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J. Amer. Soc. Hort. Sci. 106(1):84–88. 1981.

Seasonal and Chemical Influences on the Flowering of *Gypsophila paniculata* 'Bristol Fairy' Selections[1,2]

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Additional index words. baby's breath, photoperiod, gibberellic acid, dormancy

***Abstract. Gypsophila paniculata* L. cv. Bristol Fairy flowered only under long photoperiods. Neither 5°C storage up to 8 weeks nor weekly GA_3 sprays at concentration from 50 to 2,000 mg/liter induced flowering at short photoperiods. Established shoots with 12 nodes flowered after 3 weeks of 24 hours photoperiod induction, but young shoots with 5 nodes (newly pinched plants) did not flower after 3 weeks of induction. Critical photoperiod of several selections of 'Bristol Fairy' ranged from 12-18 hours. Inadvertent selection of clones with longer critical photoperiods appears to be responsible for poor winter flowering in Florida.**

The double-flowered seedling of *Gypsophila paniculata* 'Bristol Fairy' selected about 1935 by Mr. Alex Cumming, Bristol Nursery, Bristol, Connecticut (1; J. Heresko, Bristol Nursery) dominates U.S. commerce. While formerly propagated by graftage, it is now vegetatively propagated from terminal cuttings by northern specialists and field grown for winter fresh flowers in Florida and California (1, 10, W. Cunningham, Cunningham Gardens, Waldron, Ind.).

In recent winters, 30–100% of the plants in the fields have not flowered, but the cause is unclear (W. Cunningham). Flowering, a progression of inflorescence formation, includes induction, initiation, differentiation, and enlargement. In temperate species, flowering is often regulated by photoperiod (2, 8), cold (6), or both (12, 13). These seasonal factors may affect each stage of flowering, but they often primarily influence floral induction and initiation. However, genotype is the ultimate determinant of the ability to flower under specific environmental conditions (2, 7).

Night-lighting has hastened flowering of *Gypsophila paniculata* (9) and carnation, *Dianthus caryophyllus* L., another species of the Caryophyllaceae. Flower initiation of carnation is delayed by short photoperiods or low irradiance (3, 5). Six weeks of continuous light (24-hr photoperiod) promotes flowering when started at the 7th visible leaf pair, the stage at which reproductive vegetativeness ends (5). Incandescent lamps are the most efficient for extending photoperiod in carnation (4).

The objective of this study was to determine whether cultural, environmental, or genetic factors were responsible for the lack of gypsophila winter flowering in California and Florida.

Methods and Materials

Photoperiod, temperature, and their interaction were studied in greenhouses at West Lafayette using selections from 'Bristol Fairy' with reputations either for flowering in Florida and California during winter or for not flowering during winter (Table 1). The selections (CF, CNF, CFF, CFNF, MFF, MFNF, IFR) were maintained as vegetative stock under 8-hr photoperiod at 22° C night temperature (NT), and propagated by rooting terminal cuttings under natural photoperiod, potted, and grown at 8-hr photoperiods and 22°C NT until established. Plants were hard-pinched leaving about 9 nodes the day an experiment began. Unless reported otherwise, established plants were pinched, pruned to 1 shoot with 7 ± 1.5 SD nodes/plant, and staked when no longer self-supporting.

Incandescent lighting at 5 $\mu Em^{-2}sec^{-1}$ was used for photoperiods greater than the 8 hr of sunlight. The 8-hr photoperiod was maintained by black cloth over the plants from 1600 to 800 hr. Plants stored at 5°C were provided 10-hr photoperiod with 1.1 $\mu Em^{-2}sec^{-1}$ cool white fluorescent irradiance.

Days to visible bud was the elapsed time from pinch until a small, terminal cluster of flower buds 3–5 mm diameter formed. Days from visible bud to anthesis was the subsequent time to opening of the first floret of the inflorescence. Number of final nodes was the number between hard pinch and the base of the inflorescence. Inflorescence length included only the remaining panicle. Total plant height was measured from pinch to tip of the shoot, while length was measured and averaged for all branches from single, staked shoots. The number of branches greater than 3 cm in length was also recorded. The experiments were of several types, all arranged in a randomized complete block design.

Critical photoperiod. Flowering of the several selections was studied at 8-, 10-, 12-, 14-, 16-, 18-, and 24-hr photoperiods, each at 13, 18, and 22°C. The experiment lasted from Feb. 2 to Sept. 22, 1977. This is the only experiment in which plants were not staked. There were 4 replications per treatment.

