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Flowering Performance of 21 *Hydrangea macrophylla* Cultivars[1]

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Abstract

The flowering performance of 21 *Hydrangea macrophylla* cultivars was evaluated for three years at two locations. Ten plants of each cultivar were planted during 1997 in field plots at McMinnville, TN (USDA hardiness Zone 6b), and New Franklin, MO (USDA hardiness Zone 5b). The number of inflorescences was recorded every two weeks from May through September in 1999, 2000 and 2001. Daily maximum and minimum temperatures were recorded from October 1998 through September 2001. Differences among cultivars were found all three years at McMinnville and in 1999 and 2000 in New Franklin. While rankings of cultivars for number of inflorescences differed among years and locations, 'All Summer Beauty' and 'Nikko Blue' were consistently among the best performing cultivars. 'Blauer Prinz', 'Blue Wave', 'Mariesii' and 'Todi' flowered poorly all 3 years at both locations. No cultivar flowered reliably all three years of the study. Although some cultivars flowered sporadically throughout the summer, no remontant cultivars were identified. Poor flowering performance during the study appeared to be related to damage to aboveground portions of plants from a combination of early fall freezes, low winter temperatures and late spring freezes.

Index words: hydrangea, cold hardiness, cultivar evaluation.

Species used in this study: bigleaf hydrangea (*H. macrophylla* (Thunb. *Ex* J.A. Murr.) Ser.).

Significance to the Nursery Industry

Hydrangea macrophylla has undergone a tremendous resurgence in popularity in the United States during the past decade. As a result of extensive breeding efforts in Europe and Japan, hundreds of cultivars are available to the commercial grower. While most of these cultivars are listed as hardy to USDA hardiness Zone 6, their flowering performance has been inconsistent when grown in the mid- and upper-South. This three-year study evaluated the flowering performance of 21 *H. macrophylla* cultivars, which were chosen based on their popularity or anecdotal reports of cold hardiness, at USDA hardiness Zone 5b and 6b locations. All cultivars appeared capable of surviving a typical zone 5b winter, but none flowered reliably throughout the study. 'All Summer Beauty' and 'Nikko Blue' were among the best flowering cultivars overall, while 'Blauer Prinz', 'Blue Wave', 'Mariesii' and 'Todi' flowered poorly each year at both locations. Damage to aboveground parts of plants, and a subsequent reduction in flowering in all cultivars tested, was observed even following mild winters. Early fall and late spring freezes appeared to be the major weather factors involved in poor flowering during this study. Growers should consider digging field-grown *H. macrophylla* plants in the fall prior to sale and storing them in a protected area for the winter. By growing the most reliable cultivars and providing them protection for fall and spring freezes, producers will have a greater opportunity to supply retailers with a color product for sale in early summer.

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Introduction

Hydrangea macrophylla is a popular summer-flowering shrub that is valued for its large corymbs of brightly colored flowers. An Asian native, it is a widely used landscape plant in the Southeastern and Pacific Northwest areas of the United States, as well as along the Eastern seaboard. Several hundred cultivars have been bred and described (3, 4, 5). Cultivars belong either to subsp. *macrophylla* or subsp. *serrata*, with subspecies *macrophylla* further divided into two botanical varieties, *macrophylla* and *normalis* (6).

The large round inflorescences of *H. macrophylla* var. *macrophylla* cultivars are composed primarily of showy sterile flowers with a few inconspicuous fertile flowers located in the interior of the corymbs; these cultivars are referred to as mopheads or Hortenias. *Hydrangea macrophylla* var. *normalis* cultivars have flattened inflorescences composed of a center group of small fertile flowers surrounded by a ring of larger sterile flowers. The term lacecap has been coined for *Hydrangea* cultivars having this type of inflorescence (3). Both *H. macrophylla* subsp. *macrophylla* varieties have stout stems and thick textured leaves with glabrous, shiny upper surfaces (2).

