Temperature and GA₃ Effects on Emergence and Flowering of Potted *Paeonia lactiflora*

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Abstract. Various durations of rooting at 15C and storage at 5.5C and exogenous GA₃ (1000 ppm) application were used on dormant unrooted peony (*Paeonia lactiflora* Pall.) tubers of 'Sarah Bernhardt', 'Festiva Supreme', 'Krinkled White', and 'Scarlet O'Hara'. Four weeks of cooling were sufficient to break dormancy. Days to emergence, first bud color, and anthesis were reduced as the length of cold storage increased from 4 to 20 weeks. Height and number of shoots emerging per pot increased with increased cooling. All flower buds aborted when tubers were cooled for 20 weeks. When noncooled tubers were given a 1000-ppm GA₃ soil drench, shoots emerged within 7.5 days; untreated tubers failed to emerge after 5 months. When tubers were treated with GA₃, all flower buds aborted.

Herbaceous peonies are common perennials that have been used as garden plants for over 2000 years (Liberty Hyde Bailey Hortorium, 1976) and have been grown commercially as cut flowers for many years. The cultivar Sarah Bernhardt has been advertised as a cut flower in Holland for domestic and export spring sales in recent years (Holland Flower, 1981-1987). In the continental United States, peonies have been grown throughout much of the country as cut flowers (Evans and Anderson, 1987.)

Historically, peonies have been forced under greenhouse conditions to hasten flowering (Nehrling and Nehrling, 1960; Wilkins and Halevy, 1985). Clumps of rooted tubers were dug and potted in early fall (September through October), placed in cold frames for a cold treatment, and brought into the greenhouse for forcing in late December. Optimal forcing temperatures have been reported to be 13 to 16C (Wilkins and Halevy, 1985). Higher temperatures may cause flower bud abortion (Byrne and Halevy, 1986).

Byrne and Halevy (1986) indicated that flower bud initiation occurred after the current year's flower reached anthesis in June. Flower bud development continued until the onset of dormancy in the fall. Flower bud dormancy of rooted clumps could be broken by a minimum of 4 weeks of holding at 5.6C. Plants then flowered in 8 to 10 weeks when forced in the greenhouse. However, it has

not been determined whether unrooted peony tubers may be potted, rooted, and given a dormancy-breaking treatment under controlled conditions. The objective of the current study was to determine if unrooted tubers could be rooted, given a dormancy-breaking treatment, and rapidly forced in the greenhouse as potted plants.

For all experiments, unrooted tubers (three to five buds) were shipped from Champaign, Ill., to St. Paul, Minn., immediately after harvest in October. They then were potted in 305-cm³ pots containing an artificial medium consisting of 3 peat : 1 perlite : 1 loam (by volume). Within cultivars, tubers were randomly assigned to treatments. Rooting, cold storage, and greenhouse forcing were at 16, 5.5, and 18C, respectively. Plants were fertilized with 200 ppm N using various proportions of Ca(NO₃)₂ and KNO₃. Micronutrients and fungicides were applied monthly.

In the first experiment, 'Sarah Bernhardt', 'Festiva Supreme', and 'Krinkled White' were subjected to either 0, 2, or 4 weeks of rooting and then to 4 or 6 weeks of cooling before forcing in the greenhouse. The number of days to emergence, to first bud color, and to anthesis, and the height and number of shoots emerging per pot were recorded. Ten pots were used per treatment. An analysis of variance was performed to test treatment and cultivar differences. Separation of means was performed by Fisher's least significant difference test.

In the second experiment, 'Scarlet O'Hara' was used to test the effect of extended cooling periods on subsequent shoot growth and flowering. All tubers were given 4 weeks of rooting before being held in cold storage 6, 8, 10, 14, or 20 weeks. Thereafter, plants were forced in the greenhouse. Ten pots were used per treatment. The same characteristics were recorded as for the first experiment. Each characteristic was regressed against time. The treatment means, line equations, and *r*² values were determined.

