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Effect of Daylength on the Flower Bud Differentiation and Development in Coriander (*Coriandrum sativum* L.)

By

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Summary : This study examined the influence of daylength on the flower bud differentiation and development of coriander. Daylength of 8, 12, 14, 16-h and natural daylength were afforded the plants.

The plant height of longer daylength was greater, while daylength had little influence on the number of leaves. The number of days from sowing to flower bud differentiation was the smallest for the 16-h daylength (49 days) and the greatest for the 8-h daylength (73 days). On the other hand, the longer the daylength, the smaller the number of days from flower bud differentiation to flowering. The number of expanded leaves was smaller for longer daylength. Flower bud differentiation was observed even in the 8-h daylength, although it was earlier in the longer daylength. Therefore, coriander can be regarded as a quantitative long day plant as regards the flower bud differentiation. The stage of flower bud development can be classified into the following nine stages :

1) vegetative stage ; 2) predifferentiation stage ; 3) cluster differentiation stage ; 4) lateral cluster differentiation stage ; 5) early stage of floret formation ; 6) later stage of floret formation ; 7) petal development stage ; 8) stamen development stage ; 9) carpel development stage.

Key Words : Coriander, Daylength, Development, Flower bud differentiation, Quantitative long day plant

Introduction

Coriander is an umbelliferous annual plant originating in the eastern Mediterranean region. The fruits and young leaves of the plant are commonly used as a condiment herb for their flavor. The fruits are used as an ingredient to prepare curry dishes, or ground to put in various meat dishes and cakes. The leaves are used in a variety of dishes such as soup and meat[1]. In recent years, an increasing number of coriander plants have been grown and supplied to the market. They have become so popular that production is in demand through the year. Since coriander is both heat and cold tolerant, it can be grown through the year. As premature bolting has often been a problem in summer planting, it is very important to clarify the physiology of flowering.

With regard to the flower bud differentiation on umbellifers, it has been found that the flower bud differentiation of carrots and celeries is hastened by low temperature, and that of dills and fennels is stimulated by long day. However, little research has been done on the flower bud differentiation on coriander. The objective of this study was to determine the effect of daylength on the flower bud differentiation and development in coriander.

Materials and Methods

Seeds were sown on 26 September 1993, in plastic flats. Plants were transplanted at three true leaf stage in 15 cm plastic pots containing a mixture of equal portions of soil and bark manure.

The plants were given daylength of 8, 12, 14, 16 hours and natural daylength. The 8-h treatment plants were exposed to sunlight from 8 : 00 am to 4 : 00 pm and then covered with 0.1 mm thick silver polyto curtain. The 12, 14 and 16-h treatment were covered likewise, and then exposed to 60-Watt incandescent lamps, to receive

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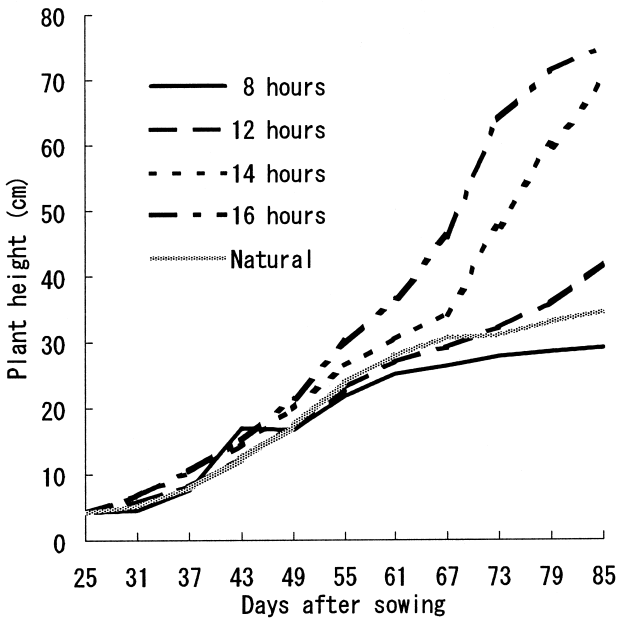

