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Chrysanthemum Growth at Cool Night Temperature[1]

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Abstract. **Twenty-six cultivars of chrysanthemum (*Chrusanthemum morifolium* Ramat.) of the standard, pot-, or spray- type were grown in greenhouses at an 8 hour short-day and a night temperature of either 15.5°C, or a split temperature of 15.5° from 1600 until 2400 and 10° from 2400 until 0800. The day temperature was kept at 22° on sunny and 18° on cloudy days. Additional light (about 3000 lx) was provided for one half of the plants in each temperature treatment on cloudy days. Good chrysanthemums were produced under all conditions with all cultivars with but a minor delay (about 3 days) at the split high-low night temperatures. The plants were taller when grown at the split cool rather than the normal night temperature. The number and size of flowers were not affected significantly by the temperature treatments. Additional light increased stem length and increased the number of flowers of the spray-, and pot-type chrysanthemums. In the growth and production of greenhouse-grown chrysanthemums the split, cool temperature treatments provide energy savings without a noticeable change in growth and quality of plants.**

The minimum temperatures required for flower initiation and good growth and flower production in chrysanthemum are of prime scientific and economic interest (1, 11).

Flower initiation in this plant is finished within 20-30 days after the beginning of the short-day treatment. The development of the flower after initiation time depends on cultivar differences and is the basis for classification of chyrsanthemums in the response group. The first 10 photo-inductive cycles are considered to be the most sensitive to temperature (12, 13). Likewise, Cathey reported (4-8) that the temperature during the vegetative, long-day period was also extremely important for growth and flower development and that, depending on cultivar, temperatures above or below 15.5°C (60°F) may cause late, or premature budding. Cathey classified the temperature response of a large number of chrysanthemum cultivars into 3 groups: 1) thermozero- plants that flower under a wide temperature range, and if the temperature is higher or lower than 15.5°C, the flowering is delayed; 2) thermopositive- plants that will not flower at temperatures below 15.5°C; and 3) thermonegative- high temperature inhibited – plants that do not flower at temperatures above 15.5°C. Ball's recommendation is to provide 15.5° day and night all winter long for year-round standards or sprays, and 16.6 – 17.2°C nights for off-season pot-chrysanthemum growth (1).

Some initial experiments involving the use of lower than commonly recommended temperatures for various periods of the overall growing time during either the day or night periods have been reported (1, 3, 10, 16).

The purpose of this work was to investigate the effect of lower temperature for part of the dark period on the growth and flowering of a number of commercially grown cvs. of chrysanthemums.

Materials and Methods

Commercially grown rooted cuttings of chrysanthemums, of the spray-, pinched pot-, and standard- types, were planted in 12.5 cm plastic pots in a growing mixture of peat and vermiculite (1:1). The reaction of the growing mixture was adjusted to pH 6.0 with limestone additions. "Soil-wet" wetting compound was added to the initial watering of the mixture at a ratio of 28 ml (1 oz) per 4.54 liters (1 gal) of water.

A wide range of cultivars with 8- to 11- and 12-week flowering response were chosen. Cultivars were: *spray type:* 'Solarama', 8 week (2); 'Blue Marble,, 9 w; 'Florida Marble', 9 w; 'Flame Belair', 9 w; 'Polaris', 9 w; 'Golden Polaris', 9 w; Yellow Divinity', 10 w; 'Divinity', 10 w; 'Old Gold', 11 w; 'Northern Lights', 11 w; 'Ice Cap', 12 w; *pinched-pot type:* 'Fiesta', 8 w; 'Royal Trophy', 9 w; 'Winter Carnival' 9 w; 'Golden Princess Anne' 10 w; *standard type:* 'Dignity', 9 w; Promenade', 9 w; 'Southern Comfort', 9 w; 'Southern Sun', 9 w; 'Golden Nob Hill', 10 w; 'Nob Hill', 10 w; 'Mountain Peak', 10 w; 'Peacock', 10 w; 'Frazer Bronze Mefo', 11 w; and 'Goldburst Mefo', 11 w; 'May Shoesmith', 11 w.

