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Effects of Application of Short-days at Different Periods of the Day on Growth and Flowering in Chrysanthemum (*Dendranthema grandiflorum*)

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ABSTRACT

Chrysanthemum (*Dendranthema grandiflorum* Kitam.) is the third most important cut flower in the international market after rose and carnation. Its successful production requires efficient use of resources to produce plants with desired characteristics for predetermined markets. The aim of the experiment was to determine the effects of short-day treatments on the growth, flowering and cut flower quality of chrysanthemum and to determine the best time of the day for the application of the short-day treatment. The experiment was laid out in a randomised complete block design (RCBD). There were four treatments i.e., applying short-day by covering the plants with black-polythene sheet from 5.00 to 9.00 AM, 11.00 AM to 3.00 PM, 4.00 PM to dusk and control (no covering). Short-days had a significant effect on the growth and flowering of chrysanthemums. The highest vegetative growth in terms of plant height, number of leaves and leaf area was obtained from un-covered (control) plants. Short-day treatment applied from 5.00 to 9.00 AM induced the highest number, length and diameter of cut flowers. The number of cut flower stems obtained from chrysanthemums that were covered at 5.00-9.00 AM was more than double that obtained from control plants. It is recommended that chrysanthemum grown under similar environmental conditions be provided with short-day between 5.00 to 9.00 AM to induce higher yield and quality of cut flowers.

Key Words: Chrysanthemum; Short-day; Plant height; Number of cut flowers; Length of cut flowers

INTRODUCTION

Chrysanthemum (*Dendranthema grandiflorum* Kitam.) is one of the leading cut flowers in the international market. It belongs to the Asteraceae Family. Modern chrysanthemum cultivars come in an astonishing variety of colours, colour combinations and petal styles (spoon, quill & flat). They are in high demand during Easter and Mother's day holidays (Biondo & Noland, 2000; Dole &Wilkins, 2005). It is a short-day plant and needs to be provided with light (long day) for vegetative growth and covered (short-day) to induce flowering. By controlling light duration and temperature, chrysanthemums can be produced throughout the year. They are herbaceous perennial plants grown as cut flowers, potted flowering plants, or bedding plant.

According to Runkle and Heins (2006), the flowering process is a complex phenomenon that affects food production (e.g., fruits, vegetables & grains), plant breeding (e.g., hybridization & dissemination of plants) and human welfare (parks, recreation facilities & home decoration). A variety of environmental factors influences the flowering process of plants, particularly light and temperature. Little can be done to modify the environment outdoors, so growth and development of field crops, in forests and in landscapes is largely controlled by the weather (Greenhill, 2008). In greenhouses, these environmental factors are commonly manipulated to control flowering and plant morphology in order to produce crops with specific characteristics in a desired period (Runkle & Heins, 2006).

Flowering in chrysanthemums is controlled naturally by the shortening of day length in late summer and autumn with flowering occurring from early autumn to winter (Dole & Wilkins, 2005). By altering the photoperiod in the greenhouse, flowers are available any day of the year. Long days are used to maintain vegetative growth of stock plants and cuttings prior to placing young plants under short-days for flowering. The critical photoperiod is 12 h or less for reproductive growth, 14 h or more for vegetative growth (Larson, 1992; Dole & Wilkins, 2005). Other obligate short-day plants include *Cosmos bipinnatus*, *Zinnia elegans*, *Euphorbia pulcherrima* etc. (Runkle & Heins, 2006).

Short-day plants cannot flower under the long days in summer, typically in autumn and thus require a certain

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length of darkness in each 24-h period before floral development can begin. Plants use phytochrome pigments to sense the day length or photoperiod (Fosket, 1994). The day length must be regulated in a timely fashion depending on the season. In summer, short-days are achieved artificially by covering the plants for part of each day with a black cloth to promote blooming (Wieland, 1998; Janick, 2008). Chrysanthemums may be grown successfully under natural day conditions during autumn to initiate flowering. When nights get longer than nine hours, they begin to set flower buds. The minimum number of consecutive short-days required to produce quality blooms depend on cultivar and its culture (Greenhill, 2008).

Furuta (2004) stated that manipulation of photoperiod to control the vegetative and reproductive state of chrysanthemums revolutionised their culture and marketing during the 1940s and 1950s. Previously, chrysanthemums were grown only during a narrow time frame in autumn to take advantage of a natural change in photoperiod. Today chrysanthemums can be precisely forced into bloom each week throughout the year. The usual photoperiodic sequence for producing chrysanthemums is to provide long days for vegetative growth followed by short-days for flowering. The amount of time provided for long days determine the vegetative size of the plants at floral initiation and ultimately how big the plants will be at the finish (Wieland, 1998). Consumer demand for cut flowers including chrysanthemums occurs all year round all over the world. The objective of this investigation, therefore was to determine the best period of the day to apply short-days to chrysanthemum plants to induce highest vegetative growth, flowering and cut flower quality.