Fig. 1 Effect of daylength on plant height of coriander

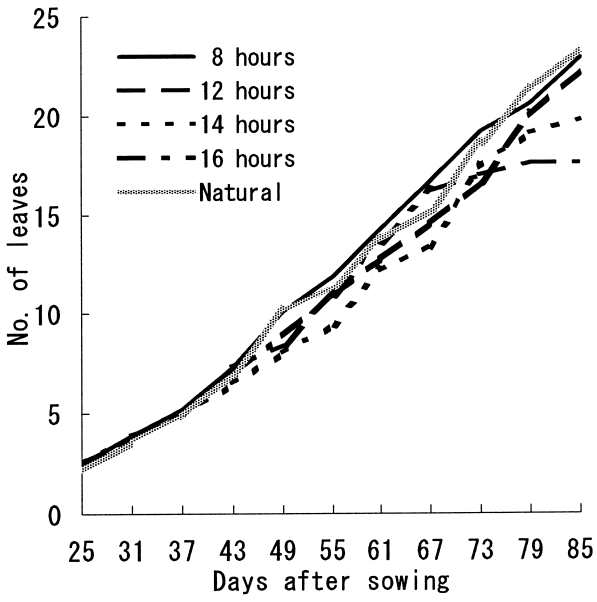

Fig. 2 Effect of daylength on number of leaves of coriander

supplemental light of 4, 6 and 8-h respectively. The experiment was conducted in a greenhouse in which the minimum night temperature was maintained at 10℃.

Samples of three plants from each treatment were collected every six days from 21 October, and the flower bud differentiation and development were observed using a stereoscopic microscope and a scanning electron microscope (SEM). For SEM, shoot apex samples were prepared, being fixed in 2% glutaraldehyde and osmiumic acid, serially dehydrated in ethanol and critically point dried after substitution with isoamyl acetate, then vapor-deposited with Au-pd. A JSM-T20 SEM was used for observation.

Results

1. Vegetative growth

The effects of daylength on plant height are shown in Fig. 1. No significant differences in the plant were found between the treatments of daylengths for 50 to 60 days after sowing. Thereafter, the 16 and 14-h daylengths showed a marked effect on the height. In 85 days after sowing, plant height on the 16-h daylength was the tallest, followed by the 14-h, 12-h, natural and 8-h daylength in that order. The difference between the 16-h and 14-h daylength was small. The 16-h daylength was almost twice as tall as the 8-h daylength. The effects of daylength on the number of leaves are shown in Fig. 2. The number of leaves increased with the growth of plants regardless of daylength and had almost the same tendencies in each treatment. From the above results, it was found that daylength greatly affects the plant height, while it has little influence on the number of leaves.

2. Daylength and Flower Bud Differentiation

Table 1 and 2 shows the relationship between the daylength treatment and the differentiation and development of the flower buds. The influence of daylength on flower bud differentiation was obvious. The greater the given daylength was, the smaller the number of days from sowing to flower bud differentiation, resulting in earlier flower bud differentiation. At 37 days from sowing, the 16-h daylength showed no flower bud differentiation. At 43 days, however, it attained the predifferentiation stage and the buds were already differentiated at 49 days. The 14-h daylength reached the flower bud differentiation stage at 55 days, the 12-h and natural daylength at 61 days and 8-h daylength at 73 days. The plants under the 16-h were 24 days earlier than the plants under the 8-h.