Hydrangea macrophylla subsp. *serrata*, which is often referred to as *H. serrata*, is found in mountain woodlands. It is generally considered to be more cold hardy than members of subsp. *macrophylla* (2). The inflorescences of *H. macrophylla* subsp. *serrata* are in mophead or lacecap arrangements. Members of this subspecies have slender stems, glabrous or pubescent leaves with thin texture and dull upper surface, and smaller flower parts and seed capsules than *H. macrophylla* subsp. *macrophylla* cultivars (2, 6).

Hydrangea macrophylla typically initiates floral primordia during the short cool days of autumn (7). Plants then enter into a period of dormancy during the winter months. Growth resumes in the spring, with flowering occurring in early summer. Damage to aboveground parts of plants following flower initiation can result in reduced flowering. Most cultivars of *H. macrophylla* are rated as hardy to USDA har-

diness Zone 6 (2). Plants grown in Zone 5 environments may survive but never flower (2), whereas plants grown in colder environments suffer high mortality rates (9). Poor flowering has been reported even in Zone 7, and has been attributed to damage to tops of plants by fall freezes prior to plants becoming fully hardened and to damage to new growth from late spring freezes (2). Claims of cold-hardiness and remontant, or reflowering, ability have been made for some *H. macrophylla* cultivars in several nursery catalogs and trade publications, but have not been quantified or supported by experimental investigations.

The objective of this study was to evaluate the flowering performance of a group of commercially available *H. macrophylla* cultivars. These cultivars were selected based on popularity or anecdotal reports of cold hardiness. Tests were conducted at both USDA hardiness Zone 5b and 6b locations to ensure that the plants were sufficiently challenged by cold winters. Data were collected not only on number of inflorescences produced each year, but also on when flowering occurred so that the re-flowering potential of these cultivars could be evaluated. Weather conditions throughout the study were monitored, and their effect on flowering evaluated. Growing degree days (GDD) were used as a measure of weather conditions conducive to plant growth, leading to a lack of hardening of plants in fall or to a breaking of dormancy in spring. The principle underlying the GDD system is that the rate of development of an organism increases linearly with temperature within an optimum range. GDDs are often used in crop modeling and insect prediction programs. Threshold temperature varies depending on species and measured response, but since 10C (50F) is often used with plant species, it was chosen for use in this study.

Materials and Methods

The following taxa were utilized in this study: *H. macrophylla* var. *macrophylla* 'All Summer Beauty', 'Alpengluhen', 'Blauer Prinz', 'General Vicomtesse de Vibraye', 'Horben', 'Madame Emile Mouillere', 'Marechal Foch', 'Masja', 'Mousseline', 'Nikko Blue', 'Pia', and 'Todi'; *H. macrophylla* var. *normalis* 'Blue Wave', 'Mariesii', 'Pink Lace Cap', and 'Tokyo Delight'; and *H. macrophylla* subsp. *serrata* 'Blue Bird', 'Blue Billow', 'Coerulea', 'Grayswood', and 'Preziosa'.

Rooted cuttings of all cultivars were purchased in spring 1996. They were immediately transplanted to #3 containers and grown in a pine bark medium amended with 6.5 kg/cu m (11.0 lb/cu yd) 19N–2.1P–7.4K Osmocote fertilizer (Scotts-Sierra Horticultural Products Co., Maryville, OH), 0.6 kg/cu m (1.0 lb/cu yd) Micromax (Scotts-Sierra Horticultural Products Co.), 0.9 kg/cu m (1.5 lb/cu yd) gypsum and 0.2 kg/cu m (0.4 lb/cu yd) Epsom salts. Plants were grown under 60% shade and micro-irrigated using spray stakes during summer 1996. They were overwintered in a hoop structure under white plastic during winter 1996–97. All plants were grown in McMinnville, TN; those used in the Zone 5b site were shipped just prior to transplanting in the field.

