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Flowering Responses to Sequential Short Day/Long Day Exposure in Chrysanthemum (*Dendranthema grandiflora* Tzvelev)

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ABSTRACT To determine the minimum number of short day (SD) required for flower initiation and development of chrysanthemum, plants were exposed to SD and long day (LD) conditions. Floral development was significantly different between continuous exposure of 16 hour long day (LD) condition and 2 or 4 SD prior to LD in chrysanthemum cvs. Envy and Lady Time, respectively. As more SD exposure was given, final leaf number was decreased and floral stage was advanced, suggesting a facultative response to photoperiodic cycles. Therefore, only 2−4 days of SD were enough to induce flower initiation. After 6 weeks of SD condition, the plants continued anthesis regardless of subsequent photoperiods. The long day leaf number (LDLN) varied between cultivars as 38.0 and 45.4 in Envy and Lady Time, respectively.

Additional key words: anthesis, final leaf number, flower initiation, long day leaf number, photoperiod

Introduction

A daylength longer than 14.5 hours is required to maintain a vegetative state in chrysanthemum (Kofranek, 1992). However, it is impossible to maintain apical meristems of chrysanthemum in a vegetative condition indefinitely under long day (LD) conditions. In continuous long days all chrysanthemum cultivars eventually initiate flower buds but these fail to develop to anthesis and form so called 'crown bud' (Cockshull, 1975). Normally, flowers are initiated when the photoperiod is less than 14.5 hours, but for further development 13.5 hours of short day (SD) photoperiod (Post, 1948) is required in chrysanthemum.

The minimum number of photoperiodic cycles required for flower initiation has been reported for other plants (Schwabe, 1971; Vince-Prue, 1975; Damann and Lyons, 1993) as well as chrysanthemum. Flower initiation of chrysanthemum can be induced by very few short photoperiods. Post and Kamemoto (1950) showed that one or two short days apparently caused no change from vegetative growth but the onset of flowering was evident after three to five short days according to cultivar. Post (1950) found that 4 to 5 consecutive short photoperiods were required for flower induction in chrysanthemum cv Goldsmith but he failed to induce flower initiation with 6 short photoperiods when no more than 3 of them were in succession. A minimum of 12 consecutive SD was required for flower initiation in other chrysanthemum cultivars (Cathey, 1969), earlier cultivars generally requiring fewer SD for flower initiation. When fewer than 8 SD are given in succession it is generally only the terminal apical meristem that is committed to flower initiation, i.e. a crown bud is formed (Post, 1950; Post and Kamemoto, 1950). Consequently, this experiment investigated the minimum number of SD for flower initiation and flower development in chrysanthemum cvs. Envy and Lady Time using sequential SD/LD exposure.

Materials and Methods

Rooted cuttings of chrysanthemum cvs. Envy and Lady Time were planted in 13 cm pots containing commercial peat compost M2 (Levington Horticulture Ltd., Suffolk). They were grown under long day condition by interrupting the night with 400-Watt high pressure sodium lamps of 12.4 Wm^{-2} from 21:00 to 03:00 at 17±3℃. Ten days after potting, the plants were pinched above the eighth leaf from the base and all side shoots were removed except one. The plants were then transferred into a glasshouse where different photoperiodic treatments commenced, and continued for 10 weeks. For one week the plants were subjected to the 16h long day photoperiod which was consisted with 8h natural light and extended fluorescent light of 1.4 Wm^{-2}. After one week of LD, the sequential exposure treatments were started at daily intervals and weekly intervals for a total of 10 weeks. Plants were treated in 10h SD comprising 8h natural daylight from 09:00 to 17:00 plus 2h of 65 Watt warm white fluorescent light tubes followed by 14h dark-

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ness each day. Treatments were of 2, 4, 6, 8, 10, 12, and 14 days and of 1, 2, 3, 4, 5, and 6 weeks of SD with transfer to continuous LD (16h: 8h natural daylight followed by 8h of 65 Watt warm white fluorescent light tubes and then 8h darkness) during the rest of time.

These treatments were compared with continuous 10h SD and 16h LD treatments. To examine the effects 5 plants of each treatment were harvested after 10 week growth. Final leaf number and stem length were recorded. Stages of floral development were assessed microscopically under a binocular microscope (Wild M8, Heerbrugg Ltd., Switzerland) and macroscopically after the flower buds are visible with the naked eye using 'time to scale' system (0 - 7) developed by Lee (2000).