Shoot age and inductive interval. Flowering of the CF selection was studied at several shoot ages and several flower inductive in-

[1]Received for publication February 25, 1980. Journal Paper no. 7904 of the Agricultural Experiment Station, Purdue University.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[2]Project supported in part by a grant from the Society of American Florists' Endowment.

Table 1. Selections of 'Bristol Fairy' collected from California, Florida, and Indiana field production sites.

Selection	Collector	Year	Source
California Flowering (CF)	P. A. Hammer	1975	Nord Flor (Encinitas, California)
California Nonflowering (CNF)	P.A. Hammer	1975	Nord Flor (Encinitas, California)
Cunningham Florida Flowering (CFF)	Mazzoni/Cunningham[z]	--	Mazzoni Farms (Boynton Beach, Florida)
Cunningham Florida Nonflowering (CFNF	Mazzoni/Cunningham[z]	--	Mazzoni Farms (Boynton Beach, Florida)
Manatee Florida Flowering (MFF)	P. A. Hammer	1976	Manatee (Bradenton, Florida)
Manatee Florida Nonflowering (MFNF)	P. A. Hammer	1976	Manatee (Bradenton, Florida)
Indiana Field Run (IFR)	Cunningham[y]	1977	Cunningham Gardens (Waldron, Indiana)

[z]Sent to Cunningham Gardens, Waldron, Indiana by Mazzoni Farms, Boynton Beach, Florida.
[y]A random mix of Cunningham Gardens' propagation stock.

tervals of 24-hr photoperiod at 18°C. Plants were transferred at ages 0, 1, 2, and 3 weeks after pinch to a 24-hr flower inductive photoperiod, while others remained in the 24-hr photoperiod continuously. Plants were pruned as they grew to leave the dominant, top axillary shoot to simplify evaluation. Number of initial nodes from hard-pinch to apical meristem was measured by dissecting microscope. The study began June 15 and ended Aug. 25, 1977. There were 5 replications per treatment.

Cold stage. To determine if cold storage promoted flowering, CF, CNF, and MFF selections were stored for 0, 2, 4, 6, and 8 weeks at 5°C and grown under 10-, 12-, 14-, 16-, and 18- hr photoperiods at 22°C. There were 5 replications per treatment. Percent flowering was the portion of surviving plants that flowered. Branches reported on flowering and nonflowering plants developed from the single, staked shoots.

To evaluate whether cold storage affected growth and flowering under commercial cut flower production conditions, 5 shipments of each of several selections after 0, 2, 4, 6, and 8 weeks of 5°C storage were field-planted at the Agricultural Research and Education Center, Bradenton, Florida. There were 3 replications per treatment.

Gibberellic acid sprays. Flowering after GA_3 application was studied with CF and CNF selections. Weekly sprays of 0, 50, 100, 250, 500, 750, 1000, 1500, and 2000 mg/liter GA_3 were applied until runoff to plants grown at 8-hr photoperiod and 18°C NT from Nov. 27, 1977, to March 8, 1978. There were 5 replications per treatment.

Results

Critical photoperiod. All selections remained vegetative under

Table 2. Flowering of several selections at 13°, 18°, or 22°C under various photoperiods (hr.).

		Flowering (%)						
		Daylength						
Temp. (°F)	Clones	8 hr	10 hr	12 hr	14 hr	16 hr	18 hr	24 hr
13	CF	0	0	0	25	50	75	z
13	CNF	0	0	0	0	0	25	z
13	CFF	0	0	0	0	25	75	z
13	CFNF	0	0	0	0	0	0	z
13	MFF	0	0	0	25	50	75	z
13	MFNF	0	0	0	0	25	75	z
13	IFR	0	0	0	0	25	50	z
18	CF	0	25	25	100	100	100	100
18	CNF	0	0	0	0	0	0	100
18	CFF	0	0	0	50	100	100	100
18	CFNF	0	0	0	0	0	25	100
18	MFF	z	z	z	z	z	z	z
18	MFNF	0	0	0	50	100	100	100
18	IFR	0	0	0	25	100	100	100
22	CF	0	0	0	25	100	100	z
22	CNF	0	0	0	0	0	25	z
22	CFF	0	0	0	50	100	100	z
22	CFNF	0	0	0	0	0	25	z
22	MFF	0	0	75	100	100	100	z
22	MFNF	0	0	25	25	100	75	z
22	IFR	0	0	25	25	75	75	z

[z]No plants in treatment.

Table 3. Plant growth and inflorescence development at 13°, 18°, or 22°C under various photoperiods (data was averaged over selection).

