shoot and root development and subsequent plant performance. A more consistent gauge of optimal transplanting time may be plant stage of development, as indicated by leaf or node number, which would address effects of crop culture and environmental conditions. The rate of leaf unfurling is a function of temperature, increasing with increasing temperature to a maximum and then decreasing at continued increased temperature (Karlsson et al. 1988, 1991). In African violet (*Saintpaulia ionantha* H. Wendl.), leaf unfurling rate was affected by a combination of plant temperature and photosynthetic photon flux (PPF) and increased linearly between 8 and 30.8 C (Faust and Heins 1993). The objective of this study was to determine how seedling development stage at transplanting from plug flats into small pots affected growth and flowering of two commonly grown bedding plants.

Materials and Methods

Seeds of Showstar® medallion flower and 'Las Vegas Pink' globe amaranth (Ernst Benary of America Inc., De Kalb, IL) were sown in 392-cell flats (28 by 14 cells, 3.95 ml per cell) containing Jolly Gardener Pro-Line Custom Germinating Mix (Old Castle Lawn & Garden, Pageland, SC) beginning on January 9, 2014, and continuing for four sowing dates in run 1 (Table 1). The first sowing date of medallion flower seed for run 2 was March 11, 2014, and was followed by four sowing dates, ending on April 11, 2014. The first sowing date of globe amaranth seed for run 2 was February 21, 2014, and was followed by four sowing dates, ending on April 4, 2014. Intervals between adjacent sowing dates of the first five sowing periods, which comprised the first experiment run, ranged from 2 to 17 days for medallion flower and from 4 to 9 days for globe amaranth, while intervals for the second run ranged from 7 to 16 days for medallion flower and from 6 to 16 days for globe amaranth.

Table 1. Sowing dates in 2014 and days from sowing to transplant for two experimental runs of two bedding plants grown in 392-cell plug flats.

Run 1		Run 2	
Sowing dates	Days sowing to transplant	Sowing dates	Days sowing to transplant
'Las Vegas Pink' globe amaranth[z]			
Feb. 7	30	Apr. 4	27
Jan. 30	38	Mar. 25	37
Jan. 21	47	Mar. 19	43
Jan. 13	55	Mar. 3	59
Jan. 9	59	Feb. 21	69
Showstar® medallion flower[y]			
Feb. 7	17	Apr. 11	19
Feb. 5	19	Apr. 4	26
Jan. 30	25	Mar. 26	35
Jan. 13	42	Mar. 19	42
Jan. 9	46	Mar. 11	50

[z]Seedlings in runs 1 and 2 were transplanted on March 9 and May 1, respectively.

[y]Seedlings in runs 1 and 2 were transplanted on February 24 and April 30, respectively.

The plug flats were filled with substrate, cut into five row units 14 cells long, and seeds of one species were sown in the middle three rows of each unit resulting in 42 cells sown. The outer two rows were not sown and served as border rows. Seed were sown by hand on the substrate surface and a light, coarse-grade vermiculite covering was applied based on the Benary Culture Guide recommendation for the two species. The sown plug units were placed in an unlit germination chamber (GC12, Phytotronics, Inc., Earth City, MO) with a 21 C (70 F) set point until 10 to 20% of the hypocotyls of a species had emerged. After removal from the chamber, the plug units were placed on a heating mat (Model PM-9A, Pro-Grow Supply Corp., Brookfield, WI) set at 21 C (70 F) under intermittent mist set 15 seconds on every 45 minutes, cycling daily from 6:00 AM to 4:30 PM, until 80 to 90% of hypocotyls for a species had emerged. The double-layer polyethylene covered greenhouse that housed the germinating seedlings had a white, polyester shade cloth cover that resulted in an 84% reduction in inside light intensity when compared to that outdoors. Heat and ventilation temperatures in the greenhouse were set at 18.3 and 27.8 C (65 and 82 F), respectively. When the cotyledons of a species were fully expanded, the plug units were moved to an unshaded 8 mm (0.3 in) twin-wall, polycarbonate-covered greenhouse with heat and ventilation set points of 18.3 and 25 C (65 and 77 F), respectively. Liquid fertilization was initially applied weekly, and then more frequently as plants grew, at 125 ppm N with a 13N-0.9P-10.8K-10Ca-1Mg formulation (Greencare 13-2-13-10Ca-1Mg, Kankakee, IL) beginning when the first mature leaf had unfurled and continued until seedlings were transplanted.

