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# Effects of Temperature and Light Conditions on Flower Initiation and Fruit Development in Strawberry

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**Abstract**

Several experiments were carried out to develop a new cultivation system for strawberry suited to Japan's cooler regions to enable June-bearing cultivars to produce high quality fruits in autumn: (1) Runner plants of cv. Nyoho were subjected to refrigerator-cooling, short-day cycles or shading treatments. Flowering was successfully advanced to early August depending on the treatment conditions. Factors affecting the treatment effectiveness were analyzed. (2) The development of fruit in cv. Morioka-16 varied considerably with the day, night and mean diurnal temperature conditions. Fruit Production with marketable value was not satisfactory at diurnal mean temperatures above 20°C, and the yield was reduced when the day temperatures exceeded 25°C. (3) Based on the results obtained, a new autumn cropping cultural system was proposed and the procedure for determining the optimal time of the processes was outlined.

**Discipline:** Horticulture
**Additional key words:** flower bud induction, cultural system, refrigerator, shading

## Introduction

After the 1980s, forcing type of strawberry cultivation became popular in Japan's warmer regions, accounting for about 90% of the present strawberry production acreage. However, domestic strawberry production is very low during the period from June to November, in spite of the strong market demand for cakes. Most of the fresh strawberries during that period are supplied by shipping from overseas.

Strawberry production during that period may be possible in the northeastern cooler regions of Japan, by making use of the cooler summer climate. One of the methods would be "to advance the forcing culture to autumn fruit production". To achieve this objective: (1) a convenient artificial method of induction of flower buds in high-quality June-bearing types of cultivars during summer (high temperature and long-day period) should be developed and (2) fruit growth should be secured during the period when temperatures are relatively high. For the former method, flower induction of runner plants by refrigerator-cooling is being widely applied in advanced strawberry production regions in Japan, although the physiological mechanisms have not been elucidated. For the latter target, there are very few reports on the relation between fruit development and growth temperature[7,12,13,16].

In the present paper, firstly, the effects of temperature and light conditions on flower bud initiation and subsequent inflorescence development were investigated through a series of experiments mainly centered on the effect of refrigerator-cooling treatment. Secondly, the effect of temperature on fruit development was defined using growth chambers. Thirdly, an autumn cropping system suited to Japan's cooler regions was examined.

All the experiments were carried out in 1988-1991 at the Morioka Branch of NIVOT, Iwate, Japan.

## Effect of refrigerator-cooling treatment on flower induction

Runner plants of Nyoho were grown according to the potted nursery system. They were exposed to continuous dark + low temperature conditions (all-day refrigerator-cooling (RC) treatments) for various

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periods of time and temperatures to investigate the physiological aspects of the treatment and to determine whether the application to the cultivation system is possible. Additionally, runner plants were subjected to various shading treatments and a short-day treatment in the nursery. After each treatment, the plants were planted under plastic cover and grown along plants cultivated according to the standard forcing culture system. The inflorescence growth and the yield/plant were observed.

Table 1 shows the flower induction effect of the RC treatment under several conditions. The flowering of a part of the RC-treated plants was successfully accelerated by more than a month (accelerated plants, AP), compared with the control. Thus RC treatments in darkness (without short-day stimulation) were found to be effective in inducing flower buds of runner plants, although the flowering of the June-bearing type of strawberries had been previously reported to be induced only under short-day conditions at temperatures ranging from 14 to 24°C[3,4,10,16]. However, the effectiveness was not

**Table 1. Effects of temperature and duration of exposure to refrigerator-cooling treatment (continuous darkness at low temperature) on flower bud induction and development of Nyoho strawberry**

| | Treatment | | Date of planting | Percentage of AP a) | Date of flower bud emergence ± SE | | Flowering date ± SE | | No. of flowers in terminal inflorescence of AP ± SE |
|---|---|---|---|---|---|---|---|---|---|
| | Temperature (°C) | Duration (d) | | | AP | NAP b) | AP | NAP | |
| A | 10 | 15 | Aug. 5 | 36 | Sep. 9 ± 0.4 | Nov. 2 ± 2.1 | Sep.20 ± 0.6 | Nov.28 ± 3.2 | 51.8 ± 5.5 |
| B | 12.5 | 15 | Aug. 5 | 50 | Sep.11 ± 0.9 | Nov. 1 ± 0.4 | Sep.24 ± 1.0 | Nov.21 ± 0.9 | 44.8 ± 1.8 |
| C | 15 | 15 | Aug. 5 | 83 | Sep. 8 ± 0.8 | Nov. 6 ± 2.8 | Sep.20 ± 1.0 | Nov.30 ± 0.7 | 43.9 ± 3.9 |
| D | 10 | 20 | Aug.10 | 25 | Sep.11 ± 1.4 | Nov. 4 ± 2.0 | Sep.21 ± 0.9 | Nov.27 ± 2.7 | 37.3 ± 4.5 |
| E | 15 | 20 | Aug.10 | 75 | Sep.13 ± 1.0 | Oct.30 ± 0.6 | Sep.24 ± 1.6 | Nov.19 ± 0.3 | 31.0 ± 2.6 |
| F | 10 | 25 | Aug.15 | 50 | Sep.17 ± 1.6 | Oct.29 ± 0.8 | Sep.27 ± 2.0 | Nov.17 ± 1.2 | 20.8 ± 2.4 |
| G | 15 | 25 | Aug.15 | 92 | Sep.18 ± 1.1 | Oct.30 ± 1.0 | Sep.30 ± 1.5 | Nov.18 ± 1.0 | 22.1 ± 1.8 |
| H | – | – | Aug.15 | – | – | Oct.21 ± 4.1 | – | Nov. 9 ± 5.1 | – |