The cuttings were planted as received during the period from October 24 to November 8 and were given supplemental fluorescent light, about 3000 lx, to insure the long-day photoperiodic response and grown at 22°C day and 18°C night temperature. The pots were placed abt about 20 cm center to center. To equalize the growth due to the different planting times all plants were soft-pinched on November 22. Plants of the standard chrysanthemum types were allowed to develop 2 shoots which were disbudded as required; those of spray or pinched-pot types were permitted to develop three non-disbudded shoots. An 8 hr, short-day regime was begun on December 19 with dark period from 1600 until 0800. On this day the plants were divided into 4 groups of 10 plants each. Plants in the group "A, cool plus light" were exposed to 17° night temperature until 2400 at which time the temperature was lowered to 10° and maintained so until 0800. Supplemental fluorescent light of about 3000 lx was provided to this group during the day time. Plants in the group "B, cool minus light" were given the same temperature treatment as those of group "A" but without the supplemental lighting. Group "C, warm plus light" as given a night temperature of 17° and supplemental light during the day period. The group "D", warm minus light" received the 17° night temperature without the additional light during the day. Thus there were 4 combinations of temperature and light and 10 single-plant replicates for each cultivar used.

Normal cultural and pest control practices were followed during the growth; the plants were fertilized weekly with soluble N-P-K (20–8.6–16.6) at a rate of 28g (1 oz) per 4.54 liter (1 gal) of water. The date the buds showed color (color on outer florets), the date the flowers were open (separated center florets), stem length and diameter, and number and size of flowers were determined.

Results and Discussion

Chrysanthemum plants had longer stems when grown at the lower than at the "normal" temperature for part of the night during the short-day period (Table 1). This trend was more pronounced where the supplemental light was provided (Fig. 1). The standard and the spray, or pot-plant types responded similarly giving for almost all cultivars a statistically significant

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Table 1. Effect of light and temperature (T^{O}) on the length of chrysanthemums stems.

Cultivars, flowering response in weeks (w)	Stem length (cm) + Light Warm (C)	+ Light Cool (A)	– Light Warm (D)	– Light Cool (B)	LSD,[z] 5%	T^{O} 1%	LSD,[z] 5%	Light 1%
Standard type								
Dignity, 9w	80.4	84.2	69.5	74.3	4.32	5.80	4.32	5.80
Promenade, 9w	56.8	63.9	57.1	58.1	3.20	4.30	3.20	NS
Southern Comfort, 9w	75.5	83.4	65.3	67.3	6.49	NS	6.49	8.71
Southern Sun, 9w	55.7	61.2	45.0	47.6	3.71	4.98	3.71	4.98
Golden Nob Hill, 10w	58.3	74.7	54.4	65.8	2.59	3.48	2.59	3.48
Nob Hill, 10w	57.4	71.7	53.3	58.9	3.69	4.95	3.69	4.95
Mountain Peak, 10w	57.8	66.6	48.7	49.7	2.50	3.36	2.50	3.36
Peakcock, 10w	64.5	71.8	60.5	66.2	4.16	5.58	4.16	5.58
Frazer Bronze Mefo, 11w	83.2	89.4	76.6	81.8	2.82	3.79	2.82	3.79
Goldburst Mefo, 11w	75.0	78.7	69.5	73.5	3.00	4.02	3.00	4.02
May Shoesmith, 11w	61.7	73.4	55.1	60.3	2.65	3.56	2.65	3.56
Spray and pot plant type								
Fiesta, 8w	49.7	56.3	46.4	49.0	3.33	4.47	3.33	4.47
Solarama, 8w	74.6	76.7	59.9	65.7	4.36	NS	4.36	5.85
Blue Marble, 9w	77.0	77.5	67.6	71.4	NS		3.10	4.16
Florida Marble, 9w	74.5	83.4	65.9	72.1	3.65	4.09	3.65	4.09
Flame Belair, 9w	74.0	81.8	71.4	74.2	5.52	7.41	5.52	NS
Golden Polaris, 9w	77.6	88.6	68.0	71.0	3.50	4.70	3.50	4.70
Polaris, 9w	70.6	83.1	67.8	77.4	3.40	4.57	3.40	4.57
Royal Trophy, 9w	46.9	58.6	47.8	46.9	2.93	3.93	2.93	3.93
Winter Carnival, 9w	62.7	74.1	60.7	61.4	3.85	5.17	3.85	5.17
Divinity, 10w	97.5	104.2	81.1	85.1	4.67	6.27	4.67	6.27
Yellow Divinity, 10w	95.9	99.7	84.2	85.3	NS		5.73	7.69
Golden Princess Anne, 10w	75.4	85.6	70.4	66.1	3.67	NS	3.67	4.93
Old Gold, 11w	99.1	112.4	83.4	98.8	6.55	8.79	6.55	8.79
Northern Lights, 11w	75.5	89.5	70.5	72.8	4.63	6.21	4.63	6.21
Icecap, 12w	92.6	97.5	86.7	81.4	NS		4.38	5.88
Mean	71.91	80.30	64.88	68.54				