When seedlings from the third sowing period were deemed of an optimal size that a grower would transplant them (Table 2), seedlings from the first five sowing periods were transplanted (February 24, 2014, for medallion flower and March 9, 2014, for globe amaranth). On this date, seedlings from the fifth sowing were at the earliest stage that plugs could be removed with the root ball intact; seedlings from the fourth sowing were intermediate between those from the third and fifth sowings based on leaf count; seedlings from the first sowing completely filled the plug cells with roots and were difficult to maintain hydrated, while seedlings from the second sowing were intermediate between those from the first and third sowings based on leaf count. Seedlings at corresponding stages of development from the last five sowing dates were transplanted on April 30, 2014, for medallion flower and May 1, 2014, for globe amaranth, and comprised a second experimental run of development stage treatments. Ten seedlings of each species representing each of the five stages of development were transplanted into 8.9 cm (3.5 in) cubic pots (Dillen Plastics, Middlefield, OH) containing Fafard 3B (Conrad Fafard, Anderson, SC), and constant liquid fertilization at a concentration of 185 ppm nitrogen was applied using a 20N-2.2P-16.6K (Greencare 20-5-20). At transplanting, shoot height and node count were recorded, and 10 additional shoots from each treatment were cut at the substrate surface, bagged and dried in a drying oven (Grieve Corp., Round Lake, IL) at 77 C (170 F) to a constant weight before weighing. Both species have opposite leaves, hence, node counts are one-half of leaf counts. Nodes were counted if the minimum length of leaves at that node was 13 mm (0.5 in). At first open flower, the date, plant height, growth index [(plant height + widest width + perpendicular width) / 3],

Table 2. **Effects of days from sowing to transplant on seedling growth at transplanting of two bedding plant species grown in 392-cell plug flats.**

Run 1				Run 2			
Days to transplant	Height (cm)	Node count	Shoot dry weight (mg)	Days to transplant	Height (cm)	Node count	Shoot dry weight (mg)
			'Las Vegas Pink' globe amaranth				
30[z]	1.8	2	9.3	27	2.2	3	26.7
38	2.1	3	50.0	37	2.2	3	38.0
47	2.1	3	49.2	43	2.5	4	38.6
55	3.0	4	88.0	59	4.2	4	70.8
59	2.8	4	97.0	69	5.3	5	85.5
Sign.[y]	L***	L***	L***		Q***	L***	L***
			Showstar® medallion flower				
17	2.5	2	12.4	19	3.7	3	24.7
19	2.4	2	21.6	26	4.4	3	35.5
25	2.7	3	23.5	35	5.4	4	41.5
42	3.5	4	47.7	42	6.5	4	54.3
46	4.2	4	50.9	50	5.4	4	49.2
Sign.	Q**	Q***	L***		Q***	Q**	Q***

[z]Sowing dates are in Table 1.
[y]Significant (Sign.) linear (L) or quadratic (Q) trends over days from sowing to transplanting using orthogonal contrasts at $\alpha = 0.01$ (**) or 0.001 (***).

and lateral shoot number were recorded. Medallion flower was deemed at first flower when the ray flowers of the first inflorescence were reflexed perpendicular to the peduncle, whereas first flower of globe amaranth was recorded when the papery bracts of the first inflorescence were fully expanded and fully colored pink.