a): Accelerated plant flowering, b): Non-accelerated plant flowering.

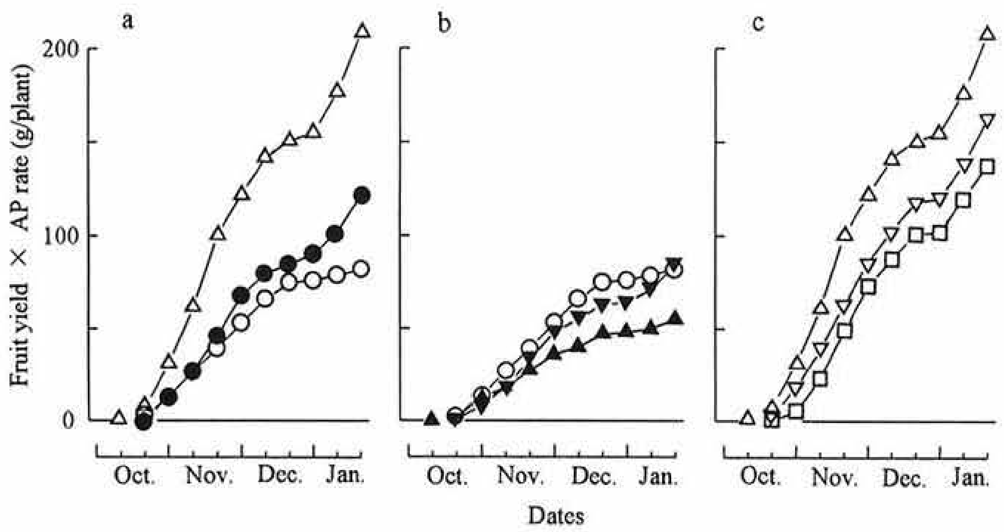


Fig. 1. Effects of temperature and duration of refrigerator-cooling treatment on fruit yield/plant multiplied by rate of AP
Symbols indicate treatments A (○), B (●), C (△), D (▲), E (▽), F (▼) and G (□). See Table 1.
a : Effect of temperature at 10°C (○), 12.5°C (●) and 15°C (△) in 15 day treatment,
b : Effect of duration of 15 (○), 20 (▲) and 25 (▼) day treatments at 10°C,
c : Effect of duration of 15 (△), 20 (▽) and 25 (□) day treatments at 15°C.

complete. The flowering of the remaining part of the treated plants was not accelerated (non-accelerated plants, NAP), and flowering was delayed by 8–21 d, compared with the control plants.

In the AP, the duration from planting to the emergence of the flower buds or to flowering was practically fixed (34 and 45 d, respectively). The first strawberries were harvested about 70 d after planting. On the other hand, none was harvested before mid-January in NAP and almost all of the control plants (Table 1). In each RC treatment, the AP produced fruits with a high marketability value around November[14]. The yield per unit area by December (calculated from the value of the fruit yield per plant multiplied by AP rate, Fig. 1) was considerably improved over the standard cultural system, and was the greatest in the plants treated at 15°C for 15 d. Treatment at lower temperatures (especially 10°C) or longer durations of the treatment decreased the fruit yield per unit area. These results suggest that RC treatment may enable to advance the strawberry harvest period provided that the rate of AP is high.

**Table 2. Flower bud induction in Nyoho strawberry in response to 5 temperature conditions during refrigerator-cooling treatment for 10 and 15 d**

| Treatment: Temperature (°C) | Treatment: Duration (d) | Percentage of AP[a)] | Perecentage of NAP[b)] |
|---|---|---|---|
| 15.0 | 10 | 5 | 95 |
| 17.5 | 10 | 6 | 94 |
| 20.0 | 10 | 0 | 100 |
| 22.5 | 10 | 0 | 100 |
| 25.0 | 10 | 0 | 100 |
| 15.0 | 15 | 53 | 47 |
| 17.5 | 15 | 40 | 60 |
| 20.0 | 15 | 22 | 78 |
| 22.5 | 15 | 0 | 100 |
| 25.0 | 15 | 0 | 100 |
| Control | 0 | 0 | 100 |

Treatments were started on August 10. After the refrigerator-cooling treatment, plants were exposed to a growth temperature of 30°C with 16 h-photoperiod.
a), b): Same as in Table 1.