Results and Discussion

After a series of different numbers of 10h SD, the plants were transferred to 16h photoperiods. The effect on development of floral stage and final leaf number was examined after 10 weeks of sequential SD/LD exposure to determine the minimum number of SD cycles required for flower initiation. The floral stages were significantly ($P<0.001$) different after different numbers of SD (Fig 1A). Only 2 SD were sufficient to promote flowering in cultivar Lady Time but 4 SD were needed in cultivar Envy. These results suggest that promotion of flower initiation was evident after 2 or 4 days of SD in chrysanthemum cvs. Lady Time and Envy. As the time progressed the differences were smaller within and between cultivars. Similar results were reported in other cultivars. Four or 5 consecutive short photoperiods were required in flower initiation in chrysanthemum cv. Goldsmith and flower initiation failed with 6 short photoperiods (total) when no more than 3 of them were in succession (Post, 1950). A minimum of 4 consecutive SD (Post and Kamemoto, 1950) or 12 SD (Cathey, 1969) was require for flower initiation in other cultivars. It was possible that the minimum number of SD for flower initiation is different depending on cultivars but earlier response cultivars generally required fewer SD for flower initiation than later cultivars (Post, 1950).

Final leaf number was significantly ($P<0.001$) different after 2 SD in Lady Time and 4 SD in Envy compared with continuous 16h LD treatment (Fig 1B). These results confirmed again that only 2 or 4 days of SD photoperiods induced flower initiation. Lady Time again appeared more responsive to photoperiod than Envy.

Development of floral stages at weekly intervals was accelerated and final leaf number decreased as the number of SD was increased (Table 1). When 1 week of SD (and 9 weeks LD) exposure was compared with continuous LD treatment there were significant differences. As the time of SD exposure increased (and the time of LD exposure decreased) flower development was promoted compared with that of continuous LD control. Plants grown under 4 to 5 weeks of SD exposure initiated flower buds and developed to anthesis normally. However, the time to anthesis was delayed 2 or 3 weeks compared with continuous SD treatment.

When 6 weeks of continuous SD exposure was compared with continuous SD photoperiod, there were no significant differences in flower development and final leaf number. This means that flower development of the plants grown under 6 weeks of continuous SD was not delayed. These results suggest that after 6 weeks of continuous SD, flower development progressed continuously without delay regardless of subsequent photoperiodic condition. Stem length decreased significantly as the SD/LD exposure increased. The increase in stem length in two cultivars was proportional to the length of LD exposure.

In continuous 16h photoperiods two cultivars eventually ini-

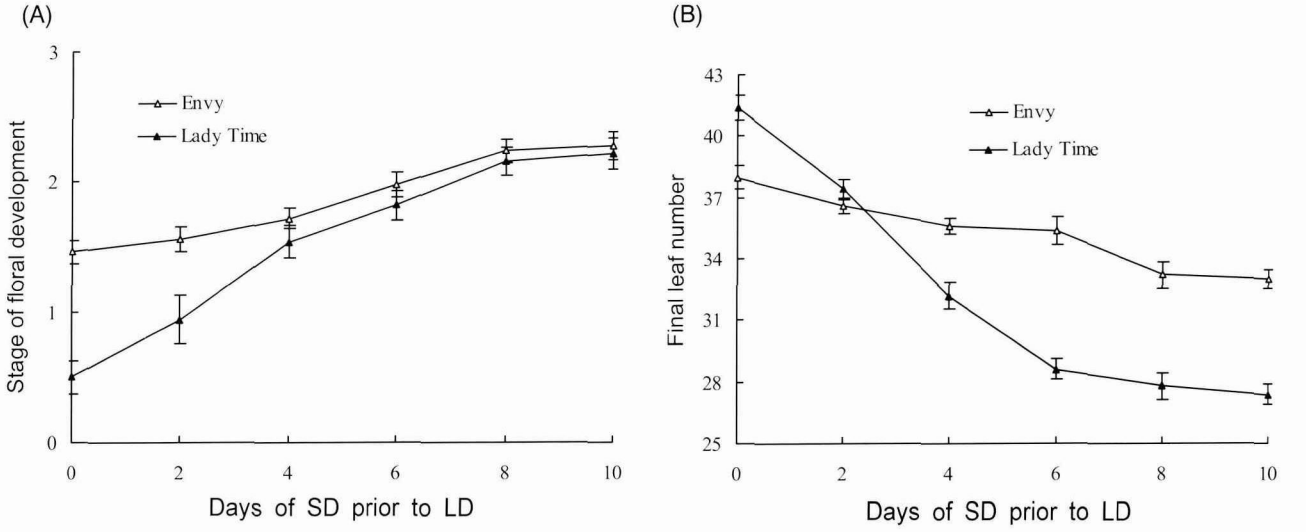

Fig 1. Effect of sequential SD/LD exposure at daily intervals on floral stage (A) and final leaf number (B) in chrysanthemum cvs. Envy and Lady Time. Days of SD (10h) followed by LD (16h) for 10 weeks. Bars indicate SEM.