MATERIALS AND METHODS

Experimental site: The investigations were carried out in lath houses in the Horticulture Department, Faculty of Agriculture, Luyengo Campus, at the University of Swaziland between January and April 2009 (summer months). The site is located at Luyengo, Manzini Region in the Middleveld agro-ecological zone. Luyengo is 26^{o} 34' S and 31^{o} 12' E. Swaziland is in the sub-tropics. The average altitude of this area is 750 m above sea level. The mean annual precipitation is 980 mm with most rainfall between October and April. The average summer temperature is about 27^{o}C and winter temperature is about 15^{o}C (FAO, 2006a &b).

Experimental design: The experiment was laid out in a randomised complete block design (RCBD), each treatment replicated four times (each replication having 25 plants in 6 L plastic bags). There were four treatments i.e., applying short-day by covering the plants with black-polythene sheet from 5.00 to 9.00 AM, 11.00 AM to 3.00 PM, 4.00 PM to dusk and control (no covering). The plants were propagated using shoot-tip cuttings. The bags were filled with growing medium, which consisted of a mixture of garden soil, compost and sand at the ratio of 1:1:1 (v/v). They were placed in different lath houses. The pots were placed at a spacing of 20 x 50 cm. Each lath house was constructed using wooden posts and planks and was 3 m long, 3 m wide and 1.5 m high. Each lath house, except for the control, was covered with black-polythene sheet at different periods of the day according to the objectives of the experiment. The pots were irrigated when necessary, until water started dripping from the bottom holes.

Data collection and analysis: Data were collected at 2, 4, 6 and 8 weeks after transplanting (WAT). Five randomly selected chrysanthemum plants were used in each replication and treatment for data collection. Data collected included: plant height, number of leaves, leaf area, number of cut flowers per plant, cut flower stem length and flower diameter. Collected data were subjected to analysis of variance (ANOVA) using M Stat-C statistical package and Duncan's New Multiple Range Test (DNMRT) was used to separate means that were significant.

RESULTS AND DISCUSSION

Plant height: During the duration of the experiments, chrysanthemums that were not covered had significantly ($P < 0.05$) higher plant height than those that were covered at different periods of the day (Table I). There was no significant ($P < 0.05$) difference in plant height of the chrysanthemums that were covered from 5.00 to 9.00 AM and those covered from 4.00 PM to dusk. The highest plant height determined 8 WAT was 19.8 cm obtained from chrysanthemums that were not covered and the lowest (15.7 cm) from those that were covered between 11.00 AM to 3.00 PM. Low plant height obtained from plants covered from 11.00 AM to 3.00 PM could probably be due to increased temperatures around the plants caused by the black-polythene sheet covering material. According to Whealy (1987), it is preferable to wait at least 5.30 to 6.00 PM in mid-summer before covering plants to avoid heat problems under the black covering material and remove the material later in the morning. The higher plant height obtained from plants that were not covered could be attributed to higher light intensity, which resulted in increased photosynthetic capacity of the plants. Similar results were reported in asters (Vrsek *et al*., 2006).

Number of leaves: At 6 and 8 WAT, chrysanthemums that were not covered had significantly ($P < 0.05$) higher number of leaves when compared to all the other treatments (Table II). At the same time of determination, no significant ($P < 0.05$) difference was observed in the number of leaves of chrysanthemums applied with short-days from 5.00 to 9.00 AM, 11.00 AM to 3.00 PM and 4.00 PM to dusk. The highest number of leaves determined 8 WAT was 37.3 obtained from chrysanthemums that were not covered and the lowest (26.8) from those that were covered between from 4.00 PM to dusk. The high number of leaves observed in plants that were not covered could also be attributed

Table I: Effect of application of short-days at different periods of the day on plant height of chrysanthemums

Short-day application	WAT/plant height (cm)			
	2	4	6	8
control (uncovered)	10.7a	13.8a	16.8a	19.8a
0500-0900 Hrs	9.3b	12.1b	14.9b	16.7b
1100-1500 Hrs	6.9c	10.2c	12.9c	15.7b
1600 Hrs-dusk	9.4b	12.0b	15.3b	17.8b

Table II: Effect of application of short-days at different periods of the day on the number of leaves of chrysanthemums

Short-day application	WAT/number of leaves			
	2	4	6	8
control (uncovered)	6.5b	12.5a	34.3a	37.3a
0500-0900 Hrs	7.3b	14.5a	26.0b	30.5b
1100-1500 Hrs	7.5b	16.3a	27.0b	31.0b
1600 Hrs-dusk	10.3a	17.4a	22.3b	26.8b

Table III: Effect of application of short-days at different periods of the day on leaf area of chrysanthemums

Short-day application	WAT/leaf area (cm^2)			
	2	4	6	8
control (uncovered)	12.1a	15.3a	16.5a	17.8a
0500-900	7.5b	8.9b	9.4b	10.1b
1100-1500	5.3c	7.3b	7.9b	9.0b
1600-dusk	8.3b	9.4b	10.7b	11.6b