As shown in Tables 2 and 3, the temperature in the RC treatment was an important factor affecting the percentages of AP and subsequent inflorescence development[6]. Higher temperatures reduced the percentage of AP and also delayed the flowering of AP. It may take a longer time to induce flower buds in treatments at temperatures higher than 17.5°C compared to 15°C. Japanese cultivars recently introduced for forcing culture like Nyoho may be more sensitive to temperature conditions for the initiation of the flower buds because even temperatures higher than 15°C could induce the flowers, although such a range of temperatures alone had been previously reported not to be effective on the flowering of some older cultivars[3,4,10,16].

Extension of the duration of the treatment by more than 15 d did not enhance the rate of AP and AP exposed to a longer treatment developed poor inflorescences (Table 1) resulting in a low yield/plant[14]. This phenomenon may be related to nutrient deficiency in the growing point of the treated plants caused by continuous exposure to darkness without a new supply of assimilates.

Determination of the permissible range of advancement of flower induction will be essential for the development of an autumn cropping system. Especially in regions with a cooler climate, natural environmental conditions change considerably from August to November, and subsequent development of the induced flower varies appreciably with the temperature[2,5]. Experimental results (Table 4) indicated that the time lag of planting which was

**Table 3. Flower bud induction and development of Nyoho strawberry in response to 4 temperature conditions during refrigerator-cooling treatment for 15 d (July 31–August 15)**

| Treatment temperature (°C) | Percentage of AP[a)] | AP: Flowering date ± SE | AP: Beginning of harvest ± SE | AP: No. of flowers in terminal inflorescence ± SE | AP: Fresh fruit yield by Dec. (g/plant) |
|---|---|---|---|---|---|
| 12 | 84 | Oct. 4.9 ± 0.8 | Nov. 16.6 ± 1.7 | 35.6 ± 0.9 | 176 |
| 15 | 85 | Oct. 6.9 ± 1.1 | Nov. 16.8 ± 1.7 | 33.9 ± 1.2 | 165 |
| 18 | 69 | Oct. 12.3 ± 1.0 | Nov. 26.5 ± 2.2 | 28.1 ± 1.0 | 111 |
| 21 | 47 | Oct. 12.8 ± 1.1 | Nov. 29.8 ± 2.2 | 29.1 ± 0.3 | 108 |

a): Accelerated plant flowering.

**Table 4. Flower bud induction and development of Nyoho strawberry in response to timing of refrigerator-cooling treatment[a)]**

| | Timing of refrigerator-cooling | | AP[b)] | | |
|---|---|---|---|---|---|
| | Beginning of treatment | End of treatment (planting) | Percentage of AP | Flowering date | Beginning of harvest |
| A | Jul. 17 | Aug. 1 | 63 | Sep. 24.9 | Oct. 25.9 |
| B | Jul. 24 | Aug. 8 | 73 | Sep. 25.2 | Oct. 28.6 |
| C | Jul. 31 | Aug. 15 | 85 | Oct. 6.9 | Nov. 16.8 |
| D | Aug. 7 | Aug. 22 | 65 | Oct. 22.4 | Dec. 29.5 |
| E | Aug. 14 | Aug. 29 | 78 | Oct. 31.6 | Jan. 15.9 |

a): Refrigerator-cooling treatment at 15°C for 15 d for flower induction.
b): Accelerated plant flowering.

preceded by RC exerted a significant effect on plant growth (speed of inflorescence growth, number of flowers, starting date of harvest, and yield pattern). The time lag consequently influenced the yield by the end of December (Fig. 2). Plants of treatment (A), which were planted on August 1, were first harvested, and produced the largest number of fruits during October among the five treatments. However, the yield was low during November and December, presumably because the growth of newly expanded leaves or roots was reduced after planting. Higher natural temperatures may enhance the competition for photosynthetic assimilates between plant organs, as we described elsewhere[7,8)]. The reduced development of flowers of higher rank in terminal inflorescences may be related to this phenomenon. The highest yield by December was obtained in plants of treatment (B). It is recommended that the RC treatment be initiated in mid-July followed by planting in early August in the regions where the experiments were conducted. If the onset of RC treatment is delayed, fruit growth becomes too slow to produce a sufficient amount of fruits during autumn.

