Effects of Day Length and Air Temperature on Stem Growth and Flowering in Sesame

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Abstract: The effects of day length and air temperature on the growth and flowering of sesame (Sesamum indicum L.) were examined to analyze the effect of seeding date on the seed yield. Short day (10-h light/14-h darkness) treatment decreased the final stem-length relative to natural day length (14.1 ~ 13.4-h), although it hardly affected the length of the stem-elongation period. The short-day treatment shortened the duration to the first flower and lowered the first flowering-node. It prolonged the flowering period, but decreased the flowering-node number on the main stem resulting from the slower rate of increase in nodes with flowers. Under a low day/night temperature condition (23/18ºC), the stem growth was very slow and flowering did not occur. As compared with a high temperature (30/23ºC), a low temperature (22/15ºC) during 15 days after emergence suppressed the seedling growth temporarily, but the seedlings resumed growth after the temperature treatment. The growth and flowering behavior after the treatment were unaffected by a low temperature during the seedling stage. On the other hand, a low temperature during the flowering period decreased the flowering-node number resulting from the slower rate of increase in nodes with flowers, although it prolonged the flowering period. In this study, the decrease in the flowering-node number by short days and low temperature was smaller than that by delay of seeding date as observed in our previous study. Thus, the effects of day length and air temperature were not the sole factors responsible for the effect of seeding date on the flowering-node number.

Key words: Flowering, Growth, Sesame, Short day length, Temperature.

In sesame cultivation in the temperate regions, the time of seeding affects the seed yield strongly. Generally, the effect of seeding date is mainly the combination of the effects of day length and air temperature. With the delay of seeding date, the day length during growth decreases and the duration of high temperature becomes short, although the air temperature during the early growth stage becomes higher. Delay of seeding date shortens the days to the first flower in Japan (Katoh et al., 1996; Kumazaki et al., 2002). This seemed to be the result of the effects of short day length and high air temperature. It was reported that an 8-hour day length lowered the first flowering node position and advanced the first flowering day as compared with a 13-hour day length (Sinha et al., 1973; Kotecha et al., 1975; Suddhiyam et al., 1992). A high air temperature of 27/20ºC (day/night) also advanced the first flowering day as compared with temperature of 22/15ºC, although it hardly affected the first flowering node position (Suddhiyam et al., 1992). In these reports, however, the first flowering node position was lowered only 1−3 nodes, and the first flowering day was advanced only 5−10 days. Thus, the effects of day length and temperature on the start of flowering are slight.

Delay of seeding date is reported to reduce the seed yield through the decrease in the capsule number per stem (Katoh et al., 1996; Ieda et al., 1999). The capsule number per stem is very important yield component. It is separated into the number of nodes with capsules and the number of capsules per node, but is mainly determined by the former, because the latter is almost the same under different conditions in each sesame cultivar. In sesame, the flowers developed on each leaf axils bloom acropetally from the lowest node for more than a month. We previously observed that the time of seeding affected the number of flowering nodes through the number of bloomed-flowers per day and flowering duration (Kumazaki et al., 2002). Thus, it is very important to examine the effects of day length and temperature on the process of increase in the number of nodes with bloomed flowers, because it relates to the determination of the node number with capsules per stem. However, the effects of day length and temperature on the flowering process have not been examined in detail, although the decrease in the...
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Capsule number by short day length (SD) was reported by Sinha et al. (1973). Here, we examined the effects of SD and air temperature on the flowering process and the related stem growth.

Materials and Methods

The experiments were conducted at Meijo University using sesame cultivar Masekin, which is a non-branching type cultivar with three flowers per leaf axil (a central flower and two lateral flowers).

1. Short-day treatment (Experiment 1)

On July 3, 2003, 4 seeds were sown in 10 pots (1/2000 a) at 4 spots in the central part of each pot containing 10 kg soils. Fertilizer (15% N, 15% P₂O₅, 10% K₂O) was applied at a rate of 30 g per pot as a uniform application. The emerged seedlings were not thinned. Five pots were exposed to 10-hour day length every day after seeding by placing the pots in the dark from 1700 to 0700. This group was named the SD group. The remaining 5 pots were exposed to natural day length as a control and named the natural day-length (ND) group. The natural day length decreased from 14.5 to 12.6 hours during the experimental period (from July 3 to September 11). Air temperature was not controlled. The air temperature in SD and ND was measured with the auto thermo recorder (NWR-9003, Nihonkeiryoki-kogyo Co., Ltd.).

Only 15 plants in the SD group and 8 plants in the ND group were examined for insect injury. The main stem length was measured at 5-day intervals from 5 days after seeding (DAS). The flowering date was recorded for every flower at all nodes on the main stem. The regression coefficient between the flowering dates of the central flower at each node and the corresponding node position on the main stem was calculated and was named the rate of increase in the flowering-nodes on the main stem. In this study, the cotyledonary node on the main stem was counted zero and the nodes on the main stem were numbered acropetally.