An analysis of variance was performed on all responses recorded at transplant and at first flower using PROC GLIMMIX in SAS version 9.3 (SAS Institute, Cary, NC). Each species and experimental run was analyzed as a separate experiment, and the data were analyzed as completely randomized designs. Where residual plots and a significant COVTEST statement with the HOMOGENEITY option indicated heterogeneous variance among treatments, a RANDOM statement with the GROUP option was used to correct heterogeneity. Node counts were analyzed using the Poisson distribution with a log link. Single degree of freedom orthogonal contrasts were used to test linear, quadratic, and cubic trends over days from sowing to transplanting (stage of development). Linear regressions were used to relate data recorded at first flower to node counts at transplanting, and regression equations were determined. All reported means are least squares means. All significances were at $\alpha = 0.05$.

Results and Discussion

'Las Vegas Pink' globe amaranth. At transplanting of globe amaranth during the first experimental run, plant height, node count and shoot dry weight increased linearly by 56, 100, and 943%, respectively, as days from sowing to transplanting increased (Table 2). Linear or quadratic increases in plant height, node count and shoot dry weight during the second experimental run, in response to increasing days to transplanting, were 141, 67, and 220%, respectively. These increases in growth were expected because of the longer periods between sowing and transplanting and the absence of any visible cessation in shoot growth due to root restriction, a response previously reported by others (Al-hemaid and Koranski 1990; Cantliffe 1993; Karlsson et al. 1988, 1991; Liu and Latimer 1995; Latimer 1991).

Time to first flower from transplanting decreased linearly, by up to 13 days or 34%, during the first experimental run and by up to 9 days or 33% in the second run, as time from sowing to transplanting increased (Table 3). In contrast, time to flower from sowing increased linearly, by up to 15 days or 22% in the first run and up to 33 days or 62% in the second run, as time from sowing to transplanting increased. Thus, seedlings of globe amaranth held longer in plug flats flowered sooner from transplanting than those held for a shorter period, but the total time from sowing to flowering was less when seedlings were transplanted earlier. Practical implications of this response are that for earlier flowering, a grower should transplant seedlings from plug flats to larger pots as soon as they can be handled; however, once transplanted, seedlings will require more bench space for longer than if they were held in plug flats until further development. Regression analysis was used to predict the magnitude of the effects of node count (NC) at transplanting on time to flower. For every additional node or leaf pair present at transplanting, there was an average decrease of 5.8 days from transplanting to first flower (T_DTFF = 47.8 – 5.8 × NC; Pr > F = <0.0001) and an average increase of 6.8 days from sowing to first flower (S_DTFF = 52.5 + 6.8 × NC; Pr > F = <0.0001) in the first run. Similarly, for every additional node present at transplanting during the second run, there was an average decrease of 3.8 days from transplanting to first flower (T_DTFF = 37.6 – 3.8 × NC; Pr > F = <0.0001) and an average increase of 13.8 days from sowing to first flower (S_DTFF = 18.5 + 13.8 × NC; Pr > F = <0.0001). These results support research reporting a delay in flowering when the holding time in plug flats was increased (Al-hemaid and Koranski 1990), one of many adverse effects associated with root restriction (Cantliffe 1993, Liu and Latimer 1995, Latimer 1991, NeSmith et al. 1992). The differences in equa-

Table 3. Effects of days from sowing to transplant on growth and flowering after transplanting of two bedding plant species grown in 392-cell plug flats.

