Pinch Height of Stock Plants during Scaffold Development Affects Cutting Production

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Additional index words. antirrhinum, chrysocephalum, diascia, lavendula, osteospermum, verbena

Abstract. Stock plants of six herbaceous species (*Antirrhinum* × *hybrida* ‘Primrose with Vein’ L., *Chrysocephalum apiculatum* ‘Golden Buttons’, *Diascia* × *hybrida* ‘Sunchimes Coral’ Link & Otto, *Lavendula dentata* ‘Serenity’ L., *Osteospermum* × *hybrida* ‘Zulu’ L., and *Verbena* × *hybrida* ‘Lanai Bright Pink’ L.) received nine different pinch treatments. Stock plants received a first pinch treatment at one of three pinch heights [low (L_1), middle (M_1), and high (H_1)] followed by a second pinch at one of three pinch heights [low (L_2), middle (M_2), and high (H_2)] in a 3 × 3 factorial arrangement. After the two pinches, cuttings were removed weekly from the stock plants. Cutting yield per stock plant increased as pinch height increased from L to H for both the first and second pinch for all species. A low first pinch followed by a low second pinch (L_1L_2) produced stock plants with the lowest cutting yield, while a high first pinch followed by a high second pinch (H_1H_2) produced the stock plants with the highest cutting yield for all species, e.g., the percentage increase in cutting yield was 133% for *Antirrhinum*, 98% for *Chrysocephalum*, 144% for *Diascia*, 80% for *Lavendula*, 250% for *Osteospermum*, and 44% for *Verbena*. This study suggests that pinch height during scaffold development of the stock plant is an important tool for increasing cutting production.

The vegetatively propagated annuals market continues to grow in the United States. Stock plants are used to produce shoot-tip cuttings for this market. Historically, several important floriculture crops have been propagated vegetatively, such as geranium (*Pelargonium* × *hortorum* L.H. Bailey) (O’Donovan, 1993), poinsettia (*Euphorbia pulcherrima* Willd. ex Klotzsch) (Ecke et al., 2004), chrysanthemum (*Dendranthema* × *grandiflorum* Kitam.) (Eng et al., 1983), and new guinea impatiens (*Impatiens hawkeri* Bull.) (Williams and Ruis, 1995), but no research has been reported on the stock plant production of more recently introduced species such as those used in this study.

A stock plant starts from a single shoot-tip cutting. After propagation, the rooted cutting is transplanted to a container or bed. The initial phase of stock plant production is termed the scaffold development phase. At this time the stock plant is pinched, i.e., apex removal, multiple times to promote lateral shoot development and build a scaffold from which future cutting production occurs. The number

of pinches performed during the scaffold phase affects the timing and yield of cutting production (Faust and Grimes, 2004). O’Donovan (1993) recommended that geranium stock plants are initially pinched to leave a 10 to 15 cm tall primary stem that contains at least four nodes, then the shoots that develop after the initial pinch are pinched to two or three nodes until the peak harvest season at which time one node is left on the stem below the harvested cutting.

The scaffold phase is followed by the production phase during which time cuttings are harvested from the stock plants. Leaf removal during the production phase is recommended on poinsettia (Wilkins, 1988) and geranium (O’Donovan, 1993) stock plants since this allows for increased light penetration into the canopy and thus increased cutting production.

The number of nodes left below the pinch affects the timing of lateral shoot development and the number of potential lateral shoots. The number of nodes left on the stem below the pinch is referred to as the pinch height in this manuscript. A low pinch has relatively few nodes remaining on the stem for lateral shoot development, while a high pinch leaves a greater number of nodes remaining on the stem. A low pinch can be performed while the shoots are relatively young, but relatively few nodes are left on the stock plant. In contrast, more production time is required before a shoot has enough nodes to perform a high pinch;

however, more nodes are left below the high pinch, so more potential shoots can develop. The objective of this study was to determine the effect of pinch height on the cutting yield of six vegetatively propagated herbaceous species. The results will provide growers with an improved understanding of how to manage stock plants to improve cutting yield.