In June 1997, plants were transplanted to field plots at the following two locations: Tennessee State University Nursery Crop Research Station, McMinnville, TN (USDA hardiness Zone 6b), on a Waynesboro silt loam with a pH of 5.5; and the University of Missouri Horticulture and Agroforestry Research Center, New Franklin, MO (USDA hardiness Zone 5b), on a Menfro-Winfield-Lindley silt loam with a pH of 6.0. Cultivars were replicated 10 times and planted in a randomized complete block design with 1.8 m (6 ft) between plants within a row. Space between rows was 3.0 m (10 ft) in McMinnville and 6.0 m (20 ft) in New Franklin. Both field plots were in full sun. Plots were mulched when planted. Plants received at least 2.5 cm (1.0 in) of water each week throughout the growing season, either from rainfall or drip irrigation. Plants were fertilized each spring at the rate of 57 kg/ha (50 lb/A) N. Plants were pruned only to remove dead stems each spring.

The number of surviving plants was recorded each spring and fall from October 1997 until September 2001. The number of new inflorescences on each plant was counted every two weeks from June to September during the 1999, 2000 and 2001 growing seasons. Inflorescences were not included in the counts until color first became evident in the petals of the sterile flowers. Plants at the McMinnville site were examined during late fall and early spring each year for evidence of freeze damage. Flowering data were analyzed using the General Linear Model Procedure of SigmaStat (SPSS Inc., Chicago). Where data were significant, Fishers' LSD procedure was used to separate means.

Daily maximum and minimum temperatures were recorded from October 1998 through September 2001. Temperatures at the McMinnville site were recorded every 10 minutes using a negative temperature coefficient thermistor in the outdoor weather station of a greenhouse climate control system. NOAA weather station data recorded at the Horticulture and Agroforestry Research Station was used for the New Franklin site. Growing degree days (GDDs) were calculated for days in which the mean temperature exceeded 10C (50F) using the following formula: GDD = {[daily maximum temperature (F) + daily minimum temperature (F)] ÷ 2} – 50. Cumulative GDDs were compiled from January 1 to the date of the last spring freeze (0C or 32F), and for 2, 3 and 4 weeks prior to the first freeze each fall.

Results and Discussion

Plant survival. Fourteen plants died in McMinnville between October 1997 and September 2001 (Table 1). All but one of these plants died during the winter months. At New Franklin, 34 plants died between October 1997 and September 2001. Approximately 40% of these plants died during the summer months. With the exception of 'Pia', all cultivars had at least 70% survival at both locations. 'Pia' was extremely susceptible to Cercospora leaf spot, which reduced the vigor of all plants of this cultivar. The plants that died each winter were ones that were particularly weak at the end of the previous growing season. 'Pia' plants that were grown under 60% shade during the same time period as this study and which had minimal leaf spot did not have a survival problem. The mortality of 'Pia' thus appeared to be related to its susceptibility to *Cercospora*, which seemed to be exacerbated by the full sun growing conditions, and not to a lack of winter hardiness.

Flowering. Over 35% of the plants that were still alive in September 2001 in McMinnville, including at least half of the 'Blauer Prinz', 'Blue Wave', 'Grayswood', 'Mariesii', 'Mousseline', 'Preziosa' and 'Todi' plants, did not flower throughout the course of this study (Table 1). In New Franklin, 21% of the surviving plants did not flower. 'Blue Wave', 'Mariesii', 'Pia' and 'Todi' had the least number of flower-

Table 1. Survival and flowering of 21 *H. macrophylla* cultivars over a 4-year period at two locations.