Temp. (°C)	Photo-period (hr)	Number of nodes	Length (cm)			Days to visible bud (VB)	Days VB to anthesis
			Shoot	Inflorescence	Shoot plus inflorescence		
13	14	28 ± 2.1[z]	19 ± 1.5	12 ± 1.0	31	220 ± 15	20 ± 5
13	16	32 ± 1.0	21 ± 3.0	18 ± 2.2	39	205 ± 18	22 ± 7
13	18	35 ± 2.4	25 ± 0.5	18 ± 1.6	43	180 ± 13	21 ± 4
18	10	38 ± 2.9	17 ± 0.5	15 ± 1.2	32	221	20
18	12	36 ± 5.1	22 ± 1.2	10 ± 1.1	32	230	16
18	14	32 ± 4.1	20 ± 1.1	19 ± 2.1	39	170 ± 15	23 ± 4
18	16	34 ± 6.3	30 ± 2.3	20 ± 5.3	50	117 ± 21	20 ± 5
18	18	26 ± 5.7	36 ± 3.1	22 ± 1.5	58	60 ± 7	23 ± 6
18	24	24 ± 6.2	42 ± 2.9	20 ± 2.6	62	50 ± 16	26 ± 10
22	12	30 ± 8.1	13 ± 1.5	13 ± 0.9	26	117 ± 10	28 ± 8
22	14	32 ± 7.3	17 ± 2.1	10 ± 0.7	27	100 ± 16	22 ± 5
22	16	23 ± 5.4	18 ± 3.0	17 ± 2.4	35	95 ± 12	15 ± 9
22	18	20 ± 5.1	34 ± 3.3	18 ± 2.2	52	63 ± 7	20 ± 5

[z]±SD.

8-hr photoperiod. The critical photoperiod for the CF, CFF, MFF, MFNF, and IFR selections was lower (12 to 18 hr) than that for CNF and CFNF (18 to 24 hr) at all temperatures (Table 2). For plants that flowered in any temperature-photoperiod combination, there were no major differences between selections in the time form the start of inductive treatment to bloom, number of nodes, plant height, shoot length, or inflorescence size. Flowering was delayed at 13°C NT, compared to 18 and 22° NT (Table 3). At all temperatures, shoot length, inflorescence size, and total plant height were greater under longer photoperiods, but quality of growth (stem strength and spacing of florets) appeared sturdiest at the 16- to 18- hr photoperiods. Days from the start of induction to visible bud decreased with increasing photoperiod, but days from visible bud to anthesis remained constant.

Shoot age and inductive interval. An 8-hr photoperiod for any duration did not promote flowering of the CF selection, whereas 24- hr photoperiods for 9 weeks, or continuously, promoted 100% bloom (Fig. 1). After 3 weeks induction at the 24-hr photoperiod, few plants with 5 to 6 initial nodes flowered, while all plants with 12 nodes flowered. All plants which flowered formed 1–3 nodes between start of inductive treatment and formation of the inflorescence.

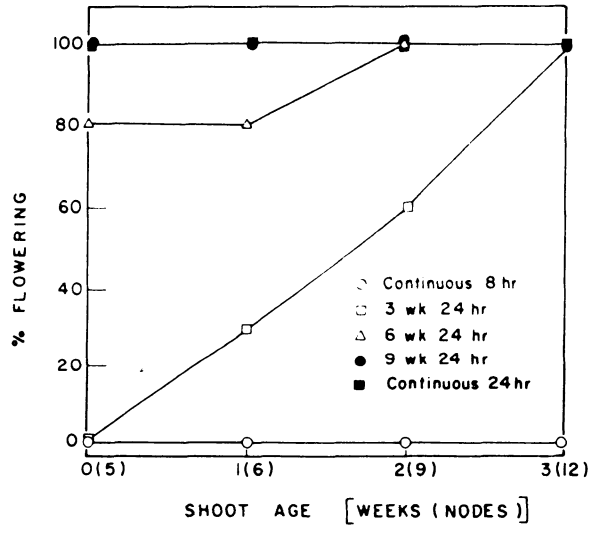

Fig. 1. Flowering of CF at 4 ages after 0, 3, 6, 9 weeks or continuous 24 hr photoperiod induction.

Cold storage. Cold storage did not greatly affect percent flowering of any selection (Table 4). Plants stored 8 to 10 weeks survived poorly (data for 10 weeks not presented). Branches on flowering and nonflowering plants increased greatly in number with increased exposure to cold.

Cold pretreatment did not consistently affect the percent flowering of the several cultivars under field conditions in Florida. While cold-treated plants reached visible bud sooner, the buds were slower to open than untreated plants (Table 5). MFF was observed to flower best over all planting dates when percent flowering, plant size, and inflorescence yields were considered, while CFNF was observed to perform consistently poorly, and on the plants that flowered, the inflorescences were few and leafy.