Materials and Methods

Forty-five, unpinched, rooted cuttings of each of five species (*Antirrhinum* × *hybrida* ‘Primrose with Vein’ L., *Chrysocephalum apiculatum* ‘Golden Buttons’, *Diascia* × *hybrida* ‘Sunchimes Coral’ Link & Otto., *Osteospermum* × *hybrida* ‘Zulu’ L., and *Verbena* × *hybrida* ‘Lanai Bright Pink’ Groenl. & Ruempl.) and 54 rooted cuttings of *Lavendula dentata* ‘Serenity’ L. were transplanted into 16.5-cm-diameter (2.2-L) containers at the start of the experiment. One cutting was planted in each container, and each plant represented an experimental unit. Containers were placed at 30 × 30-cm spacing (center-to-center), so that the canopy of neighboring plants did not overlap during the experiment.

Fifteen *Antirrhinum*, *Diascia*, *Osteospermum* and *Verbena* plants and eighteen *Lavendula* plants were randomly treated with one of the three following pinch treatments on the primary shoot: low (L_1), middle (M_1), or high (H_1). Pinch height was defined by the number of nodes remaining on the shoot following the pinch. The timing of the pinch treatments and the number of nodes left below each pinch was unique for each species (Table 1). Following the first pinch, lateral shoots developed, then a second pinch was performed on the lateral shoots. The second pinch was also performed at one of three heights: low (L_2), middle (M_2), or high (H_2), as defined in Table 1. The result was nine pinch treatment combinations arranged in a 3 × 3 factorial design. The nine individual treatment combinations are labeled as: L_1L_2 , L_1M_2 , L_1H_2 , M_1L_2 , M_1M_2 , M_1H_2 , H_1L_2 , H_1M_2 and H_1H_2 . The main effects for pinch height are described with a single letter, e.g., L, M and H for the low, middle and high pinches, respectively.

The timing of the pinch treatments varied on the first and second pinch for each species (Table 1). For example, the first pinch was applied to the primary shoot of *Antirrhinum* on day 7, and 2, 4, and 6 nodes were left on the stock plant for the L_1 , M_1 and H_1 treatments, respectively. Thus, the amount of tissue removed during the first pinch varied with the pinch height treatment. The second pinch was performed as soon as the shoots had developed enough nodes for the pinch to take place, e.g., for *Antirrhinum* the second pinch was applied on day 21, 27 or 33, and 2, 4, or 6 nodes were left below the pinch for the L_2 , M_2 or H_2 treatment, respectively.

Following the two pinch treatments, cuttings were removed weekly from the stock plants when the developing shoot met the following two criteria. The cutting stem was a specified length (Table 2) and two nodes or one node pair, depending on leaf arrangement of

Received for publication 14 May 2004. Accepted for publication 3 Sept. 2004. Technical Contribution No. 4904 of the Clemson University Experiment Station. This material is based upon work supported by CSREES/USDA, under project number SC-1700135. Additional support for this research was provided by FIRST. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the USDA.

Table 1. The pinch dates and the number of nodes remaining on the shoots after the pinch for each of the nine pinch height treatments and six species.