Table 1. Effect of sequential SD/LD exposure at weekly intervals on final leaf number, stem length and final flower stage in chrysanthemum cvs. Envy and Lady Time.

Treatment (weeks)[z]	Floral stage		Final leaf number		Stem length	
	Lady Time	Envy	Lady Time	Envy	Lady Time	Envy
Control[y]	0.30 g[x]	1.40 g	45.4 a	38.0 a	38.9 a	41.3 a
1	2.18 f	2.10 f	28.4 b	34.6 b	32.2 b	39.4 b
2	2.98 e	2.56 e	23.8 c	32.0 c	27.8 c	31.8 c
3	3.74 d	3.56 d	23.8 c	30.4 d	24.6 d	29.3 d
4	5.80 c	5.70 c	23.6 c	28.0 e	24.0 d	26.6 e
5	6.48 b	6.50 b	22.2 d	27.8 e	22.4 e	26.2 e
6	6.84 a	6.76 ab	20.6 e	26.4 f	21.0 f	26.0 e
10	7.00 a	6.84 a	20.4 e	26.4 f	19.5 g	23.8 f

[z]Weeks of SD prior to LD.

[y]Continuous LD for 10 weeks.

[x]Means followed in the same column by different letters are significantly different. DMRT ($P<0.05$).

tiated flower buds (crown bud) but their further development was arrested and did not reach anthesis. Their period of vegetative growth or time to flower initiation was quantified in terms of the number of leaves and bracts formed below the flower buds. Leaf number on the main stem is used as a measurement of total vegetative growth or as an indication of the flower initiation (Cockshull, 1972). The long day leaf number (LDLN) varies between cvs. and is determined genetically (Cockshull and Kofranek, 1985). The LDLN was 38.0 and 45.4 in cvs. Envy and Lady Time respectively (Table 1).

Therefore, the more SD are given, flower initiation and development advanced, suggesting a facultative response to photoperiod, which were observed in other SDP such as Kalanchoe (Schwabe, 1956) and soybean (Hamner, 1969). In chrysanthemum (Cockshull, 1972), the number of flowers increased in proportion to the number of inductive days. It was thereby suggested that flower number in plants is an estimate both of the intensity of the stimulus produced and of its duration. The possibility arises that photoperiods regulate the movement of stimulus increasing the floral development. This stimulus may be carbohydrate at the floral parts (Lejeune et al., 1991; 1993; Houssa et al., 1991).

According to the results of sequential SD/LD treatment the flowering responses were divided as follows:

Continuous LD

The two cultivars eventually initiated floral primordia which failed to reach anthesis in continuous long days. After flower initiation vegetative lateral shoots from the axils of the uppermost leaves began to develop. This means that flower initiation was limited to the terminal apical meristem.

2 SD to 10 SD

Flower initiation was induced but development was arrested and eventually break or crown buds were formed. They failed to reach anthesis with many bracts developed. Leafy branches were formed from the axils.

12 SD to 21 SD

In general, flower buds that had initiated failed to develop. In those that reached anthesis, time to anthesis was considerably longer. The incidence of abnormal flowers increased. Branching was buddy not leafy.

28 SD to 35 SD

Initiated flowers developed to anthesis normally but time to anthesis was extended by 2 to 3 weeks.

After 42 SD

There were no significant differences compared with continuous SD treatment. This agrees well with the other workers (Cockshull and Hughes, 1968) who found that after approximately 6 weeks SD, floral development continued to anthesis. It may be accepted that artificial short day treatment for flowering can be discontinued after six weeks (Anon, 1973).

교호적 단일/장일 처리에 대한 국화의 개화반응

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초 록

교호적인 단일과 장일을 처리하여 국화의 화아분화 개시와 발달에 필요한 최소 단일소요일수를 결정하기 위해 본 실험을 수행하였다. 16시간의 계속 장일과 비교한 결과 국화 '엔비'는 2일간의 단일, '레이디 타임'은 4일간의 단일처리에 의해 화아발달의 단계가 유의성 있는 차이를 나타냈다. 그러므로 2-4일 간의 단일로도 화아분화 개시를 일으키는 충분한 효과가 있었다. 교호적인 단일처리일수

를 늘릴수록 최종엽수는 감소하였고, 화아발달의 단계는 증가하였다. 이것은 단일에 대한 광주기적인 반응이 양적인 것임을 보여주는 것으로 판단된다. 단일 6주를 처리한 국화의 경우 그 이후의 광조건이 단일 또는 장일인가에 관계없이 모두 정상적인 개화가 가능하였다. 장일엽수(LDLN)는 '엔비' 38.0, '레이디 타임' 45.4로 품종 간의 서로 다른 특성을 나타냈다.

추가 주요어 : 개화, 최종엽수, 단일소요일수, 화아분화, 장일엽수, 일장

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