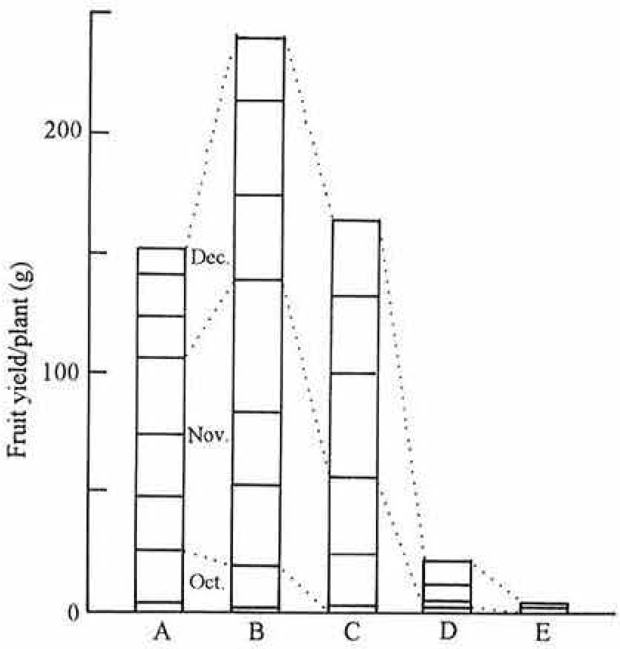


Fig. 2. Effect of timing of refrigerator-cooling treatment on fruit yield/plant of AP by December
A–E represent the timing of refrigerator-cooling. See Table 4.

## Why do NAP occur in the RC-treated plants?

The reason why both AP and NAP occurred in the RC-treated plants was worth investigating. The occurrence of NAP is considered to be due to devernalization of initiated flower buds caused by the high temperatures to which they were exposed after the treatment, because a few abnormal flowers (Plate 1) were observed in the treated plants. In these flowers, petals and stamens were apparent, but leaves were differentiated subsequently at the top of receptacles. Such flowers have been previously described[1,9,15)]. The reversion from reproductive to vegetative organs accompanied with the formation of defective organs has been observed in various species (e.g. chrysanthemum, cauliflower). The occurrence of these flowers suggests that devernalization may occur without remarkable morphological changes during the process of flower bud formation in strawberry. This assumption is supported by the results in Table 5, which shows that the percentages of AP among the plants exposed to 30°C after RC were clearly lower than those among the plants subjected to the 23°C treatment. The percentage of AP was enhanced by prolonging the duration of the RC treatment (15°C) from 5 to 20 d. It is assumed that the flower bud differentiation stage at the end of the RC treatment became advanced as the duration increased, and less reversion from reproductive to vegetative growth occurred in the treated plants.

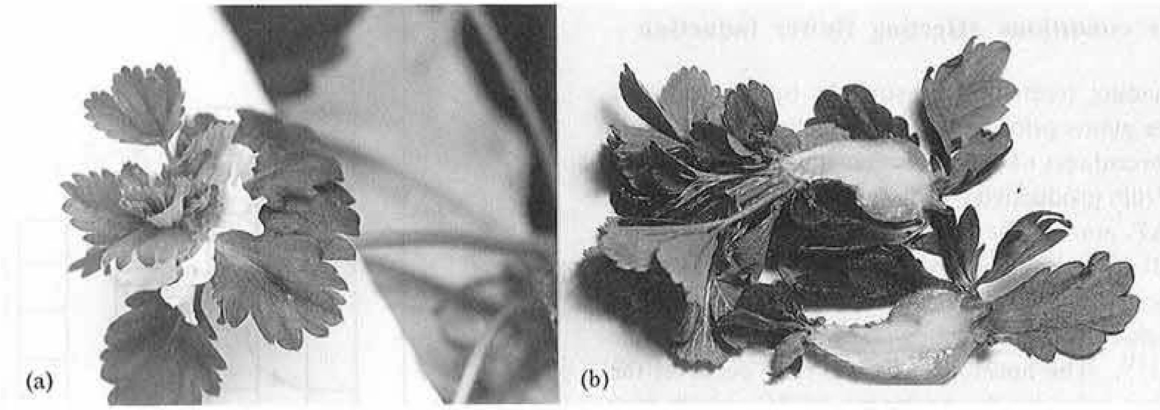

Plate 1. Reversion from reproductive to vegetative development in strawberries subjected to refrigerator-cooling treatment
(a) 5 days after anthesis, (b) 39 days after anthesis.