Gibberellic acid treatment. Weekly sprays of GA_3 did not promote flowering of the CF or CNF selections in short photoperiods (Fig. 2), but higher concentrations greatly increased height of the central shoot, number of branches, and branch length. As central shoots increased in height, new branches arose. Plants were tallest at 1,500 to 2,000 mg/liter GA_3, and the number and length or branches were greatest at 1,000 to 2,000 mg/liter. Branching was noted within 3 weeks from the start of application.

Discussion

Conditions which delayed flowering of gypsophila included photoperiods shorter than 14 hr, and cool temperatures (Tables 2 and 3). Delays in flowering may also have been due, in part, to season, crowding, shading, or horizontal branching of unstaked plants (11). However, lack of flowering during winter short photoperiods in Florida and California fields apparently was caused primarily by clones which require longer photoperiods than are naturally available in winter months (Tables 2 and 4). Presumably the original cultivar mutated, and the process of selecting cuttings based on vegetativeness and cutting vigor in long summer photoperiods, rather than ability to flower at a winter photoperiod has contributed to the malady.

Shoot length increased with photoperiod as in carnation (3). Even though inflorescence length, shoot length, and total plant

Table 4. Flowering and branching of 3 selections grown 8 months under 10-18 hr photoperiod and 22°C after 0-8 wk 5°C storage.

Clone	Cold (weeks)	Photoperiod (hr) after cold treatment				
		10	12	14	16	18
		Flowering (%)				
CF	0	0	0	40	100	100
	2	0	0	25	100	100
	4	0	0	0	100	100
	6	0	0	20	60	100
	8	–	0	0	100	100
CNF	0	0	0	0	40	100
	2	0	0	0	60	100
	4	0	0	0	100	100
	6	0	0	0	20	100
	8	0	0	0	75	100
MFF	0	20	80	75	100	100
	2	0	25	50	100	100
	4	100	0	0	100	100
	6	0	–	–	100	100
	8	–	–	100	100	100
		No. branches on flowering plants				
CF	0	–	–	0	1 ± 0.1[z]	1 ± 0.2
	2	–	–	0	1 ± 0.3	1 ± 1.0
	4	–	–	–	2 ± 0.9	3 ± 1.1
	6	–	–	2	7 ± 3.3	5 ± 1.0
	8	–	–	–	8 ± 4.6	8 ± 3.8
CNF	0	–	–	–	0	0
	2	–	–	–	2 ± 2.1	1 ± 1.5
	4	–	–	–	2 ± 1.3	2 ± 1.1
	6	–	–	–	6	6 ± 1.0
	8	–	–	–	6 ± 1.5	9
MFF	0	1	0.3 ± 0.2	0.5 ± 0.3	0.2 ± 0.1	0.9 ± 1.0
	2	–	0		2.0	2.0 ± 0.8
	4	0	–		1.0	3.0
	6	–	–		3.0	7.0 ± 2.9
	8	–	–		8.0 ± 1.0	9.0 ± 1.5
		No. branches on nonflowering plants				
CF	0	0.3 ± 0.1	0	0	–	–
	2	0.3 ± 0.1	0	0	–	–
	4	1 ± 0.3	0.2 ± 0.2	1 ± 0.5	–	–
	6	2 ± 0.5	2 ± 0.3	3 ± 1.3	8 ± 2.4	–
	8	–	2 ± 0.5	7	–	–
CNF	0	0.4 ± 0.2	0.2 ± 0.1	0	0	–
	2	0.4 ± 0.5	0	0.6 ± 0.3	1 ± 0.3	–
	4	3 ± 1.1	0.6 ± 0.5	1.0 ± 0.4	0	–
	6	3 ± 1.3	4 ± 2.6	5.0 ± 3.1	9 ± 2.8	–
	8	2 ± 1.6	0	6.0 ± 3.5	5	–
MFF	0	0.3 ± 0.3	0	0	–	–
	2	0.3 ± 0.3	0	0	–	–
	4	–	2	3	–	–
	6	5	–	–	–	–
	8	–	2.0 ± 0.5	7	–	–

[z]±SD.

height were greatest at the 24-hr photoperiod, visible quality was often poorer since plant stems were weak and flowers were spaced further apart in the panicles. Thus, the sturdiest plants with the largest inflorescences formed at 16 to 18 hr photoperiod.

Inability to flower of small plants vegetatively propagated from mature stock (reproductive vegetativeness) was clearly indicated at 3 weeks of floral induction at a 24-hr photoperiod. Shoots with 5 initial nodes did not flower while all shoots with 12 initial nodes flowered. Thus, total node number on a stem included a minimum number of nodes (i.e., 12), plus a component of leaves from extended growth under noninductive conditions, plus growth (1 to 3 nodes) from start of induction to initiation of the inflorescence.