	McMinnville, TN			New Franklin, MO		
Cultivar	No. plants alive on Sept 30, 2001	Survivors that never flowered (%)	Survivors that flowered all 3 years (%)	No. plants alive on Sept 30, 2001	Survivors that never flowered (%)	Survivors that flowered all 3 years (%)
All Summer Beauty	10	10	10	10	0	40
Alpengluhen	9	22	22	8	12	25
Blue Billow	9	44	0	7	28	0
Blue Bird	10	0	0	8	12	0
Blauer Prinz	10	70	0	7	38	0
Blue Wave	10	80	0	10	50	0
Coerulea	10	0	0	8	0	12
General Vicomtesse de Vibraye	10	20	0	10	0	10
Grayswood	9	67	0	7	0	14
Horben	8	38	0	9	0	11
Madame Emile Mouillere	7	0	14	10	30	0
Marechal Foch	10	0	0	9	0	56
Mariesii	9	89	0	7	71	0
Masja	10	10	0	7	14	14
Mousseline	10	50	0	10	10	10
Nikko Blue	10	0	30	9	0	33
Pia	7	43	14	4	50	0
Pink Lace Cap	10	30	0	10	30	10
Preziosa	9	67	0	7	43	14
Todi	10	70	0	10	60	0
Tokyo Delight	9	22	0	9	22	11

ing plants in New Franklin. A few 'All Summer Beauty', 'Alpengluhen', 'Madame Emile Mouillere', 'Nikko Blue' and 'Pia' plants in the McMinnville planting flowered in 1999, 2000 and 2001. Several plants in New Franklin flowered all 3 years, with 'All Summer Beauty', 'Marechal Foch' and 'Nikko Blue' having the greatest number of plants that flowered each year.

The first inflorescences were observed in late May 1999 on some cultivars in both the McMinnville and New Franklin plantings. In 2000 and 2001, flowering did not begin until early June at both locations. The early flowering in 1999 was likely due to the early last spring freeze that year (Table 2). A few cultivars, such as 'Blue Billow', 'Coerulea', 'General Vicomtesse de Vibraye', 'Horben' and 'Preziosa', produced most of their inflorescences prior to July 1 each year and showed little evidence of extended or re-blooming tendencies. In contrast, only about half of the inflorescences of 'Alpengluhen', 'Blauer Prinz', 'Madame Emile Mouillere', 'Marechal Foch', 'Masja', 'Mousseline' and 'Pia' were produced in May or June each year. 'Madame Emile Mouillere' in particular continued to flower throughout the summer. 'All Summer Beauty' and 'Nikko Blue' also flowered sporadically during the summer. Flowering by month for 'All Summer Beauty', 'Coerulea', 'Horben', 'Madame Emile Mouillere', 'Marechal Foch' and 'Nikko Blue' are shown in Fig. 1.

For the McMinnville planting, there were significant differences among cultivars for number of inflorescences all three years. 'All Summer Beauty', 'Blue Billow', 'Blue Bird' and 'Coerulea' produced greater numbers of inflorescences than any cultivars except 'Nikko Blue' and 'Pia' in 1999 (Table 3). In 2000, 'All Summer Beauty' and 'Horben' were among the best flowering cultivars in McMinnville. 'Nikko Blue' outperformed all cultivars except 'Madame Emile Mouillere' during the final year of the study.

Significant differences among cultivars were observed at the New Franklin site in 1999 and 2000 only. In 1999, 'All Summer Beauty' outperformed all cultivars except 'General Vicomtesse de Vibraye', 'Marechal Foch' and 'Nikko Blue'. In 2000, 'All Summer Beauty', 'Grayswood', 'Preziosa' and 'Tokyo Delight' were among the cultivars that produced the most inflorescences.

At both locations, flowering was much lighter in 2000 and 2001 than in 1999. In McMinnville, a mean of 3.4 inflorescences/plant were recorded in 1999, but only 0.3 to 0.5 inflorescences were observed in 2000 and 2001. In 1999, the New Franklin planting averaged 5.0 inflorescences/plant. In 2000 and 2001, this number was reduced to 1.6 and 0.5, respectively. None of the better flowering cultivars flowered as heavily in 2000 and 2001 as they did in 1999 at either location. For example, while 'All Summer Beauty' produced

Table 2. Summary of winter weather conditions over a 3-year period in McMinnville, Tennessee and New Franklin, Missouri.