**Table 5. Effect of high temperature (30°C) + long-day (16 h-photoperiod) condition after refrigerator-cooling treatment on flower bud induction of Nyoho strawberry**

| Duration of refrigerator-cooling (d) | Growth condition after refrigerator-cooling | | Percentage of AP[a)] | Percentage of NAP[b)] |
|---|---|---|---|---|
| | Temperature (°C) | Photoperiod (h) | | |
| 5 | 30 | 16 | 4 | 96 |
| | 23 | 16 | 0 | 100 |
| 10 | 30 | 16 | 4 | 96 |
| | 23 | 16 | 26 | 74 |
| 15 | 30 | 16 | 33 | 67 |
| | 23 | 16 | 93 | 7 |
| 20 | 30 | 16 | 81 | 19 |
| | 23 | 16 | 100 | 0 |
| Control | | | 0 | 100 |

Refrigerator-cooling treatment (15°C) was started on August 8.
a), b): Same as in Table 1.

**Table 6. Flower bud induction and development of Nyoho strawberry in response to 20 d shading treatments prior to refrigerator-cooling treatment[a)]**

| Shading treatment | | Percentage of AP[b)] | AP | | |
|---|---|---|---|---|---|
| Materials | Percentage of sunlight reduction | | Date of flower bud emergence ± SE | Flowering date ± SE | Beginning of harvest ± SE |
| A Cheesecloth | 75 | 95 | Sep. 10.8 ± 0.8 | Sep. 21.1 ± 0.9 | Oct. 20.1 ± 1.2 |
| B Heat insulation film (1) | 77 | 100 | Sep. 10.9 ± 0.5 | Sep. 20.5 ± 0.6 | Oct. 20.3 ± 0.7 |
| C Heat insulation film (2) | 95 | 90 | Sep. 11.1 ± 1.0 | Sep. 21.9 ± 1.2 | Oct. 21.9 ± 1.7 |
| D Control | 0 | 85 | Sep. 13.9 ± 0.8 | Sep. 24.4 ± 1.0 | Oct. 23.6 ± 1.3 |

a): Refrigerator-cooling treatment at 15°C for 15 d (July 24-August 8) for flower induction.
b): Accelerated plant flowering.

## Other conditions affecting flower induction

Shading (reduction of sunlight by 75–95%) of runner plants prior to RC was effective in increasing the percentages of AP. Besides, flower development and fruit productivity in autumn were improved in the AP among the shade-treated plants (Table 6, Fig. 3). The reduction of sunlight presumably acted in the treated plants as a stimulus which changed the balance of endogenous plant hormones to some extent[11]. The hormonal changes may occur at the growing point by the beginning of RC, which may result in a reduction of the days from the beginning of RC to flower bud induction. As shading is a simple practice which enables to secure the occurrence of AP, it may be applied to maximize the use of RC treatment for the autumn cropping system. However, further prolongation of the duration of shading would not lead to further improvement of the management due to the high incidence of over-accelerated flowering plants which may prevent scheduled shipping[6].

Additionally, effects of short-day cycles or shading without exposure to RC on flower induction were examined (Table 7). In the regions where the experiments were conducted, when heat insulation films newly introduced were used as a tunnel material for the treatments, the mean plant temperature throughout the treatments did not exceed 21–23°C in July.

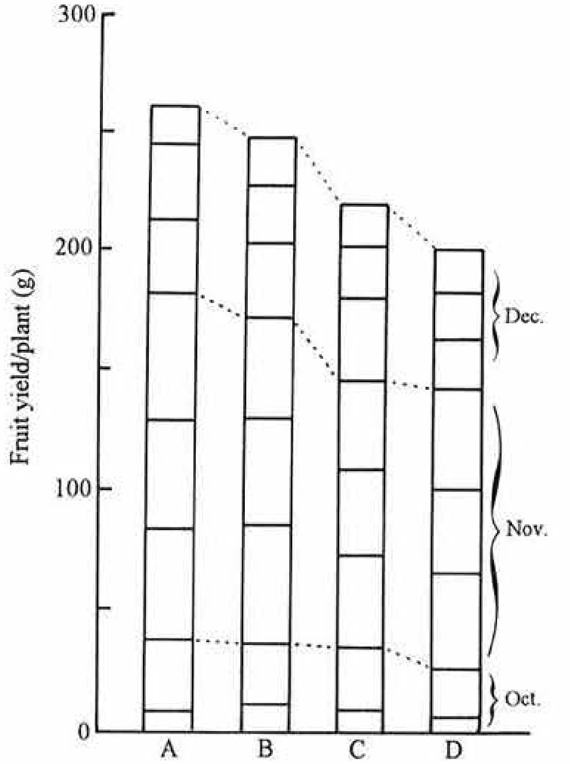


Fig. 3. Effects of 20-day shading treatments prior to refrigerator-cooling treatment on fruit yield/plant of AP by December
A–D represent the means of shading treatments prior to refrigerator-cooling: A, Cheesecloth with 75% sunlight reduction; B, Heat insulation film with 77% sunlight reduction; C, Heat insulation film with 95% sunlight reduction; D, No-shading (control). See Table 6.

