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Pinch Treatment and Photoperiod Influence Flowering of *Delphinium* Cultivars

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Abstract. **Two studies were conducted to determine the influence of decapitation (pinch treatment) and photoperiod treatments on stem length, days from planting to harvest, and flowering stem yield in two delphinium cultivars. Plants of *Delphinium ×belladonna* Hort. ex Bergmans 'Völkerfrieden' received a hard pinch (removal of apex and all stem and leaf tissue associated with leaves ≤10 cm), soft pinch (removal of apex and all stem and leaf tissue associated with leaves ≤4 cm), or no pinch. Plants of the *D. elatum* L. 'Barbara' series were grown under either long- or short-day photoperiod, each treatment with or without receiving a soft-pinch. Time from planting to harvest was longer in pinched plants than in nonpinched plants of both cultivars regardless of photoperiod. Flowering stems were longer in hard- and soft-pinched plants of 'Völkerfrieden' compared to nonpinched plants, and with 'Barbara', stem length of pinched plants was either longer or similar to that of nonpinched plants regardless of photoperiod. At 30 days after the commencement of harvest, yield of flowering stems for hard-pinched plants of 'Völkerfrieden' was higher than that for nonpinched plants, but yield from soft-pinched plants was similar to that for those not pinched. Stem yield for 'Barbara' was higher for pinched plants under the long-day photoperiod, but under short days, yield from pinched plants was similar to that for those not pinched. Long days appear to increase yield and reduce production time in delphinium cultivars. Commercial benefits may be realized by growing nonpinched plants for earliness and pinched plants for longer stems and higher yield.**

Cultivars and hybrids of *Delphinium ×belladonna* and *D. elatum* are widely used for cut flower production throughout the world. 'Völkerfrieden' is a belladonna-type delphinium that was introduced in Germany in the late 1970s (Penningsfeld et al., 1980) and has recently become available to cut-flower growers in North America. This plant appears to be a prolific producer of flowering stems for the floral trade and is adaptable to greenhouse and field culture (Geertsen and Bredmose, 1985). The 'Barbara' series of elatum-type delphiniums, recent introductions from Europe, uniformly display large double flowers on substantial stems that are well suited for cut-flower production.

Young delphinium plants remain in a rosette at <13 °C, with stem elongation and flowering initiated >13 °C (Wilkins, 1985). Upon induction of stem elongation, the plants form a central shoot with pronounced apical dominance. Following removal or senescence of the primary stem, outgrowth of lateral buds produces numerous basal shoots that produce a subsequent "flush" of flowering stems. Hybrid delphiniums may produce up to three such flushes of flowering stems in a single season (Armitage, 1993).

Removal of the shoot apex by decapitation, or pinching out the growth tip, removes the source of apical dominance and induces outgrowth of lateral buds (Cline, 1991). The apical meristem and young, expanding leaves constitute a metabolic sink and auxin source that inhibit the outgrowth of lateral buds (Weiss and Shilo, 1988). Auxins exported from these tissues may limit xylem cytokinin concentrations and maintain apical control through a hormonal interaction (Bangerth, 1992). Apex removal may be quantified as either a "hard" or "soft" pinch, and plant response to such decapitation may vary, according to the extent of tissue removal (Berghage et al., 1989). Early decapitation of young delphinium plants may release lateral buds from inhibition, increasing the number of flowering stems in the initial flush. Production of branched plants by programmed pinching may also enable growers to delay flowering, thus targeting production for peak marketing periods. A hard pinch, which removes a larger proportion of the young leaves and associated stem tissue, may be more effective in removing correlative inhibition of the lateral buds.

Long-day photoperiod promotes stem elongation and hastens flowering in delphinium (Wilkins, 1985). Additionally, flower yield and quality in delphinium are enhanced by cool conditions (Armitage, 1993). Pinching techniques and photoperiod manipulation may enable growers to optimize scheduling and production of this crop if the quality of cut stems is not compromised by these treatments. The objective of our studies was to determine the effects of pinch and photoperiod treatments on stem length, time to flower, and yield of flowering stems in *D. ×belladonna* 'Völkerfrieden' and *D. elatum* 'Barbara Blue' and 'Barbara Pink'.