[z]Least significant difference at 5%, or 1% level; NS = nonsignificant.

difference at the 1% level. The only exceptions to this trend were the 'Blue Marble', 'Yellow Divinity', and 'Icecap'; the stem length of these cultivars was not affected significantly by the temperature treatment. In these temperature and growth relations no differences between the plants of the short response, 8-week, or the longer, 12-week, cultivars were noted.

As expected, the additional light significantly increased the stem length of chrysanthemums in both the cool and normal environment. The longer stem growth in the cool environment may be one of the cultural factors to be considered in pot chrysanthemum production since, under those conditions, there may be a need for a slightly greater amount of growth retardant to be used in order to obtain the desirable size of plants. Conversely, the standard or the spray- type chrysanthemums may be grown for a slightly shorter time before the short-day treatment to obtain the desired length of stems. The development of longer stems for the thermopositive 'Encore' growing at low night temperatures was noted earlier (6).

The number of flowers on the spray, or pot plant type chyysanthemums was affected very little by the low night temperature treatment (Table 2). However, it appeared that the plants grown at cool temperatures had slightly lower number of flowers than those grown in the greenhouse at normal temperatures. Two cultivars were exceptions to this general trend: 'Yellow Divinity' had a significantly lower number of flowers when grown at the cool, and no-light environment; 'Icecap' had significantly more flowers when grown at the cool temperature in the presence or absence of additional light. If this were substantiated by further experimentations, 'Icecap' may prove to be a valuable chrysanthemum for growing at a cool and perhaps low light environment.

The number of flowers was lower when the plants were grown at either the cool or warm temperature but without the additional light. However, a number of cultivars, i.e. 'Fiesta', 'Flame Belair', 'Golden Polaris', 'Winter Carnival', 'Golden Princess Anne', 'Old Gold', and 'Northern Lights' did not respond to the additional light treatment and the number of flowers was not significantly changed.

The size of flowers of the standard type chrysanthemums: 'Dignity', 'Southern Comfort', 'Southern Sun', 'Golden Nob Hill', 'Nob Hill', 'Mountain Peak', 'Peacock', 'Frazer Bronze Mefo', 'Goldburst Mefo', and 'May Shoemsith' was not affected

Fig. 1. 'Mountain Peak' chrysanthemums, grown at different night temperatures and day lighting conditions. A = cool plus light; B = cool minus light; C = warm plus light; and D = warm minus light.

Table 2. Effect of light and temperature (T°) on the number of flowers of the spray-, or pot-plant type of chrysanthemum.