2. Air-temperature treatment during the growth period (Experiment 2)

On June 16, 2002, the seeds were sown in 20 pots (1/5000 a), each containing 10 kg soils. Fertilizer (15% N, 15% P₂O₅, 10% K₂O) was applied at a rate of 25 g per pot as a uniform application. The plants were divided into two groups. One group was placed in a growth chamber (S-206W, Koito Industries, Ltd.) kept at 30/25°C (day/night, 0600-1800/1800-0600) and the other in a growth chamber (S-203W, Koito Industries, Ltd.) kept at 23/15°C after seeding under natural sun light. The plants were thinned to one plant per pot, divided into two groups, and exposed to 30/23°C and 22/15°C from 5 to 20 DAS (15 days) in the growth chambers. After the temperature treatment, the plants were grown under natural conditions. Only 8 plants in the 30/23°C plot and 6 plants in the 22/15°C plot were examined because of poor establishment. The measurements were the same as those in experiment 1.

3. Air-temperature treatment during the early growth stage (Experiment 3)

On June 19, 2005, the seeds were sown in 16 pots (1/5000 a), each containing 3 kg soil. Fertilizer (15% N, 15% P₂O₅, 10% K₂O) was applied at a rate of 15 g per pot as a uniform application. The plants were thinned to one plant per pot, divided into two groups, and exposed to 30/23°C and 22/15°C from 5 to 20 (15 days) in the growth chambers. After the temperature treatment, the plants were grown under natural conditions. Only 8 plants in the 30/23°C plot and 6 plants in the 22/15°C plot were examined because of poor establishment. The measurements were the same as those in experiment 1.

4. Air-temperature treatment during the flowering period (Experiment 4)

The plants were grown in 2005 as in experiment 3 using 28 pots (1/5000 a). The plants were thinned to one plant per pot, divided into two groups, and grown under 30/23°C and 22/15°C conditions after the first flowering day in the growth chambers. Fourteen plants in both plots were examined. The measurements were the same as in experiment 1.

Results

1. Effect of short-day treatment on stem growth and flowering

In this experiment, the average day length under natural conditions was 14.1 hours before flowering and
13.4 hours during the flowering period. The maximum air temperature fluctuated between 22.6°C and 34.8°C, and the minimum air temperature fluctuated between 18.7°C and 26.5°C under natural conditions. The air temperature during the SD treatment from 1700 to 0700 was slightly higher than that in the ND treatment, although the difference was only 0.6°C on the average. The average of daily mean air temperature was 25°C before flowering and 27°C during the flowering period under both conditions.

The main stem elongated during the first 55 days in both SD and ND groups (Fig. 1). The end of elongation coincided with the end of flowering. The main stem length was shorter in the SD group than in the ND group after 45 DAS.

In the SD group, the start of flowering was about 8 days earlier and the first flowering node was about 3-node lower than that in the ND group (Table 1). The rate of increase in the flowering-node number was lower in the SD group than in the ND group. The flowering period in the SD group was about 9 days longer than that in the ND group, because flowering started 8 days earlier and ended slightly later in the SD group (Fig. 1). However, the plants had a smaller number of flowering nodes in the SD than ND group.

2. Effect of air temperature during the growth period on stem growth and flowering

The plants grew poorly at 23/18°C (Fig. 2). As a result, the plants kept at 23/18°C were only 20 cm in length at 60 DAS and did not start flowering within 60 days, although the plants kept at 30/25°C were over 110 cm in length at 60 DAS and started flowering at 54 DAS.

3. Effect of air temperature during the early growth stage on stem growth and flowering

Since the plants in the 23/18°C plot grew poorly in experiment 2, the temperature effect during the early

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Table 1. Effect of short days on the flowering on the main stem.

| Treatment | Start of flowering (DAS) | First flowering node | Rate of increase in flowering-node number | Flowering period (days) | Number of flowering nodes |
|-----------|--------------------------|----------------------|------------------------------------------|-------------------------|--------------------------|
| ND        | 39.6                     | 4.9                  | 0.83                                     | 16.9                    | 14.6                     |
| SD        | 31.9                     | 2.1                  | 0.44                                     | 25.7                    | 11.1                     |

**a**: The plants were grown under 10-hour short day length (SD) and natural day length (ND) after seeding.

**b**: DAS = days after seeding.

**c**: The node number on the main stem was counted from the base excluding the cotyledonary node.

**d**: Rate of increase in the nodes with central flowers on the main stem.

**e**: Difference was significant at the 1% level by t-test.
growth stage was studied in this experiment. After the air-temperature treatment, the maximum, minimum and mean temperatures were 31.9°C, 23.5°C and 26.9°C, respectively, on the average.

The rate of stem elongation in 22/15ºC plot was lower than that in the 30/23ºC plot from 5 to 20 DAS (Fig. 3). At the end of temperature treatment (20 DAS), the stem length in the 22/15ºC plot was only one-fourth of that in the 30/23ºC plot. After the treatment, however, the rate of stem elongation in the 22/15ºC plot was higher than that in the 30/23ºC plot. As a result, the final stem length in the 22/15ºC plot was the same as that in the 30/23ºC plot.