Species	Pinch ht treatment		Pinch date (days after transplant)		Nodes remaining on shoots after	
	1st pinch	2nd pinch	1st pinch	2nd pinch	1st pinch	2nd pinch
<i>Antirrhinum</i>	Low	Low	7	21	2	2
	Low	Middle	7	27	2	4
	Low	High	7	33	2	6
	Middle	Low	7	21	4	2
	Middle	Middle	7	27	4	4
	Middle	High	7	33	4	6
	High	Low	7	21	6	2
	High	Middle	7	27	6	4
	High	High	7	33	6	6
<i>Chrysocephalum</i>	Low	Low	10	35	4	2
	Low	Middle	10	35	4	4
	Low	High	10	35	4	6
	Middle	Low	10	35	6	2
	Middle	Middle	10	35	6	4
	Middle	High	10	35	6	6
	High	Low	10	35	8	2
	High	Middle	10	35	8	4
	High	High	10	35	8	6
<i>Diascia</i>	Low	Low	7	17	2	2
	Low	Middle	7	24	2	4
	Low	High	7	33	2	6
	Middle	Low	7	17	4	2
	Middle	Middle	7	24	4	4
	Middle	High	7	33	4	6
	High	Low	7	17	6	2
	High	Middle	7	24	6	4
	High	High	7	33	6	6
<i>Lavendula</i>	Low	Low	2	26	3	3
	Low	Middle	2	32	3	5
	Low	High	2	39	3	7
	Middle	Low	4	26	5	3
	Middle	Middle	4	32	5	5
	Middle	High	4	39	5	7
	High	Low	8	26	7	3
	High	Middle	8	32	7	5
	High	High	8	39	7	7
<i>Osteospermum</i>	Low	Low	11	49	5	2
	Low	Middle	11	56	5	6
	Low	High	11	63	5	10
	Middle	Low	32	56	10	2
	Middle	Middle	32	63	10	6
	Middle	High	32	70	10	10
	High	Low	42	63	15	2
	High	Middle	42	70	15	6
	High	High	42	84	15	10
<i>Verbena</i>	Low	Low	5	21	2	2
	Low	Middle	5	29	2	4
	Low	High	5	34	2	6
	Middle	Low	10	21	4	2
	Middle	Middle	10	29	4	4
	Middle	High	10	34	4	6
	High	Low	21	29	6	2
	High	Middle	21	34	6	4
	High	High	21	41	6	6

Table 2. The experimental dates and the specified cutting stem length for each of the six species.

Species	Transplant date	Final cutting harvest date	Cutting stem length (cm)
<i>Antirrhinum</i>	20 Dec. 2002	31 Mar. 2003	3.8
<i>Chrysocephalum</i>	7 Jan. 2003	14 Apr. 2003	3.2
<i>Diascia</i>	20 Dec. 2002	17 Mar. 2003	3.8
<i>Lavendula</i>	13 Feb. 2003	19 May 2003	3.2
<i>Osteospermum</i>	25 Nov. 2002	28 Apr. 2003	2.5
<i>Verbena</i>	6 Dec. 2002	12 Mar. 2003	2.5

each species, remained on the shoot following cutting removal. The number of cuttings harvested per stock plant was recorded weekly.

The experimental dates were unique for each species (Table 2). From 25 Nov. to 19 May the mean daily light integral was $10.2 \text{ mol} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ and the mean greenhouse air temperature was 22.9°C . Ambient photoperiods were provided throughout the experiment. Plants were fertilized twice weekly with 20N–8.6P–16.6K Peat-Lite Special (O.M. Scott, Marysville, Ohio) at $250 \text{ mg} \cdot \text{L}^{-1}$ N. Water was applied as needed the remainder of the week.

For each species, three pinch height treatments were applied during the first and second pinches resulting in a 3×3 factorial design. The individual treatments were arranged in a completely randomized pattern inside the greenhouse. ANOVA were performed for each species and at each cumulative harvest date using PROC GLM (SAS Institute, Cary, N.C.). LSD (5% level) was used to determine differences between the main effects (pinch height) at each harvest date. The final cumulative cutting yields for all nine subclasses (first and second pinch height combinations) were compared using pairwise comparisons with LSD at the 5% level.

Results

Pinch height affected the final cumulative cutting yield for all species, while no statistical interaction was observed between the pinch height of the first and second pinches (Table 3); therefore, the effect of pinch height on the first and second pinches exhibited an additive effect on cutting yield. Final cutting yield increased as pinch height increased for both the first and second pinches (Table 4). For example, the main effect means for *Antirrhinum* were 81, 102, and 118 total cuttings for L_1 , M_1 , and H_1 , and 71, 111, and 118 total cuttings for L_2 , M_2 , and H_2 . The combined first and second pinch heights yielded 60, 108, to 140 cuttings for the L_1L_2 , M_1M_2 , and H_1H_2 treatments, respectively. Comparing L_1L_2 to H_1H_2 for the other species shows cutting yield increases of 98%, 144%, 80%, 250%, and 44% for *Chrysocephalum*, *Diascia*, *Lavendula*, *Osteospermum*, and *Verbena*, respectively. In general, differences between the L and M treatments were more frequently significant than between M and H.