**Table 7. Flower bud induction and development of Nyoho strawberry in response to 5 flower induction treatments[a] prior to planting[b]**

| Treatment | Percentage of EP[c] | Percentage of AP[d] | Percentage of NAP[e] | AP: Date of flower bud emergence ± SE | AP: Flowering date ± SE | AP: Beginning of harvest ± SE | AP: No. of flowers in terminal inflorescence ± SE |
|---|---|---|---|---|---|---|---|
| A Shading | – | 100 | 0 | Sep. 5.1 ± 1.8 | Sep.15.6 ± 1.8 | Oct.25.0 ± 3.2 | 31.1 ± 2.3 |
| B Shading + Short-day (1) | – | 100 | 0 | Aug.30.6 ± 0.9 | Sep. 7.4 ± 1.5 | Oct.12.0 ± 1.8 | 23.0 ± 2.7 |
| C Shading + Short-day (2) | – | 100 | 0 | Sep. 3.7 ± 0.8 | Sep.11.6 ± 1.2 | Oct.12.5 ± 3.5 | 26.0 ± 1.9 |
| D Shading + Refrigerator-cooling | 14 | 86 | 0 | Sep. 7.3 ± 1.3 | Sep.16.3 ± 1.6 | Oct.24.0 ± 1.8 | 28.7 ± 5.0 |
| E Refrigerator-cooling | 0 | 100 | 0 | Sep. 9.0 ± 2.3 | Sep.20.4 ± 2.7 | Oct.27.4 ± 3.5 | 35.3 ± 2.9 |

a): A, Shading for 44 d (June 18–August 1); B, C, Shading for 14 d (June 18–July 2) was followed by 30 short-day cycles (July 2–August 1); D, Shading for 14 d (July 3–17) was followed by 15 d refrigerator-cooling treatment (July 17–August 1); E, Refrigerator-cooling for 15 d (July 17–August 1).
Shading: 85% sunlight reduction by covering the plants with a heat insulation film (White-silver for sunlight-reduction),
Short-day (1): 8 h-photoperiod, covering the plants with a heat insulation film (White-silver 100),
Short-day (2): 8 h-photoperiod, covering the plants with a heat insulation film (Peerless film),
Refrigerator-cooling: Plants were kept at 15°C for 15 d.

b): Plants in 5 treatments were planted on August 1.

c): Excessively accelerated plant flowering in which flower buds were induced during shading in treatment D.

d): Accelerated plant flowering in which flower buds were induced during treatments.

e): Non-accelerated plant flowering.

The application of treatments consisting of 30 short-day cycles or 44-day shading led to an optimum flower induction effect[6], hence providing useful options for flower induction.

## Effect of temperature on fruit development

Runner plants (cv. Morioka-16) subjected to cold storage (−1°C) were prepared. Uniform runners (20−30 g fresh weight) were planted in polyethylene pots (18 cm in diameter) containing soil. The plants were grown in a greenhouse under a natural temperature/photoperiod regime until the anthesis of primary flowers. Then the pots were transferred to growth chambers and grown under controlled environments with varied day (12 h) − night (12 h) temperatures. Only 13 berries (7 berries on terminal inflorescence and 3 berries on 2 axillary branches) per plant were allowed to develop. Days from anthesis to harvest of each flower were observed. Fruit fresh weight, fruit Brix value and fruit acidity were measured at harvest.

The results indicated that the diurnal temperature regime (not only diurnal mean temperature but also diurnal difference between day and night temperatures) first affected the number of days from anthesis to harvest in treated inflorescences (Fig. 4). The effect of day temperatures on the number of days from anthesis to harvest is considered to be more appreciable than that of night temperatures.

Comparison of fruit fresh weight in flowers of the same rank in terminal inflorescences of the treated