	McMinnville			New Franklin		
	1998–1999	1999–2000	2000–2001	1998–1999	1999–2000	2000–2001
Average mean daily temperature, Dec–Feb, °C (°F)	6.5 (43.8)	5.8 (42.4)	2.4 (36.4)	1.1 (34.0)	1.9 (35.5)	–3.4 (25.9)
Minimum temperature, °C (°F)	–10.6 (13.0)	–10.6 (13.0)	–12.8 (9.0)	–25.0 (–13.0)	15.6 (4.0)	–26.1 (–15.0)
Date of first freeze	Nov 5	Oct 23	Oct 7	Nov 6	Oct 18	Oct 7
Date of last freeze	Mar 28	Apr 9	Apr 19	Mar 28	Apr 12	Apr 17
Cumulative growing degree days, Jan 1 through last freeze[z]	140	296	321	22	174	173

[z]Growing degree day = {[daily maximum temperature (F) + daily minimum temperature (F)] ÷ 2} – 50 for days in which the mean daily temperature was greater than 10C (50F)

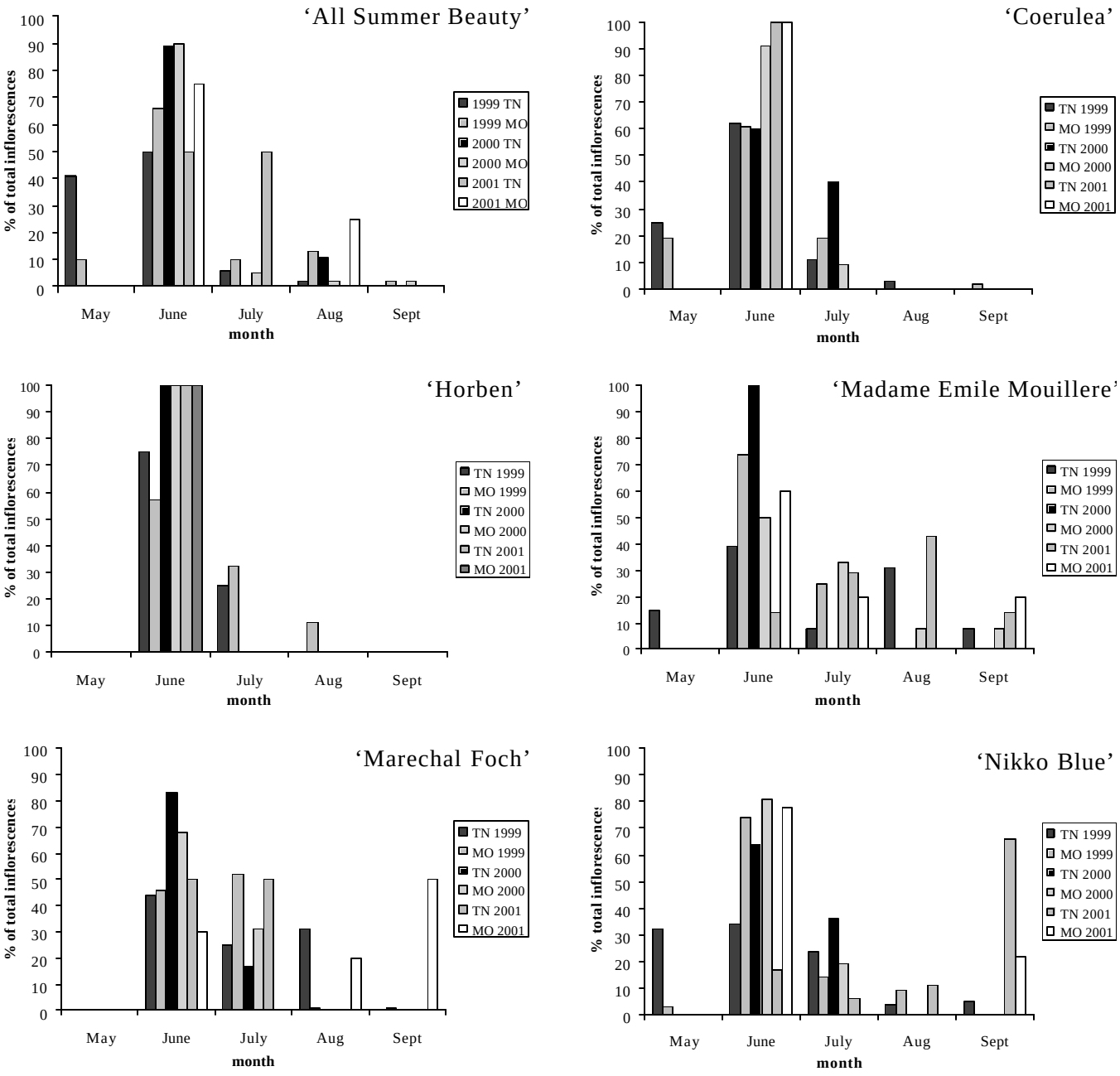

Fig. 1. Time of flowering of six *H. macrophylla* cultivars during three summers in two locations. Data are presented as number of inflorescences produced each month/total number of inflorescences produced from May through September each year.

more inflorescences than any other cultivar in New Franklin during 2000, flowering was reduced by 71% from 1999.

Relationship between flowering and weather conditions. A number of factors may have contributed to the overall poor flowering performance observed in 2000 and 2001; however, the difference in flowering between 1999 and 2000 does not appear to be related to overall winter temperatures. Minimum temperatures and average mean daily temperatures in McMinnville during winters 1998–1999 and 1999–2000 were very similar, whereas winter 1999–2000 was milder than that of 1998–1999 in New Franklin (Table 2). Winter temperatures may have contributed to poor flowering performance observed in summer 2001, especially among the plants at New Franklin. At both locations, average mean daily temperatures from December 2000 through February 2001 were 3 to 5C (6 to 10F) lower than those from