The plant height at the flower bud differentiation stage was also compared. It was found that shorter daylength resulted in greater plant height at the differentiation stage. The 16-h daylength showed flower bud differentiation when the height was 15 cm, while the 8-h daylength was already 26 cm tall when it reached the development stage. On the other hand, the plant height at the flowering stage was greater for longer daylength. The 16-h daylength was twice as tall as the 8-h daylength at the flowering stage. The number of leaves at the flower bud differentiation decreased as

Table 1 Effects of daylength on flower bud differentiation and development in coriander

	Days after sowing										
Daylength	37	43	49	55	61	66	73	79	85	91	97
8h	×	×	×	×	△	△	○	○			◎[1]
12h	×	×	×	△	○	○	○		◎[3]	◎[7]	◎[10]
14h	×	×	△	○	○		◎[1]	◎[8]	◎[8]	◎[10]	
16h	×	△	○			◎[1]	◎[6]	◎[10]			
Natural	×	×	×	△	○	○				◎[6]	◎[9]

× Not differentiated ; △ Predifferentiation ;○ Umbel differentiated ; ◎ Flower opened.

Superscrips indicate number of plants flowered.

Table 2 Effects of daylength on flower bud differentiation, bolting and flowering in coriander

	Flower bud differentiation			Bolting			Flowering		
Daylength	Height (cm)	No.of leaves	Days after sowing	Height (cm)	No.of leaves	Days after sowing	Height (cm)	No.of leaves	Days after sowing
8h	25.9	17.0	73.0	29.2	24.0	88.0	33.2	29.4	102.0
12h	25.1	10.9	61.0	31.4	16.0	70.3	51.6	24.1	91.0
14h	19.8	8.2	55.0	31.6	10.3	62.7	65.2	19.6	80.8
16h	14.9	7.2	49.0	29.9	11.1	55.0	64.3	17.8	73.4
Natural	24.3	11.4	61.0	31.1	18.9	73.0	42.8	25.0	94.0

daylength increased. The 16-h daylength showed the smallest number of expanded leaves, followed by the 14 -h, 12-h and natural, and 8-h daylength in that order. The 16-h and 14-h daylength showed similar number of leaves. The differentiation between the 16-h and 8-h daylength was ten leaves.

Similarly, the 16-h and 14-h daylength showed the smallest number of leaves at the flowering stage as well. The 8-h daylength showed the greatest number of leaves and the 12-h and natural daylength were an intermediate response. Daylength also influenced the growth of the plants after flower bud differentiation and longer daylength hastened bolting and flowering. The period from flower bud differentiation to flowering was the shortest for the 16-h daylength (24 days), followed by the 14-h daylength (26 days), 12-h daylength (30 days) and 8-h daylength (29 days). The greatest difference, however, between the treatments was as small as 6 days.

As the difference of period from flower bud differentiation to flowering was not considerable, it can be said that the difference of flowering date is mainly due to the difference of the number of days from sowing to flower bud differentiation.

3. Development of Flower Buds

The development stage of flower buds is illustrated in Fig. 3 to 11. The shoot apices showed an apical dome shape. This stage is called the vegetative stage (Fig. 3). After this stage, the apices were thickened and rounded up. This stage is the predifferentiation period (Fig. 4). The apices became flat and then both ends rose to develop two protuberances. Protuberances were also found in the axils. This stage is the cluster differentiation stage (Fig. 5). As clusters increased, lateral clusters in the axils also developed (Fig. 6). Clusters on the outer side of the axis developed faster compared to those on the inner side, some of which did not fully develop eventually. Then protuberances appeared on the top of the clusters. This is floret formation (Fig. 7). While floret increased, peduncles began to grow (Fig. 8). With regard to the development of florets, when the pedicels of florets had slightly grown, primary protuberances of sepals were observed. Then inside the

sepals, 5 primary protuberances of petals appeared (Fig. 9). At this stage, three of the five petals developed greatly while the growth of the remaining two slowed down. Later, five stamens appeared inside the petals (Fig. 10). At the same time, the center of the florets receptacles became flat and later developed two protuberances. This is the differentiation of carpels (Fig. 11). When petals had fully developed, the protuberances in the floret center thickened and the carpels could be clearly identified.