Run 1						Run 2					
Days to transplant	DTFFT[z]	DTFFS[y]	Height (cm)	Growth index (cm)[x]	Node count	Days to transplant	DTFFT	DTFFS	Height (cm)	Growth index (cm)	Node count
'Las Vegas Pink' globe amaranth											
30[w]	38	68	18.4	21.7	5	27	27	54	30.2	28.1	5
38	29	67	12.5	20.0	4	37	26	63	32.1	27.9	5
47	29	76	12.2	20.2	4	43	26	69	32.3	28.4	6
55	25	80	10.2	18.5	4	59	21	80	23.1	23.3	5
59	25	83	10.2	18.4	4	69	18	87	20.2	20.4	5
Sign.[v]	L***	L***	Q**	L***	Q**		L***	L***	Q**	L***	Q**
Showstar® medallion flower											
17	35	52	6.2	15.6	4	19	22	41	12.5	18.1	4
19	33	52	5.8	16.3	3	26	22	48	13.1	19.1	4
25	31	56	6.3	15.2	3	35	21	56	12.6	17.0	4
42	22	64	5.9	12.8	4	42	18	60	15.3	17.3	5
46	20	66	6.2	13.9	4	50	20	70	13.3	16.0	5
Sign.	L***	L***	NS	L***	NS		NS	L***	NS	L**	L**

[z]DTFFT = days to first open flower from transplanting.

[y]DIFFS = days to first open flower from sowing.

[x]Growth index = (shoot height + widest width + width perpendicular to first width) / 3.

[w]Sowing dates are in Table 1.

[v]Non-significant (NS) or significant (Sign.) linear (L) or quadratic (Q) trends over days from sowing to transplanting using orthogonal contrasts at $\alpha = 0.01$ (**) or 0.001 (***).

tion slopes (5.8 vs 3.8 for T_DTFF, 6.8 vs 13.8 for S_DTFF in the first and second runs, respectively) and intercepts (47.8 vs 37.6 for T_DTFF, 52.5 vs 18.5 for S_DTFF in the first and second runs, respectively) between the two runs indicate that other factors besides node counts were affecting time to flower. Seedlings in the two runs were sown and transplanted at different times from early January to mid-April (Table 1), a period during which environmental conditions, including light intensity and duration changed dramatically. Previous research has shown that an increase in daily light integral, the rate at which photosynthetically active radiation is delivered over a 24-hour period, reduced the time to flower and increased the total plant dry mass of several bedding plant species (Faust et al. 2005). Our results illustrate that in spite of the strong relationship between node count at transplanting and time to flower, changes in other factors, most likely light intensity and duration, limit the usefulness of developmental stage as a predictor of flowering.

Plant height at first flower decreased quadratically, up to 45% in the first run and up to 37% in the second, as time from sowing to transplanting increased. The greatest decrease in height during the first run, 32%, occurred with seedlings held in plug cells for the two shortest periods, while in the second run, seedlings held the three shortest periods were similar in height but 28 to 37% taller than those held longer (Table 3). Holding plants longer in plug cells than optimal can restrict growth and development, including growth rates (Latimer 1991) and plant height (Al-hemaid and Koranski 1990). Suppression of height growth may be desirable if weather conditions promote shoot elongation or plants must be held beyond an optimal size before marketing. Conversely, the suppression in height growth could make the plants less marketable at first flower. In contrast to the quadratic decrease in height, growth index at first flower decreased linearly in both runs as time from sowing to transplanting increased, possibly another adverse effect of holding plants in plug cells too long. Regression analysis was also used to predict the magnitude of the effects of node count at transplanting on plant height and growth index (GI). For every additional node present at transplanting, there was an average decrease in plant height of 3.5 cm (Height = 23.9 – 3.5 × NC; Pr > F = <0.0001) and an average decrease in growth index of 1.5 cm (GI = 24.7 – 1.5 × NC; Pr > F = <0.0001) in the first run. Likewise in the second run, for every additional node present at transplanting, there was an average decrease in plant height of 5.2 cm (Height = 47.3 – 5.2 × NC; Pr > F = <0.0001) and an average decrease in growth index of 3.5 cm (GI = 39.1 – 3.6 × NC; Pr > F = <0.0001). The magnitude of growth reductions at first flower with increasing node number at transplanting in the second run when compared to the first run may have occurred because of earlier root restriction in the plug flats under the higher light intensity and duration conditions of the second run. Adverse effects on plant growth, including reduced growth rates (Latimer 1991), plant leaf area, root and shoot biomass (Cantliffe 1993, Liu and Latimer 1995), final plant height and diameter, and fresh and dry weights (Al-hemaid and Koranski 1990), have previously been reported when root restriction occurs. Node counts at first flower were minimally affected by treatments, but were not of horticultural significance. Lateral shoot counts, previously reported to be reduced when roots were restricted (van Iersel 1997), were not affected by the time from sowing to transplanting (data not shown).