Cultivars, flowering response in weeks (w)	No. of flowers + Light Warm (C)	No. of flowers + Light Cool (A)	No. of flowers – Light Warm (D)	No. of flowers – Light Cool (B)	LSD,[z] T° 5%	LSD,[z] T° 1%	LSD,[z] Light 5%	LSD,[z] Light 1%
Fiesta, 8w	19.2	15.5	14.9	14.5	NS		NS	
Solarama, 8w	15.7	15.6	12.0	8.8	NS		2.72	3.65
Blue Marble, 9w	13.1	15.9	11.5	11.3	NS		3.19	4.29
Florida Marble, 9w	15.4	13.6	10.0	10.9	NS		2.43	3.26
Flame Belair, 9w	14.2	16.1	12.5	12.9	NS		NS	
Golden Polaris, 9w	19.0	20.1	17.8	16.8	NS		NS	
Polaris, 9w	28.0	25.0	15.6	15.0	NS		3.37	4.52
Royal Trophy, 9w	23.9	17.2	15.5	15.7	NS		4.97	6.68
winter Carnival, 9w	17.8	17.9	16.2	15.4	NS		NS	
Divinity, 10w	18.5	17.1	14.6	13.2	NS		2.97	3.99
Yellow Divinity, 10w	17.8	16.5	15.9	9.6	3.76	5.05	3.76	5.05
Golden Princess Anne, 10w	18.4	18.9	18.1	15.3	NS		NS	
Old Gold, 11w	19.7	19.3	21.2	20.5	NS		NS	
Northern Lights, 11w	12.8	18.8	15.6	12.5	NS		NS	
Icecap, 12w	17.5	24.4	12.5	19.1	4.80	6.45	4.80	6.45
Mean	18.06	18.12	14.92	14.10				

[z] Least significant difference at 5% or 1% level; NS = nonsignificant.

by either the low light or low temperature treatments. The exception to this was 'Promenade' where the low temperature treatments produced significantly larger flowers.

The appearance of the first color and the full opening of the blooms was delayed by about 3 days by the cool temperature treatment. The additional length of growing time and the related expenses may be considered a drawback, perhaps a minor one, of this growing procedure.

Loeser (10) showed that 'Improved Yellow Marble' and other 'Marble' cultivars were well adaptable for growth at low temperatures and that other, such as 'Helen', 'Flamenco', and 'Superior' responded similarly to 'Marble'. 'Elegance' and 'Golden Elegance' also gave good quality flowers. Work by Carow and Zimmer (3) similarly showed that flowering of 'White Mable' was not markedly delayed due to temperature shifts from 10° to 19°C and vice versa during the dark period. 'Elegance' was mentioned as low temperature tolerant by van der Hoeven and Vijberger (9). Our results also show that the 'Marble' cultivars grew well at the low night temperature. Most of these cultivars are classifiable as thermo-neutral or thermonegative ones, indicating that chrysanthemums from these groups are particularly suitable for low temperature growing. It should be noted here that with certain cultivars or in certain cases a cold treatment may induce flowering of chrysanthemums (15, 18).

For the thermopositive cultivars i.e. 'Encore', the lowering of the night temperature was detrimental for bud initiation and good growth (6). However, later experiments have shown that even with these cultivars the lowering and manipulation of night temperature may result in good growth of chrysanthemums. For example, Vince (19) showed that flowering of a number of English greenhouse chrysanthemums was delayed by low night temperatures of 4.5° to 10°C. However, when the low night temperatures were applied after the bud had become visible macroscopically, little or no delay in flowering occurred. Similarly, the flowering of the thermopositive cv. Lemon Spider was not delayed much if the night temperature was lowered to 10° after the first 15 short days (3). The flowering and quality of 'Princess Anne' also was not affected by lowering of the night temperature (20).

The cool temperature could have affected the starch-sugar interconversion (17), or the sensitivity of the glycolic acid pathway (photo-respiration) (14). Plant growth at temperatures not normally used will indicate trends in response to environment and may make possible identification of characteristics for maximum economical yields.