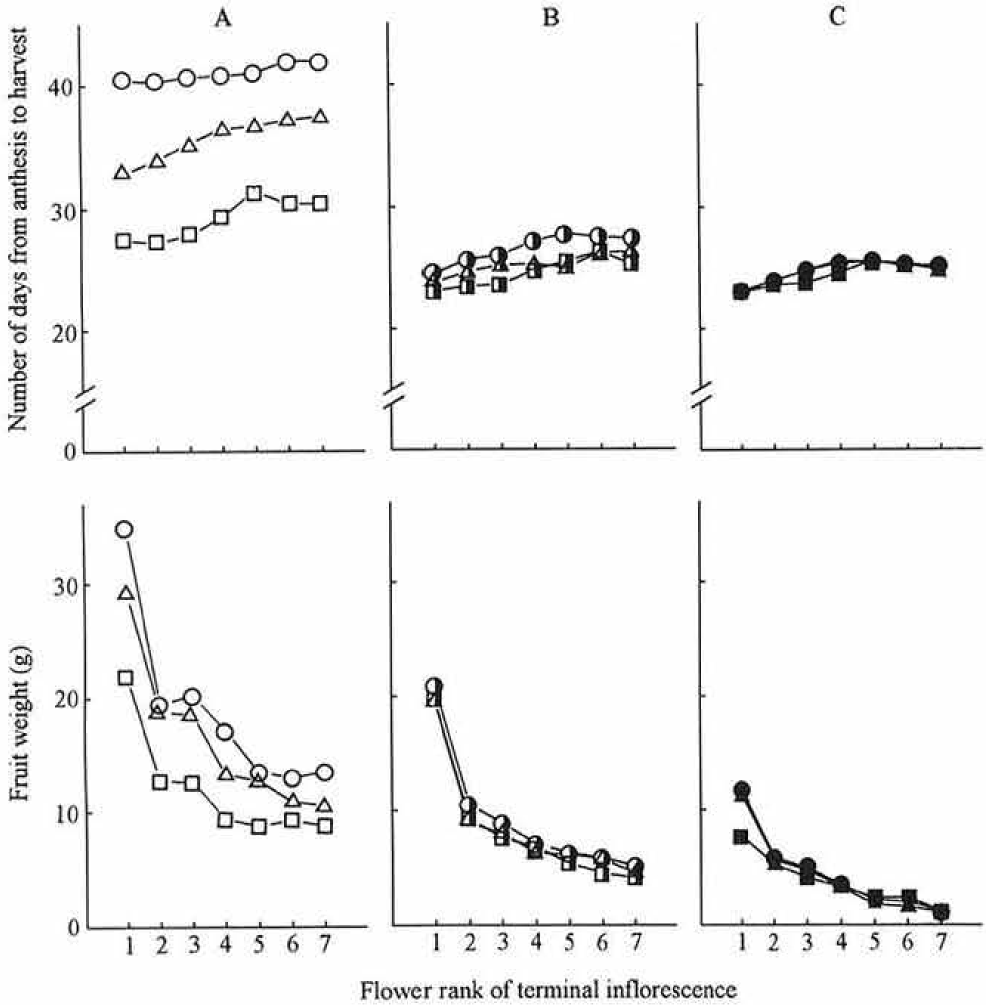


Fig. 4. Effect of day/night temperatures on number of days from anthesis to harvest (upper) and fruit fresh weight (lower) for each flower rank (1 is primary) in terminal inflorescence
Day/night temperatures were: (A) 15°/15°C(○), 20°/10°C(△), 25°/5°C(□); (B) 20°/20°C(◐), 25°/15°C(▲), 30°/10°C(◨); (C) 25°/25°C(●), 30°/20°C(▲) 35°/15°C(■).

plants (Fig. 4) indicated that a lower mean temperature resulted in a larger fruit, and that, for the same mean temperature regime, a smaller difference between day and night temperatures also resulted in a larger fruit. These results were similar to those obtained by Saito & Ito[13] and Went[16].

Consequently, it is obvious that the final fruit fresh weight for a flower rank in terminal inflorescences of the treated plants is closely related to the number of days from anthesis to harvest. The duration of the period during which the fruit imports photosynthetic assimilates is considered to be one of the most important factors determining the final fruit size[8]. The effects of temperatures for the treatments were similar to the total fruit yield of terminal inflorescences, which were significantly expressed as shown in Table 8. Moreover, a longer period from anthesis to harvest (when the flower was exposed to a lower mean temperature, especially to a lower day temperature) also contributed to a higher Brix value of fruit (Table 9). The amount of sugars finally accumulated in fruit may depend upon the length of the period during which the fruit imports photosynthates.

## Autumn cropping system suited to cooler regions

Especially in the cultivation system aimed at

**Table 8. Effect of day/night temperatures on total fresh fruit yield of terminal inflorescence**

| Mean temperature (°C) | Day/night temperature (°C) | Fresh fruit yield per plant | | |
|---|---|---|---|---|
| | | Total of 1st–3rd berries (g) | Total of 4th–7th berries (g) | Total of terminal inflorescences (7 berries) (g) |
| 15 | 15/15 | 74.5 ± 3.6 | 57.1 ± 1.6 | 131.6 ± 4.5 |
| 15 | 20/10 | 66.5 ± 1.6 | 47.4 ± 3.7 | 113.9 ± 4.4 |
| 15 | 25/ 5 | 47.1 ± 1.8 | 36.3 ± 1.1 | 83.4 ± 2.5 |
| 20 | 20/20 | 40.3 ± 1.7 | 24.5 ± 1.3 | 64.8 ± 2.6 |
| 20 | 25/15 | 36.3 ± 1.8 | 22.8 ± 1.0 | 59.1 ± 2.2 |
| 20 | 30/10 | 36.6 ± 1.7 | 20.8 ± 1.1 | 57.4 ± 2.1 |
| 25 | 25/25 | 21.8 ± 1.2 | 7.8 ± 0.3 | 29.6 ± 1.3 |
| 25 | 30/20 | 21.2 ± 1.5 | 7.8 ± 0.4 | 29.0 ± 1.4 |
| 25 | 35/15 | 17.1 ± 0.8 | 9.3 ± 0.3 | 26.4 ± 1.0 |

Mean value ± standard error (n = 7).