comparable time periods during the previous 2 years. Both sites experienced the lowest temperatures of the study in January 2001, although the –13C (9F) minimum temperature at McMinnville was considerably higher than the –18 to –20C (0 to –5F) minimum temperatures expected for a zone 6b location.

Fall weather conditions, particularly in 2000, may have contributed to the poor flowering performance of some of the *H. macrophylla* cultivars in this study. Dates of first fall freezes were very similar between the two locations, but differed among years (Table 2). The first fall freeze in 1998 occurred approximately 2 weeks later than in 1999 and 4

Table 3. Flowering performance of 21 *H. macrophylla* cultivars at McMinnville (TN) and New Franklin (MO) over a 3-year period.

	Mean number of inflorescences					
	1999		2000		2001	
Cultivar	TN	MO	TN	MO	TN	MO
All Summer Beauty	8.5ab[z]	13.3a	0.9ab	3.9a	0.2bc	1.2a
Alpengluhen	2.7cde	6.9bcde	0.8ab	1.5bc	0.6bc	0.9a
Blauer Prinz	0.8de	1.3ef	0.0b	1.6bc	0.1bc	0.1a
Blue Billow	8.4ab	5.1bcdef	0.8ab	2.4abc	0.0c	0.0a
Blue Bird	11.8a	4.1cdef	0.5ab	0.5c	0.0c	0.0a
Blue Wave	0.3e	2.1ef	0.0b	0.2c	0.0c	0.0a
Coerulea	10.9a	6.6bcdef	0.5ab	1.4bc	0.4bc	1.8a
General Vicomtesse de Vibraye	3.7cde	11.9ab	0.8ab	2.2abc	0.0c	0.8a
Grayswood	0.8de	5.8bcdef	0.0b	3.4ab	0.0c	0.1a
Horben	0.5e	2.8cdef	1.4a	2.3abc	0.2bc	0.4a
Madame Emile Mouillere	1.8cde	2.4def	0.4ab	1.2bc	1.0ab	1.0a
Marechal Foch	1.6cde	8.9abc	0.6ab	2.1abc	0.2bc	1.1a
Mariesii	0.2e	1.9ef	0.0b	0.0c	0.0c	0.0a
Masja	1.6cde	4.6cdef	0.2b	0.8bc	0.8bc	0.6a
Mousseline	0.5e	4.8cdef	0.5ab	0.5c	0.1bc	0.1a
Nikko Blue	5.6bc	8.6abcd	1.3a	1.8abc	1.8a	1.0a
Pia	5.5bcd	3.0cdef	0.1b	0.5bc	0.6bc	0.0a
Pink Lace Cap	2.2cde	5.4bcdef	0.2b	1.0bc	0.0c	0.5a
Preziosa	2.2cde	0.9ef	0.0b	3.1ab	0.0c	0.1a
Todi	0.8de	0.3f	0.0b	0.1c	0.0c	0.0a
Tokyo Delight	1.6cde	5.2bcdef	0.9ab	3.0ab	0.0c	0.7a