The developmental scale of flower bud differentiation was referred after that in the celery by Iwami *et al*[2] and Roelofse *et al*[3], and the celeriac by Booij *et al*[4]. The stage of flower bud development were classified as follows : 1) vegetative stage ; 2) predifferentiation stage ; 3) cluster differentiation stage ; 4) lateral cluster differentiation stage ; 5) early stage of floret formation ; 6) later stage of floret formation ; 7) petal development stage ; 8) stamen development stage ; 9) carpel development stage.

Discussion

It was found that the growth and flower bud differentiation are accelerated by long daylength and retarded by short daylength. Daylength also affected the growth after flower bud differentiation. Bolting, budding and flowering were also hastened by longer daylength. Putievsky[5] conducted a study on the influence of daylength on the growth and yield of coriander and reported that longer daylength resulted in faster growth, greater yield and earlier flowering and maturing. In our study, where the minimum night temperature was maintained at 10℃, the results showed tendencies similar to those found in Putievsky's observation.

With regard to the flower bud differentiation of umbellifers such as carrots and celeries, it has been known that flower buds are induced in plants that have reached a certain size and been exposed to low temperature for a certain period [6,7,8]. Hamner and Naylor[9] reported that dill was a typical long day plant which did not flower under daylength of 11-h or less but did flower under daylength 14-h or more. Also, Naylor[10] reported that the flower bud differentiation and bolting of dill were accelerated by long daylength. Putievsky[5] found that the flowering and maturing of dill were hastened by high temperature, with the daylength condition maintained equal. Kawai[11] conducted a study on the flower bud differentiation and growth of Florence fennel and reported that the longer the daylength was, the more accelerated the flower bud differentiation. Especially, the acceleration of flower bud differentiation was notable when the daylength was more than 12 hours. Umbellifers can be classified into two types. For carrot and celery, flower bud differentiation is accelerated by exposure to low temperature. For dill and fennel, flower bud differentiation is accelerated by long daylength. Apparently, coriander belongs to the latter type. Although the flower bud differentiation was affected by day length, however, flowering occurred even under 8-h daylength. Therefore, coriander can be considered as a quantitative long day plant. Bolting of coriander tends to occur in high temperature and this is often a problem. Therefore, it can be assumed that temperature also affects flower bud differentiation. Iwami *et al*[2] found that the flower bud differentiation and bolting of celery differed among varieties. Therefore, differences among varieties must also be examined.

The stages of flower bud development were morphologically divided into nine stages. These stages were divided according to the results of studies conducted on celery[3] and celeriac[4]. Bracts did not develop, however, in the proximal of the pedicels and five small bracts were observed in the proximal on the florets. These bracts developed with the florets. Among the five petals, only three developed steadily and the development on the remaining two slowed down. These findings differed greatly from flower bud development of other umbellifers.

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コリアンダーの花芽分化と発育に及ぼす日長の影響

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要約：コリアンダーの花芽分化と発育に及ぼす日長の影響について検討した。日長は 8，12，14，16 時間及び自然日長とした。

草丈は長日ほど大きくなったが，葉数は日長の影響をあまり受けなかった。播種から花芽分化までの所要日数は，16 時間日長が最も短く 49 日であった。一方，8 時間日長は最も長く 73 日であった。また，花芽分化から開花までの所要日数は長日ほど短くなった。花芽分化時の展開葉数は長日ほど少なかった。

花芽分化は 8 時間日長でも見られたが，長日ほど早くなかった。したがって，コリアンダーは花芽分化に関しては，量的長日植物と考えられる。

花芽の発育過程は次のように分けることができる。

1．未分化，2．分化初期，3．花房分化期，4．側花房分化期，5．小花形成期，6．小花増加期，7．花弁形成期，8．雄ずい形成期，9．雌ずい形成期

キーワード：コリアンダー，日長，発育，花芽分化，量的長日植物

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