The effect of pinch height on the cutting yield over time displayed one of two distribution patterns for all six species as demonstrated by *Lavendula* (Fig. 1). For example, the first pinch of *Lavendula* resulted in no significant treatment differences from day 46 to 67, while H_1 had a higher cutting yield than L_1 from day 74 to 95 (Fig. 1A). Similarly, the first and second pinch of *Antirrhinum*, *Chrysocephalum*, and *Verbena* and the first pinch of *Diascia* showed no treatment effects during the first 2 to 5 weeks of cutting production, thereafter consistent treatment effects were observed through the duration of the experiment (data not shown). The second cutting distribution pattern over time is demonstrated by the second pinch treatment for *Lavendula* (Fig. 1B). For example,

Table 3. Significance of pinch height treatment on the final cumulative cutting yield for each species. ANOVA were performed with the SAS GLM procedure (SAS Institute, Cary, N.C.).

Pinch ht treatment	Species					
	<i>Antirrhinum</i>	<i>Chrysocephalum</i>	<i>Diascia</i>	<i>Lavendula</i>	<i>Osteospermum</i>	<i>Verbena</i>
Significance						
First (F)	***	***	***	**	***	*
Second (S)	***	***	***	***	***	***
F × S	NS	NS	NS	NS	NS	NS

NS, ***, ** Nonsignificant or significant at $P \leq 0.05$, 0.001, 0.0001, respectively.

Table 4. The effect of the first and second pinch height on the final cumulative cutting yield per stock plant of six herbaceous species. Each stock plant received one of three pinch height treatments for the first and second pinch resulting in a 3×3 factorial arrangement. Low pinches had the fewest nodes remaining below the pinch, while high pinches had the most nodes remaining below the pinch. The node number remaining on the stock plant below each pinch varied with species (Table 1). The cutting yield represents the total cuttings harvested over 101, 97, 87, 95, 154, and 96 d for *Antirrhinum*, *Chrysocephalum*, *Diascia*, *Lavendula*, *Osteospermum*, and *Verbena*, respectively.

Species	1st pinch ht	Final cutting yield (cuttings/stock plant)		
		2nd pinch ht		
		Low	Middle	High
<i>Antirrhinum</i>	Low	60 e	91 cd	93 cd
	Middle	76 de	108 bc	121 ab
	High	80 d	133 a	140 a
<i>Chrysocephalum</i>	Low	53 f	64 ef	77 cde
	Middle	71 cde	81 bcd	93 ab
	High	69 de	85 bc	105 a
<i>Diascia</i>	Low	63 f	98 de	117 cd
	Middle	89 e	134 abc	146 ab
	High	113 cd	128 bc	154 a
<i>Lavendula</i>	Low	44 d	54 cd	63 bc
	Middle	46 d	64 bc	70 ab
	High	54 cd	65 b	79 a
<i>Osteospermum</i>	Low	16 f	31 de	42 bc
	Middle	29 e	47 b	48 b
	High	39 cd	49 ab	56 a
<i>Verbena</i>	Low	153 e	193 bcd	211 abc
	Middle	187 cd	207 abc	200 abcd
	High	179 d	214 ab	220 a

^aMean separation within rows and columns for each species by LSD, $P \leq 0.05$.

the second pinch of *Lavendula* resulted in L_2 producing more cuttings than H_2 on days 53 and 60, while H_1 produced more cuttings than L_2 from day 67 through the remainder of the experiment (day 95). Similarly, the L treatments initially produced more cuttings than H for the first and second pinch of *Osteospermum* and the second pinch of *Diascia* while the H treatments eventually produced the most cuttings (data not shown).