Showstar® medallion flower. Similar to globe amaranth, medallion flower increased in height, node count, and shoot dry weight at transplanting as time from sowing to transplanting increased, but the increase was linear only in shoot dry weight during the first run (Table 2). In other cases, the change was quadratic. At transplanting of medallion flower during the first experimental run, plant height, node count and shoot dry weight increased by 68, 100, and 310%, respectively, as days from sowing to transplant increased. Increases in plant height, node count and shoot dry weight during the second experimental run, in response to increasing days to transplanting, were 76, 33, and 120%, respectively.

Time to first flower from transplanting decreased linearly, by up to 15 days or 43%, during the first experimental run, but not in the second run, as time from sowing to transplanting increased (Table 3). In the second run, seedlings sowed during the first two periods flowered after a similar number of days as corresponding seedlings from the first run. However, seedlings sowed on the last three dates of the second run flowered an average of 11 days earlier than corresponding seedlings from the first run, possibly due to higher daily light integrals later in spring, a response previously reported by Faust et al. (2005), and indicate a shortcoming of predicting time to flower based on time from transplanting. In contrast, time to flower from sowing increased linearly, by up to 14 days or 27% in the first run and up to 29 days or 71% in the second run, as time from sowing to transplanting increased. Thus, as with globe amaranth, seedlings of medallion flower held longer in plug flats flowered sooner from transplanting than those held for a shorter period, but the total time from sowing to flowering was less when seedlings were transplanted earlier. For every additional node present at transplanting, there was an average decrease of 5.4 days from transplanting to first flower (T_DTFF = 45.1 – 5.4 × NC; Pr > F = <0.0001) and an average increase of 5.5 days from sowing to first flower (S_DTFF = 41.7 + 5.5 × NC; Pr > F = <0.0001) during the first run. Similarly, for every additional node present at transplanting during the second run, there was an average decrease of 1.5 days from transplanting to first flower (T_DTFF = 26.3 – 1.5 × NC; Pr > F = <0.0106) and an average increase of 8.2 days from sowing to first flower (S_DTFF = 23.1 + 8.2 × NC; Pr > F = <0.0001). Thus, node counts were a strong predictor of time to flower within a run; however, environmental conditions (Faust et al. 2005) or other factors contributed to differences in the magnitude of response between runs.

In contrast to that of globe amaranth, plant height of medallion flower at first flower was not affected by time from sowing to transplanting (Table 3). Growth index decreased linearly in both runs by about 11% as time from sowing to transplanting increased. Regression analysis predicting the magnitude of the effects of node count at transplanting on plant height and growth index were not significant for plant height in either run or GI in the second run. For every additional node or leaf pair present at transplanting, there was an average decrease in GI of 1.0 cm (GI = 17.9 – 1.0 × NC; Pr > F = <0.0001) in the first run. Node counts at first flower were not affected by treatments in the first run and only minimally affected in the second. Lateral shoot counts were not affected by the time from sowing to transplanting in either run (data not shown).

With both globe amaranth and medallion flower, time to first flower from transplanting decreased linearly in both runs, except with medallion flower in the second run, as time from sowing to transplanting increased. In contrast, time to flower of both species from sowing increased linearly as time from sowing to transplanting increased. However, the magnitude of the increase or decrease in time to flower differed between the two runs indicating that other factors, most likely light intensity and duration, besides node counts were affecting time to flower. The effects of these other factors limit the usefulness of developmental stage as a predictor of flowering.

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