**Table 9. Effect of day/night temperatures on Brix value, acidity and Brix/acidity ratio in fruit**

| Mean temperature (°C) | Day/night temperature (°C) | Brix | Acidity (%) | Brix/acidity ratio |
|---|---|---|---|---|
| 15 | 15/15 | 10.6 | 1.03 | 10.3 |
| 15 | 20/10 | 9.0 | 0.95 | 9.5 |
| 15 | 25/ 5 | 9.2 | 0.90 | 10.2 |
| 20 | 20/20 | 7.9 | 1.25 | 6.3 |
| 20 | 25/15 | 7.4 | 1.09 | 6.8 |
| 20 | 30/10 | 6.8 | 0.93 | 7.3 |
| 25 | 25/25 | 5.2 | 0.87 | 6.0 |
| 25 | 30/20 | 5.4 | 0.93 | 5.8 |
| 25 | 35/15 | – | – | – |

Data indicate the mean value of first, second and third berries in terminal inflorescence.

producing fruits in relatively warmer seasons, temperatures during the period of fruit development exert a significant effect on fruit yield and also on fruit quality[2,5]. Experimental results (Table 4, Fig. 2) indicated that the time lag of planting which was preceded by RC exerted a significant influence on plant growth and consequently autumn yield. To develop an autumn cropping system suited to cooler regions by using artificial flower bud induction methods (like RC), it may be essential to determine the permissible range of advancement to avoid a reduction of fruit size or fruit quality.

Based on the results of our previous reports[7], we concluded that the development of strawberry fruits varies markedly with temperature conditions in the range of 15 and 20°C, fruit production with a marketable value is not satisfactory at diurnal mean temperatures above 20°C, and that the yield is likely to be reduced when the day temperatures exceed 25°C even if the diurnal mean temperatures are maintained below 20°C.

We suggest that the new autumn cropping system should be adjusted to each region as shown in Fig. 5. In Fig. 5, period (A) indicates the so-called June-crop under open culture in the region where the present experiment was conducted. Temperatures during that period were in the range of 12–18°C (y). Actually the crop exhibited a high quality, which is in agreement with the conclusion reached above. In the case of the autumn crop, the setting of the period of fruit development should not be advanced beyond period (B). By excessive advancement of the period the temperature may exceed 15°C, and consequently the fruit quality may decrease. In this region, harvest should be started in mid-October. The present results confirmed this assumption, since the optimum inflorescence development and fruit quality were obtained in autumn from the plants in which harvest started in mid-October. To improve the productivity of the system, it is most important that the fruits develop under optimum temperature conditions. For the determination of the timing of the processes, at first, the period of fruit development should be deduced from the data of year-round temperatures. Thereafter the timing of flower induction treatment (i.e. RC, short-days, shading, etc.) should be set up.

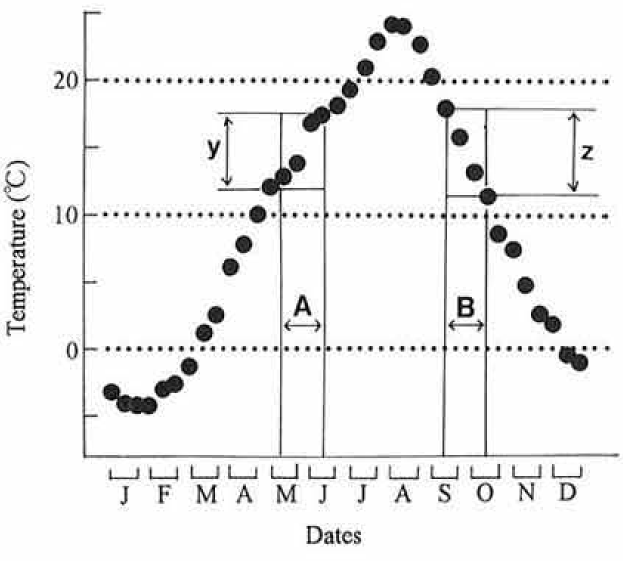


Fig. 5. Recommended timing for strawberry fruit development in an autumn cropping system in relation to year-round fluctuations of temperature in Morioka (region where experiments were conducted)
A: Period of fruit development in ordinary open culture.
B: Period of fruit development in the recommended autumn cropping system.
y: Range of temperatures during period (A).
z: Range of temperatures during period (B).

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