Discussion

Low pinch heights resulted in the lowest cutting production for all six species in this study. This is in agreement with the observations made on geranium stock plants (O'Donovan, 1993). We hypothesize that there are two reasons for this response. First, the onset of lateral shoot development following a pinch appeared to be slower for L than the M and H treatments. In some cases, axillary buds began to develop lateral shoots prior to

Fig. 1. The effect of pinch height of the first and second pinches on the main effect means of cumulative cuttings harvested over time from *Lavendula* 'Serenity' stock plants. Pinch height refers to the number of nodes remaining on the stem below the pinch site. The fewest nodes were left below the low pinch, while the most nodes were left below the high pinch. Vertical bars represent the $LSD_{0.05}$ for each harvest date.

receiving a high pinch. The increased lag time from pinch to first unfolded leaf on the lateral shoots for L may be a result of a lack of axillary bud maturity at the time of the pinch. Second, the lowest nodes on the stem usually had the smallest leaves, i.e., leaf size increased on the stem as the node position increased from the base of the stem to the apex; therefore, stock plants receiving low pinches had relatively low leaf areas that resulted in lower light interception. The combined effect is that L treatments produced relatively small stock plants that had slower shoot growth and development than the M or H pinch height treatments.

The number of shoots that develop in a given area can be limited by the number of nodes in the canopy or the daily light integral (Faust et al., 2005). In this experiment there was not always a significant difference between the H and M treatments despite the differences in the number of nodes remaining after the pinch treatments. Therefore, the daily light integral provided during this experiment may have limited shoot development. Grueber (1985) reported no cutting yield benefit when 9, 11, or 13 nodes were left on the primary stem following the initial pinch of poinsettia stock plants. We hypothesize that H has a greater potential benefit to cutting production if the daily light integral is sufficiently high to support shoot development from all the nodes left on the stock plant. Moe (1994) proposed that a daily light integral of 10 to 20 $\text{mol} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ is optimal for medium light crops and 20 to 30 $\text{mol} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ for high light crops. All of the species used in this study perform well in full sunlight locations outdoors, so we expect that $>10 \text{ mol} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ would be beneficial to cutting yield.

Flowering is closely related to node position with the probability of flowering increasing as node position increases; therefore, the H treatments have the potential to negatively affect cutting quality by increasing flower development on the nodes harvested as part of the cuttings (Evans et al., 1992). It is possible that H allows the production of lateral shoots that are in close proximity to the terminal flower and are more likely to initiate a flower at a relatively low node count. The result is a cutting that may have flower buds present which may result in earlier flowering than desired. Although no negative effects were observed from the H treatments applied in this study, premature flower development may be more of an issue on stock plants produced under environmental conditions that are more conducive to flowering, such as the higher solar radiation and longer photoperiods typical of summer production (Erwin et al., 2004).

Cutting yield during the initial weeks of production were affected by the timing of the pinch treatments. Since the second pinch height treatment was applied on different dates, the initial weeks of cutting harvest resulted in the L_2 treatments initially producing more cuttings than M_2 and H_2 for *Diascia*, *Lavendula* and *Osteospermum*; however, when the M_2 and H_2 treatments started to produce cuttings, they rapidly exceeded the cumulative yield of the L_2 treatments (Fig. 1). The differences between the pinch height treatments became

clearly defined after 2 to 5 weeks of cutting production.

This study suggests that the pinch height during the scaffold development phase of stock plant production can significantly impact cutting yield. In some cases, L allowed for cuttings to be harvested more quickly than M and H; however, the cutting production of M and H treatments quickly exceeded L. Therefore, low pinches during scaffold development should be avoided, while medium or high pinches improve cutting yield while having a minimal impact on the timing of cutting production. This research should provide commercial stock producers with an increased understanding of how to manage stock plants to improve cutting yields from stock plants.

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