This work shows that the generally accepted growing conditions for many chrysanthemum cultivars may be modified without a significant effect on growth and flowering by use of relatively low temperatures during part of the dark period of the short-days.

These experiments illustrate an energy-saving approach to commercial chyrsanthemum production.

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A Synoptic Analysis of Peach and Cherry Flower Bud Hardiness[1]

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Abstract. **Flower buds from 10 'Bing' cherry (*Prunus avium* L.) and 5 'Elberta' peach (*Prunus persica* [L.] Batsch) orchards were tested for cold resistance each week for 3 years during the dormant and pre-bloom periods. The cold resistance of dormant buds was most affected by temperature prior to sampling. Additionally, buds from certain sites were consistently more resistant than buds from others. Elevation, soil type, and cultural practices are the site characteristics likely to influence cold resistance of buds. During the pre-bloom period differences among sites were closely related to bud development which, in turn, was associated with elevation and temperature.**

Differences in survival following damaging freezes may be due to differences either in cold resistance of the plant or the minimum temperature at the site. Survival of *Prunus* flower buds after a damaging low temperature is strongly dependent upon the lowest temperature experienced. A decrease in temperature of 1°C can reduce the number of surviving flower buds from 50% to 15% (10).

The temperature that results in 50% damage to a population of dormant peach or cherry flower buds (T_{50}) at a given site is determined primarily by temperature during the days immediately preceding the freeze (6, 9). As buds swell in the spring, however, the stage of development primarily determines hardiness (7).

Peach and cherry cultivars differ in bud hardiness. Quantitative evaluations of relative hardiness among cultivars have been hampered by variability and insufficient replication. For example, in one analysis of dormant peach flower bud hardiness (4), mortality of the flowers of 91 cultivars ranged from 0 to 99%. However, a value of 50% was not significantly different from 13% or 88%. The range from 50% to 13% is about the same as that represented by 1°C (10).

Cultural practices may influence survival of flower buds. For example, the hardiness of peaches in high and low nitrogen status differed by about 0.4°C in one study (5).

Activation of low temperature protection measures requires that the critical temperature be known. Some growers in the Yakima Valley are protecting peach and cherry buds during winter. Because critical temperatures vary widely, depending on preceding temperature, a warning system to predict critical temperature was initiated. It became necessary to learn how large an area could be served by observations at one location.

This study was designed to determine what variations in hardiness exist within a major fruit-producing area at any one time and at different times during the dormant season.

Materials and Methods

Ten 'Bing' cherry orchards and 5 'Elberta' peach orchards were selected to represent the range of elevations and the major producing districts of the Yakima Valley (Table 1).

Each orchard was sampled once a week from December (dormant) until April (near anthesis). Orchards west of the WSU Irrigated Agriculture Research and Extension Center (IAREC) were sampled one day, those east the next day. The IAREC orchard was included with both groups as a base. All data from the second day were adjusted by adding or subtracting the amount necessary to equalize the 2 IAREC figures.

Each cherry or peach orchard was represented by a sample of about 400 to 500 buds. After collection, the twigs were held near ambient temperature in an insulated chest during transportation to the laboratory. The samples were transferred directly from the insulated chest to the freezer, which was pre-set to –4°C during dormancy, and to +1° when –4° became injurious. The test procedure followed standard methods (8). The freezer was programmed to lower temperature at 1.1° per hour after the time necessary to assure the desired temperature at 8:00 AM.

After freezing, the buds were sectioned, examined individually and classified as dead or alive based on tissue browning. The data were expressed as percentages, plotted against temperature and reported as the temperature required to kill 50% of the buds (T_{50}).

Regression equations were calculated to determine relationships among average T_{50}, bloom development and elevation. Sites were compared by analysis of variance with sampling dates serving as replications. Analysis of variance was performed on the cherry data collected at all 10 sites over a 2-yr period. Dormant season was separated from pre-bloom at the date cherry T_{50} rose above –20°C. This occurred in early February. Pre-bloom ended when more than one site had T_{50} above –5°

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