In the third experiment 'Scarlet O'Hara' was used to determine if gibberellic acid (GA₃) could be used to break dormancy of non-cooled tubers. Tubers were placed in the greenhouse for forcing immediately after potting and received either 0 or 1000 ppm (118 mg a.i./pot) GA₃ as a soil drench. The number of shoots that emerged and days to emergence were recorded. Six pots were used per treatment.

In expt. 1, the number of days to shoot emergence was reduced with increased rooting time (Table 1). In expts. 1 and 2, the number of days to emergence was reduced with longer cold storage (Tables 1 and 2). 'Krinkled White' emerged sooner than 'Sarah Bernhardt' and 'Festiva Supreme' (Table 1). For 'Scarlet O'Hara', tubers held for 20 weeks emerged while at 5.5C, i.e., before greenhouse forcing (Table 2).

Terminal flower bud abortion limited the number of observations for days to first bud color and anthesis. Bud abortion was most prevalent on 'Sarah Bernhardt' and 'Festiva Supreme' in expt. 1. In expt. 2, all 'Scarlet O'Hara' tubers stored cold for 20 weeks had terminal flower buds abort. Results for days to first bud color and anthesis were based on those buds reaching the respective developmental stages. The number of days to first bud color was unaffected by the length of the rooting and cooling treatments in expt. 1 (Table 1). When not preceded by a rooting treatment, the number of days to anthesis was reduced as the length of cold storage increased. When preceded by a rooting treatment, the duration of cold storage did not significantly affect the number of days to anthesis. 'Krinkled White' required fewer days to reach first bud color than either 'Sarah Bernhardt' or 'Festiva Supreme'. In expt. 2, the number of days to first bud color and anthesis was reduced with increased cold storage (Table 2).

In expt. 1, height increased as the length of cold storage was increased from 4 to 6 weeks (Table 1). However, for 'Scarlet O'Hara' in expt. 2, height was not correlated with increased cooling time (Table 2). Heights for all cultivars ranged from ≈ 22 to 36 cm.

The number of shoots emerging per pot was not significantly affected by either duration of the rooting or cold storage in expt. 1. 'Krinkled White' produced more shoots than 'Sarah Bernhardt', which produced more shoots than 'Festiva Supreme'. For 'Scarlet O'Hara' in expt. 2, the mean number of shoots per pot increased with increased storage time (Table 2); however, the number of shoots was not highly correlated with this variable (*r*² = 0.26).

Tubers treated with GA₃ emerged 7.5 ± 1.5 (× ± SD) days following the application. GA₃-treated tubers initially produced 4.1 ± 1.7 shoots per pot and were 31.7 ± 4.1 cm high 4 weeks after the treatment. Control plants failed to emerge after 5 months, even though they were well-rooted.

All flower buds aborted on GA₃-treated tubers. It is plausible that the abortion was induced by the high rate of GA₃ and that lower rates might overcome dormancy with-

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* Table 1. Effects of rooting (16C) and cooling (5.5C) treatments on emergence and flowering of *Paeonia lactiflora* 'Sarah Bernhardt', 'Festiva Supreme', and 'Krinkled White' tubers (expt. 1).

Cultivar	Weeks of rooting/cold storage						Significance			LSD (0.05) ^z
	0/4	0/6	2/4	2/6	4/4	4/6	Treatment	Cultivar	Treatment × cultivar	
<i>Days to emergence</i>										
Sarah Bernhardt	60.3	48.8	50.8	46.3	48.7	39.8				7.6
Festiva Supreme	59.6	48.7	52.2	44.0	48.3	37.8				6.2
Krinkled White	42.7	30.8	38.3	30.8	31.8	31.2	**	**	*	6.4
<i>Days to first bud color^y</i>										
Sarah Bernhardt	76.0	75.3	---	77.0	75.0	---				7.4
Festiva Supreme	85.0	80.3	76.0	77.5	74.0	66.0				10.1
Krinkled White	75.5	66.5	69.0	65.2	67.0	67.5	**	**	NS	5.8
<i>Days to anthesis^y</i>										
Sarah Bernhardt	---	87.7	---	80.0	90.5	---				4.6
Festiva Supreme	---	86.5	---	---	---	76.0				62.9
Krinkled White	82.5	70.2	71.7	71.5	71.3	75.5	**	**	NS	6.3
<i>Ht (cm)</i>										
Sarah Bernhardt	22.2	32.9	23.5	30.4	26.8	30.5				10.1
Festiva Supreme	22.2	36.2	22.7	32.7	27.3	35.9				9.4
Krinkled White	24.7	33.8	25.2	31.8	38.5	30.5	NS	**	NS	9.1
<i>No. shoots/pot^x</i>										
Sarah Bernhardt	2.5	2.5	1.7	2.3	2.5	2.2				1.1
Festiva Supreme	1.3	2.3	1.5	1.3	1.8	2.7				0.8
Krinkled White	2.5	3.0	3.0	3.5	2.7	3.0	**	*	NS	1.1