The start of flowering was slightly later in the 22/15ºC plot than in the 30/23ºC plot, and the first flowering node was lower in the 22/15ºC plot, although these differences were not significant (Table 2). In the 22/15ºC plot, the rate of increase in the flowering-node number, the flowering period and the number of flowering nodes were similar to those in the 30/23ºC plot.

4. Effect of air temperature during the flowering period on stem growth and flowering

During the period before flowering, the maximum, minimum and mean temperatures were 31.2°C, 23.2°C and 26.6°C, respectively, on the average. After the start of temperature treatment, the stem elongation rate was lower in the 22/15ºC plot than in the 30/23ºC plot (Fig. 3). At the end of temperature treatment (20 DAS), the stem length in the 22/15ºC plot was only one-fourth of that in the 30/23ºC plot. After the treatment, however, the rate of stem elongation in the 22/15ºC plot was higher than that in the 30/23ºC plot. As a result, the final stem length in the 22/15ºC plot was the same as that in the 30/23ºC plot.

Flowering started at 42 DAS and the first flowering node was 5.6th node in both plots because the plants were grown in a natural condition before flowering (Table 3). The rate of increase in the flowering-node number in 22/15ºC plot was lower than that in 30/23ºC plot. The flowering period in 22/15ºC plot was 5 days longer than that in 30/23ºC plot, resulting from the delay in the end of flowering in the 22/15ºC plot. However, the number of flowering nodes in the 22/15ºC plot was less than that in the 30/23ºC plot.

Discussion

The SD treatment advanced the first flowering day and lowered the first flowering node position as compared with the natural day length (Table 1) as previously reported (Sinha et al., 1973; Kotecha et al., 1975; Suddhiyam et al., 1992). Thus, the SD treatment prolonged the flowering period, because it did not affect the end of flowering (Fig. 1). However, it decreased the rate of increase in the flowering-node number (Table 1), and therefore decreased the flowering-node number on the main stem. These results suggested that the short day-length decreased the capsule number per plant in sesame as reported by Sinha et al. (1973). In buckwheat, the day length directly affected the rate of increase in the flowering-cluster number on the main stem (Michiyama et al., 2003, 2005). In this study, whether the SD influenced the rate of increase in the flowering-node number directly or through the amount of solar radiation was
not determined. The decrease in the flowering node number by SD probably resulted in a short stem-length (Fig. 1 and Table 1), because the internode length was almost the same in both groups.

At the low day/night temperature of 23/18°C, the stem growth was greatly suppressed and flowering did not occur for 60 days (Fig. 3). In soybean (Sato, 1976), the temperature, which severely inhibits shoot growth and delays the start of flowering, is as low as 15/10°C. These results indicate that the critical low temperature for growth is 8°C higher in sesame than in soybean. Sesame seems to be markedly sensitive to a low temperature.

The low temperature (22/15°C) during the first 15 days after emergence suppressed the seedling growth temporarily, but the suppressed growth was recovered under the following natural condition in experiment 3 (Fig. 3). Our results indicate that the environmental conditions during the early growth stage do not affect either the growth or flowering, e.g., the rate of increase in the flowering-node number, the flowering period and the flowering node number (Table 2). The low temperature during the flowering period decreased the rate of increase in the flowering-node number, although it prolonged the flowering period (Table 3). These decreases in the flowering node number in the SD group and 22/15°C plot were only around 20% of those in the ND group and 30/23°C plot. We previously observed that the flowering node number in the plants seeded on May 22, 23, 27 had 57 nodes with flowers on the main stem, but the plants seeded on August 28 had only 18 nodes with flowers in the field (Kumazaki et al., 2002). The flowering node number in the plants seeded on August 28 was 69% fewer than that in the plants seeded on May 22. In the present experiments, the decrease in flowering node number by SD treatment and low temperature was smaller than that by the delay of seeding date. Thus, it seems that the effects of day length and temperature on the flowering of sesame are different from those in buckwheat, although both are short-day plants that exhibit a similar flowering pattern.

The flowering node number on the main stem in the SD group and 22/15°C plot was 3 and 7 nodes fewer than that in the ND group and 30/23°C plot, respectively (Tables 1 and 3). These decreases in the flowering node number in the SD group and 22/15°C plot were only around 20% of those in the ND group and 30/23°C plot. We previously observed that the plants seeded on May 22 had 57 nodes with flowers on the main stem, but the plants seeded on August 28 had only 18 nodes with flowers in the field (Kumazaki et al., 2002). The flowering node number in the plants seeded on August 28 was 69% fewer than that in the plants seeded on May 22. In the present experiments, the decrease in flowering node number by SD treatment and low temperature was smaller than that by the delay of seeding date. Thus, it seems that the effects of day length and air temperature are not the sole factors responsible for the effect of seeding date on the flowering node number. Further studies on the effects of other environmental factors are required.

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