Materials and Methods

'Völkerfrieden' (Expt. 1)

On 21 Dec. 1993, 27 tissue-cultured explants of 'Völkerfrieden' (New World Plants, Escondido, Calf.) were grown in a glass greenhouse and maintained at an air minimum of 12 °C. Plants were planted in raised beds, filled to a depth of 25 cm with a commercially prepared peatlite-bark medium (Fafard Growing Mix No. 3B; Conrad Fafard, Agawam, Mass.). The medium was amended with a slow-release 18N–3.75P–9.93K fertilizer (Osmocote 3–4 month formulation, The Scotts Co., Marysville, Ohio), incorporated at the rate of 5 kg·m^{-3}. Planting density was five plants/m^2. Plants received night-break lighting with 60-W incandescent lamps to provide ≈5 μmol·m^{-2}·s^{-1} at plant level throughout the experiment (1000–0200 HR). Plants were watered manually, and supplemental applications of a 15N–0P–12.5K soluble fertilizer (Peters Dark Weather Feed, The Scotts Co.) were made weekly with N at 250 mg·L^{-1}. A grid of support netting was suspended 65 cm above the bed surface and maintained throughout the experiment.

Plants were divided into three completely randomized groups of nine plants each, and pinch treatments were applied on 7 Jan. 1994. Nine plants each were not pinched, received a soft pinch, or a hard pinch. Soft pinch was defined as removal of the apical tip and all stem and leaf tissue associated with leaves ≤4 cm in diameter. Two to three nodes, with associated leaf tissue, remained on the soft-pinched plants. Hard pinch was defined as removal of the apical tip and all stem and leaf tissue associated with leaves ≤10 cm in diameter. Hard-pinch treatment reduced plants to about one node and one to two leaves above the crown of the plant.

Stems were harvested by cutting ≈3 cm above the base when the first floret of the inflorescence abscised. Harvest began on 7 Mar. 1994 and continued over 90 days ending on 7 June 1994. All flowering stems were harvested and data collected included date of flowering, stem length, and stems per plant. Data were tested by analysis of variance (ANOVA), using the SAS (release 6.11) General Linear Model procedure to test main effects. Mean separation was accomplished by Duncan's multiple range test (SAS Institute, Cary, N.C.).

'Barbara' (Expt. 2)

On 9 Dec. 1994, tissue-cultured explants of 'Barbara Blue' and 'Barbara Pink' (Jeff McGrew Hort. Prod. and Services, Mount

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Vernon, Wash.) were planted in 11-L containers in a commercially prepared peatlite-bark medium (Sun Gro Special Blend LB2; Sun Gro Horticulture, Belview, Wash.). Plants were grown in a glass greenhouse with air averaging 18 °C days and 13 °C nights during the course of the study. Fertility was maintained by soluble fertilizer applications with each irrigation of 15N–13.6P–11.8K (Peter's Peat Lite Special, The Scotts Co.), alternating every third application with $Ca(NO_3)_2$. Nitrogen concentration of fertilizer applications varied between 100 and 300 mg·L^{-1}. Additionally, a topdress application of a 18N–3.75P–9.93K slow-release fertilizer (Osmocote 3–4 month formulation) at 2 kg·m^{-3} was made 4 weeks after planting.

Plants were divided into two completely randomized groups of 48 each, 24 'Barbara Blue' and 24 'Barbara Pink' in each group. Throughout the experiment, one group received long days (LD) with 60-W incandescent lamps to provide ≈5 µmol·m^{-2}·s^{-1} at plant level (1000–0200 HR), while the other group received short days (SD) by black-cloth application (1700–0800 HR). Each group was subdivided by pinch treatment, with 12 plants of each cultivar receiving a soft pinch and 12 remaining unpinched.

Each stem was harvested when ≈80% of the florets in the inflorescence had reached anthesis by cutting them ≈3 cm above their bases. Harvest began on 10 Apr. 1995, and the study was terminated on 7 June 1995 due to excessively high greenhouse temperatures. Data collected at harvest were date of flowering, stem length, stem width, and stems per plant. Data were tested by ANOVA, using the SAS (release 6.11) General Linear Model procedure to test main effects and interactions. Mean separation was accomplished by Duncan's multiple range test (SAS Institute, Cary, N.C.).

Results

'Völkerfrieden' (Expt. 1)

Stem length. Compared to nonpinched plants, flowering stems of 'Völkerfrieden' were longer in soft- and hard-pinched plants (Table 1). Stem length ranged from 1.0 m in nonpinched plants to 1.4 m in hard-pinched plants. Stem length increased with an increasing degree of tissue removal from decapitation. Stems of soft- and hard-pinched plants were 18% and 34% longer than those of nonpinched plants, respectively. Among pinched plants, stem length in hard-pinched plants was 13% longer than that of soft-pinched plants. Harvested stems were similar in appearance among pinched and nonpinched plants.

Days to harvest. Time from planting to harvest was longer in pinched plants than in nonpinched plants but was similar for the two pinched groups (Table 1). Soft- and hard-pinched plants flowered 16% and 19% later than nonpinched plants, respectively.