^zMean separation within rows, Fisher's least significant difference test, 5% level. Each treatment consisted of 10 pots with a pot constituting a replication.

^yIn some cases terminal flower buds aborted prior to showing color and reaching anthesis.

^xCombination of vegetative and reproductive shoots.

NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01 , respectively.

Table 2. Effect of 4 weeks of rooting (16C) and duration of cold storage (5.5C) on emergence and flowering of *Paeonia lactiflora* 'Scarlet O'Hara' tubers (expt. 2).

Criterion	No. weeks of cold storage					Line equation	r^2
	6	8	10	14	20		
Days to emergence	37.0	27.4	23.5	18.9	0.0 ^z	$y = 41.4 - 5x$	0.85
Days to bud color	67.5	54.5	47.5	26.7	---	$y = 76.9 - 10x$	0.89
Days to anthesis	72.4	58.7	51.9	29.4	---	$y = 83.1 - 9x$	0.82
Ht (cm)	26.7	22.7	32.6	27.8	33.1	$y = 23.3 - 2x$	0.09
No. shoots/pot ^x	2.0	2.7	3.0	2.9	3.2	$y = 1.1 + 0.8x$	0.26

^zTubers emerged in cooler before greenhouse forcing.

^yTerminal flower buds aborted before showing color and reaching anthesis.

^xCombination of vegetative and reproductive shoots.

out causing bud abortion. Additional vegetative shoots continued to emerge up to 12 weeks after the GA₃ treatment. These shoots appeared to arise from buds initiated after harvest. It is unclear whether these would have normally developed as reproductive shoots during the next season had GA₃ not been applied.

Azaleas are the only other floricultural crop where GA₃ has been demonstrated to completely substitute for a dormancy-breaking cold requirement (Ballantyne and Link, 1961; Boodley and Mastalerz, 1959), although in some species, gibberellins have been shown to partially substitute for a cold treatment (Moe and Berland, 1986; Rees and Hanks,

1979; Rudnicki et al., 1976; Saniewski et al., 1977). Work is needed to determine optimal GA₃ dosage rates.

Bud abortion presents a major difficulty in forcing unrooted peony tubers. Frequently, only one bud per tuber (per pot) reached anthesis, although additional buds were present and enlarged before aborting. Abortion could be a result of the limited carbohydrate supply available to the developing buds. Tuber weights were not taken before potting, but the tuber weight, and thus the carbohydrate supply, could be correlated with flower bud abortion. The forcing temperatures used in these studies may have contributed to flower bud abortion since high

temperatures have been reported to cause flower bud abortion in peony. Further, photoperiod might be involved, as all treatments were forced under photoperiods significantly shorter than the photoperiod under which peonies normally emerge and flower.

Based on these studies, it would be possible to root, provide a dormancy-breaking cold treatment, and force herbaceous peonies under controlled conditions using unrooted tubers rather than large clumps. If more flowers per tuber could be obtained by reducing flower bud abortion, the herbaceous peony could be adapted to pot culture. Commercially available cultivars have diverse flower types and canopy forms. Therefore, cultivar selection would be necessary to determine those cultivars best suited for this type of culture.

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