[z]Values within a column followed by the same letter do not differ significantly according to Fisher's LSD test (P = 0.05).

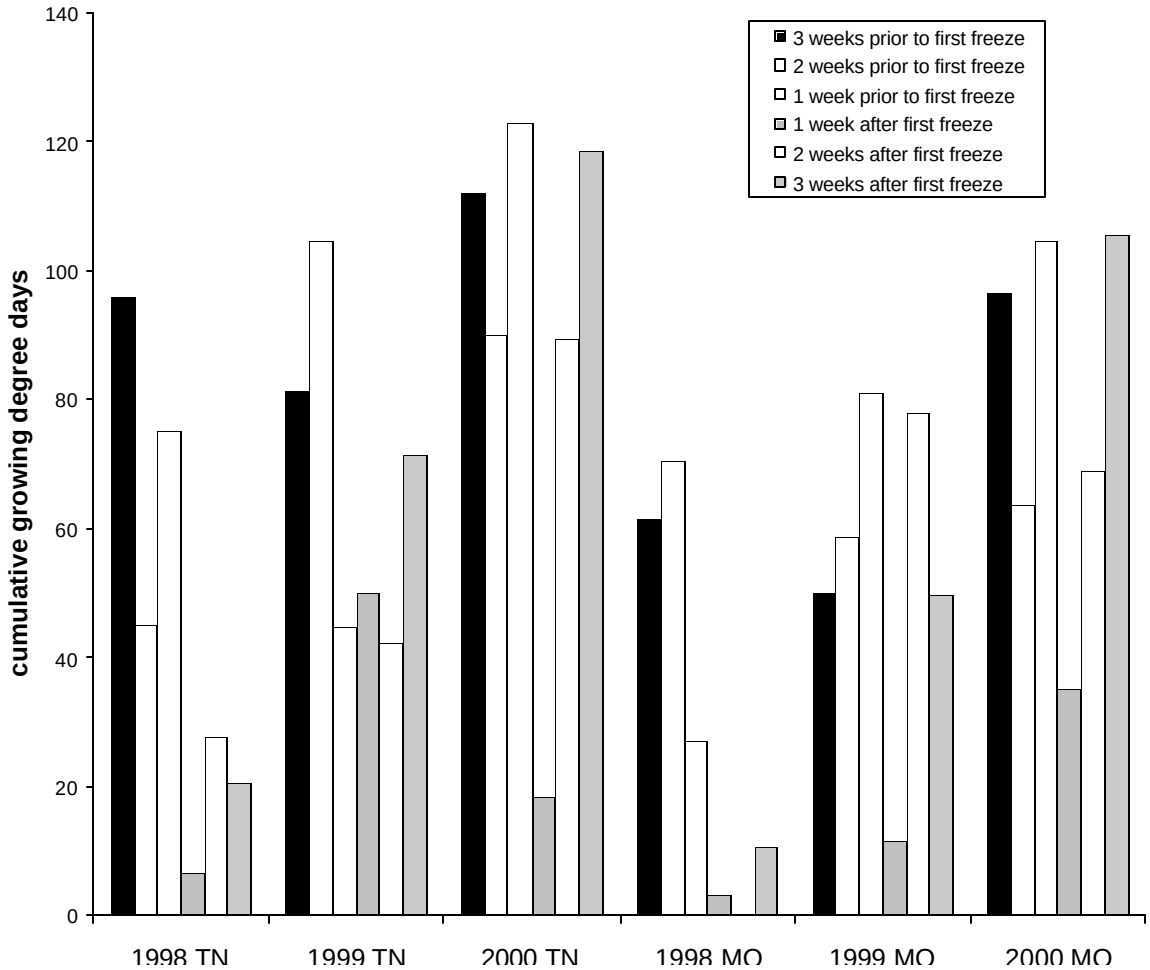

Fig. 2. Weekly cumulative growing degree days from 3 weeks before to 3 weeks after the first fall freeze in McMinnville (TN) and New Franklin (MO) during 1998, 1999 and 2000.

weeks later than in 2000. Because of the early frost date, temperatures preceding the first frost in 2000 were considerably higher than in previous years, especially 1998 (Fig. 2). In both 1999 and 2000, plants at the McMinnville site were still tender when exposed to the first freezing weather. Damage to terminal buds of these plants was noted following the first freeze.

In addition to damage caused by early fall freezes, weather conditions following the first freeze may have reduced flowering. Woody perennial plants typically set terminal buds and begin to enter into a period of dormancy during the cool, short days of autumn. Before dormancy has fully developed, buds often may be stimulated to resume growth by warm temperatures (8). Shoot growth from lateral buds, particularly those in the upper half of the plants, was observed in McMinnville on many plants 2 to 3 weeks following the first freeze each year. These shoots were then killed by subsequent freezing weather. All spring growth that occurred on the McMinnville plants during the three years of the study came from buds located at the base of stems or on the crown of the plant. Substantial dieback was also observed in the New Franklin planting each year, but it was not known whether it was due to fall or winter temperatures. Cultivars, such as 'Blauer Prinz', 'Blue Wave', 'Mariesii' and 'Todi', that performed poorly all three years may not have the ability to flower from basal buds. While many cultivars flowered relatively well in 1999, they may have produced greater numbers of inflorescences if they had been exposed to more favorable weather conditions during fall 1998.