Neither GA_3 treatment nor 5°C storage increased the percent flowering, although both promoted branching (Table 4, Fig. 2). These treatments may be useful to increase cutting production during propagation or to increase the number of inflorescences during cut flower production. Best quality plants with largest stem diameter were found at low concentrations.

Techniques to increase winter flowering would include the following: 1) continual testing of flowering selections such as MFF and CF for floriferousness under winter photoperiods to avoid propagating undesirable mutants with longer critical photoperiods; 2) promotion of the percent of flowering plants, possibly by northern growers using long photoperiods during rooting and establishment of cuttings; and 3) pretreatment of established cuttings with 6–8 weeks of 5°C storage or 3 weekly GA_3 applications

Table 5. Growth and flowering of several selections in a Florida field with or without 5°C storage before shipment (data averaged for 2-8 weeks 5° storage).

Shipping date	Storage at 5°C	Clone						
		CF	CNF	CFF	CFNF	MFF	MFNF	MEAN
				Flowering (%)				
Nov. 4	no	100	0	100	50	100	100	75
Nov. 4	yes	100	100	66	0	100	50	80
Dec. 15	no	100	100	100	100	100	100	100
Dec. 15	yes	100	100	100	100	100	100	100
				Days to visible bud				
Nov. 4	no	54 ± 2[z]	–	112 ± 20	121	125 ± 12	98 ± 11	100 ± 28
Nov. 4	yes	64 ± 8	86 ± 11	74 ± 23	–	63 ± 6	69	71 ± 13
Dec. 15	no	98 ± 1	112 ± 13	118 ± 1	124	100 ± 1	101	106 ± 10
Dec. 15	yes	70 ± 18	79 ± 6	75	80	81 ± 1	76 ± 1	76 ± 7
				Days to visible bud to anthesis				
Nov. 4	no	39 ± 1	–	26 ± 2	20	23 ± 2	29 ± 1	27 ± 7
Nov. 4	yes	55 ± 4	45 ± 12	46 ± 4	–	38 ± 11	47	44 ± 8
Dec. 15	no	19 ± 1	19 ± 3	19 ± 1	14	18	16	18 ± 2
Dec. 15	yes	31 ± 10	27 ± 2	24	26	25 ± 1	24	28 ± 5

[z]±SD.

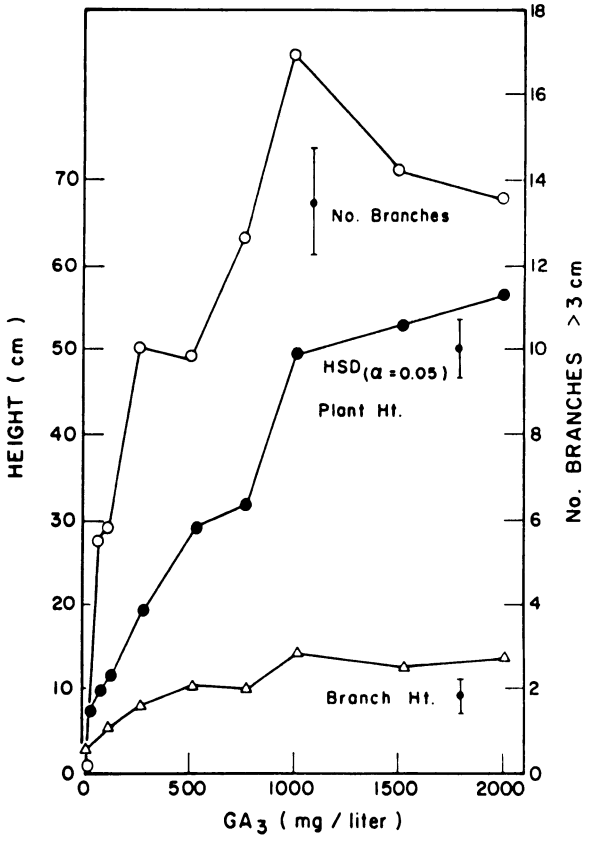

Fig. 2. Average number of branches and height (plant and branch) for plants sprayed weekly with GA_3 for 3.5 months at 8 hr photoperiod (data are averaged for the CF and CNF cultivars).

at 1,000 to 2,000 mg/liter to increase branching in the field (and possibly the number of inflorescences). Since flowering plants contain few commercially desirable shoots for cuttings, artificial short photoperiod treatment of stock clones may be desirable during summer to produce vegetative cuttings or meristems for propagation.

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