Table IV: Effect of application of short-days at different periods of the day on number of cut flowers per plant, flower diameter and cut flower stem length of chrysanthemums

Short-day application	Parameter/mean value		
	Number of flowers	Cut flower stem (cm)	Flower diameter length (cm)
control (uncovered)	28.3b	13.5a	6.7a
0500-900	62.8a	15.5a	7.1a
1100-1500	28.3b	8.5b	4.8c
1600-dusk	36.5b	11.8a	5.4b

Means along columns followed by same letter not significantly different, Mean separation by DNMRT ($P \leq 0.05$)

probably to higher light intensity and subsequent higher photosynthesis, thus stimulating vegetative growth. According to Vrsek *et al*. (2006), light duration and assimilation by plants results in increased photosynthetic activity, which affects all other plant phenomena, including flowering.

Leaf area: The leaf area of chrysanthemum plants that were not covered with black-polythene sheet was significantly ($P < 0.05$) higher at all times of determination than those that were covered at different periods of the day (Table III). However no significant ($P < 0.05$) difference in leaf area was observed between chrysanthemum plants applied with short-days from 5.00 to 9.00 AM, 11.00 AM to 3.00 PM and 4.00 PM to dusk. The highest leaf area (17.8 cm^2) determined 8 WAT was obtained from plants that were not covered and the lowest (9.0 cm^2) from plants covered from 11.00 AM to 3.00 PM. The low leaf area observed in plants covered from 11.00 AM to 3.00 PM could be attributed probably to unfavourable high temperature conditions around the plants, because of covering them in the middle of the day, when it is hottest.

Number of cut flowers: The number of cut flowers obtained from chrysanthemums covered from 5.00 to 9.00 AM was significantly ($P < 0.05$) higher than that obtained from all the other treatments (Table IV). However there was no significant ($P < 0.05$) difference in the number of cut flowers obtained from plants that were not covered (control), covered from 11.00 AM to 3.00 PM and 4.00 PM to dusk. The highest number of cut flowers (62.8) was obtained from plants covered from 5.00 to 9.00 AM and the lowest (28.3) from those covered from 11.00 AM to 3.00 PM. The number of cut flower stems obtained from chrysanthemums that were covered from 5.00 to 9.00 AM was more than twice that obtained from control plants. The low number of cut flower stems obtained from control plants could probably be attributed to lack of short-day induction for flowering. The low number of cut flower stems obtained from plants applied with short-days from 11.00 AM to 3.00 PM could probably be attributed to inhibition of flowering by heat stress. According to Runkle and Heins (2006), far red lights promote branching in many plants. This explains the high number of cut flowers observed in the plants that were covered and low number of cut flowers in the control plants.

Cut flower stem length: Chrysanthemum covered from 11.00 AM to 3.00 PM had significantly ($P < 0.05$) lower cut flower stem length when compared to all the other treatments (Table IV). However there was no significant ($P < 0.05$) difference in cut flower stem length in plants that were not covered, those covered from 5.00 to 9.00 AM and 4.00 PM to dusk. The highest cut flower stem length (15.5 cm) was obtained from plants covered from 5.00 to 9.00 AM and the lowest (8.5 cm) from those covered from 11.00 AM to 3.00 PM. However Lopez *et al*. (2006) found no significant effect on cut flower stem length in gladiolus upon application of photoperiod. According to Runkle and Heins (2006), application of far red filters in greenhouse results in reduced extensive growth in a variety of species including vegetables and ornamental plants. The high cut flower stem length obtained from chrysanthemums, which were provided with short-days at 5.00 to 9.00 AM could be attributed probably to occurrence of high far red lights under the covered environment as compared to control plants.

Flower diameter: A significantly ($P < 0.05$) higher flower diameter was obtained from plants that were not covered and those that were covered from 5.00 to 9.00 AM (Table IV). Plants that were covered from 5.00 to 9.00 AM had the highest flower diameter (7.1 cm), while those covered from 11.00 AM to 3.00 PM had the lowest flower diameter (4.8 cm). The low flower diameter in plants applied with short-days from 11:00 am to 15:00 pm could probably be attributed to prevailing high temperature, because of covering the plants in the middle of the day. According to Janick (2008) experience with growers showed that although chrysanthemums can tolerate heat, it does best with some morning shade.

CONCLUSION

Provision of short-days by covering chrysanthemums using black-polythene sheet resulted in significant reduction in plant height and leaf area. Covering the plants in the middle of the day i.e., from 11.00 AM to 3.00 PM resulted in highest reduction in vegetative growth in terms of plant height and leaf area. Application of short-day treatment early in the morning i.e., from 5.00 to 9.00 AM, resulted in highest yield of cut flowers (number of cut flowers/plant) and highest quality in terms of flower diameter and cut flower stem length. Production of chrysanthemums under similar environmental conditions should, therefore be undertaken by provision of short-days from 5.00 to 9.00 AM to obtain high yield and quality of cut flowers.

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