Spring weather conditions were also considered as a factor in the reduced flowering that was observed at both locations in 1999 and 2000. At both locations, the last spring freeze in 1999 occurred 1.5 to 3 weeks earlier than in 2000 and 2001 (Table 2). In addition, the number of GDDs accumulated between January 1 and the last freeze in 1999 was substantially less than in 2000 and 2001. Shoot growth from basal buds was noted in the McMinnville planting during March 2000 and 2001; damage to these new shoots was observed following subsequent freezing temperatures. Differences in cumulative GDDs between New Franklin and McMinnville in 1999 and 2000 may also explain the heavier flowering in New Franklin than in McMinnville both of those years.

In summary, all cultivars tested in this study appeared able to survive a typical Zone 5b winter. Of the 21 cultivars in this study, 'All Summer Beauty' and 'Nikko Blue' appear to have the most reliable flowering. However, none of the cultivars tested flowered well all three years of the study nor did any exhibit the remontant ability that has been reported for the new cultivar 'Dooley' (2). While winter weather may have reduced flowering, especially at the Missouri site during the last year of the study, damage to aboveground parts of plants following fall and spring freezes appeared to have been a major factor in the poor flowering performance noted during the study.

While extensive work on floral initiation and dormancy requirements for greenhouse production has been conducted (1), little is known about possible differences in floral initiation or dormancy chilling requirements for *H. macrophylla* cultivars grown as outdoor plants. Plants with reduced floral initiation requirements might be more likely to flower following damage to previous year's growth. Alternatively, plants with greater chilling requirements might be slower to respond to warm temperatures in late winter and early spring and thus be less likely to incur damage from late spring freezes. The lack of reliable flowering from any of the cultivars tested in this study points to the need to develop *H. macrophylla* cultivars better adapted to the stresses imposed by the fluctuating fall and spring temperatures that are common throughout much of the United States.

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