Stem yield. At 30 days after the commencement of harvest, yield of flowering stems for hard-pinched plants was 213% higher than that for nonpinched plants, while yield for soft-pinched plants was similar to that for nonpinched plants (Table 1). Yields of flowering stems for pinched and nonpinched plants were similar when measured over the entire 90-day harvest of the experiment. Nonpinched plants flowered earlier than pinched plants and, therefore, had sufficient time to produce a second flush of flowering stems toward the end of the harvest period.

Table 1. Stem length, days from planting to harvest, and yield of flowering stems for *Delphinium* 'Völkerfrieden' with three pinch treatments.

Pinch treatment	Stem length (m)	Days to harvest	Stem yield (no.) 30 days	Stem yield (no.) 90 days
None	1.00 c[z]	127 b	1.0 b	3.1 a
Soft pinch	1.21 b	145 a	2.2 ab	3.0 a
Hard pinch	1.37 a	148 a	3.1 a	2.9 a

[z]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

Table 2. Stem length, days from planting to harvest, and yield of flowering stems for pinched and nonpinched plants of *Delphinium* 'Barbara Blue' and 'Barbara Pink' under long- and short-day photoperiods.

Criterion	Day length: Long, Pinched	Long, Nonpinched	Short, Pinched	Short, Nonpinched
		Barbara Blue		
Stem length (m)	1.37 a	1.22 ab	1.33 a	1.01 b
Days to harvest	163 b[z]	134 c	173 a	155 b
Yield (stems/plant)	5.75 a	1.67 b	1.08 b	1.42 b
		Barbara Pink		
Stem length (m)	1.45 a	1.21 b	1.09 b	1.14 b
Days to harvest	14 b	137 c	174 a	155 b
Yield (stems/plant)	5.18 a	1.67 b	1.00 b	1.33 b

[z]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

'Barbara' (Expt. 2)

Stem length. Stem length ranged from 1.0 m for SD, nonpinched plants of 'Barbara Blue' to 1.4 m for LD, pinched plants of 'Barbara Pink' (Table 2). In 'Barbara Blue', stem length was similar in pinched and nonpinched plants grown under LD photoperiod, but in plants grown under SD, stems from pinched plants were longer than those from nonpinched plants. In 'Barbara Pink', stems of pinched plants were longer than those not pinched grown under LD, but similar in plants grown under SD. Comparing stem length between photoperiod treatments, stems of LD, pinched plants of 'Barbara Blue' were longer than SD, nonpinched plants. LD, pinched plants of 'Barbara Pink' produced longer stems than either pinched or nonpinched plants grown under SD conditions.

Days to harvest. Days from planting to harvest were similar in 'Barbara Blue' and 'Barbara Pink', within a given photoperiod–pinch treatment combination (Table 2). LD treatment resulted in fewer days to harvest for pinched and nonpinched plants, compared to SD treatment within the same pinch treatment. Nonpinched plants produced harvestable stems in fewer days than pinched plants regardless of photoperiod. LD, nonpinched plants produced flowering stems ≈16% sooner than SD, nonpinched plants, and ≈22% sooner than LD, pinched plants.

Stem yield. Decapitation resulted in a higher yield of flowering stems among LD, pinched plants when compared to LD, nonpinched plants of both cultivars (Table 2). Yield from pinched plants was ≈227% more than that for nonpinched plants grown under LD conditions. Yield from plants grown under SD was similar regardless of pinch treatment. The longer time to flower in SD, pinched plants resulted in fewer flowering stems reaching a harvestable stage before termination of the study.

Discussion

Pinching lengthened the duration from planting to harvest of flowering stems of delphinium cultivars Völkerfrieden, Barbara Blue, and Barbara Pink. Under LD conditions, however, stems were longer and yield was higher among pinched plants. These qualities are important to cut flower producers. Our results indicate that a production program for these delphinium cultivars could include nonpinched plants for earliness and pinched plants for enhanced stem length and yield. Long-term yield of nonpinched plants likely would be similar to that of pinched plants, because harvesting itself removes the tissues responsible for apical control. Pinching, however, resulted in a higher, more concentrated yield earlier in the production cycle, which may enable growers to optimize production for peak marketing periods.

Night-break lighting to provide LD also appears to be an effective component of an efficient production program for hybrid delphinium crops. Our data indicate that LD increases yield and reduces time to harvest in delphinium. By reducing time to harvest, night-break lighting may also reduce net energy expenditures for greenhouse production.

In 'Völkerfrieden', stem length increased with increasing degree of tissue removal, and yield was highest among hard-pinched plants.

A hard pinch that removes a larger amount of young expanding leaves and stem tissue than a soft pinch induces outgrowth of more lateral buds and promotes elongation of flowering stems.

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