Development of Inflorescences in *Cymbidium* (Orchidaceae)

I. Difference in Temperature Effects Depending on the Developmental Stage of Inflorescences

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This article gives evidence with reference to the abortion of inflorescences in *Cymbidium* Sazanami 'Harunoumi.' Inflorescences at various stages were treated under high (30°C day/25°C night) and low (14°C day/10°C night) temperatures for different periods. The high temperature treatments resulted in a high rate of abortion in inflorescences kept for 60 days, regardless of the developmental stage. Inflorescences kept for 40 days showed abortion only at well-developed stages, and those kept for 20 days were little affected at any stage. In experiments where inflorescences kept under low temperature for 20, 40 or 60 days were transferred to high temperature, no anthesis occurred in inflorescences kept for 20 days or 40 days, but most of those kept for 60 days developed into normal anthesis. The temperature effects were highly dependent on the developmental stages of the inflorescences and the existence of a stage sensitive to temperature is suggested.

The development of young reproductive structures such as flower buds or inflorescences are greatly affected by unsuitable environmental conditions, resulting in their death, shedding or a return to vegetative growth. These phenomena called blinds were reported for various plants including lilies,¹⁻³⁾ tulips,⁴⁻⁸⁾ roses,⁹⁻¹¹⁾ and gladioli.¹²⁾ These phenomena were also attributed to various factors such as high temperature,⁶⁻⁸⁾ low temperature and/or low light intensity,^{1,9,13-16)} and ethylene.^{4,5,17)}

In *Cymbidium* orchids, especially in miniature cymbidiums produced by the hybridization with *Cym. pumilum*, inflorescences stop their development at an early stage in mid-summer under the culture conditions prevailing in Japan. This phenomenon called abortion in the present paper is a serious problem for cymbidium growers.

CASAMAJOR¹⁸⁾ observed a similar phenomenon in *Cymbidium lowianum* under experimental conditions (26°C day/10 or 6°C night; transposed from Fahrenheit, 16 hr day). More recently IWASE and KAKO¹⁹⁾ showed that the high day/night temperature of 30/25°C caused total blindness whereas lower temperatures of 23/18°C or 14/10°C induced inflorescence development.

In this paper the effect of temperature on the development of *Cymbidium* inflorescences was further investigated to establish whether it is dependent on the developmental stage of inflorescences and to determine the durations of low temperature requirement and high temperature tolerance.

MATERIALS AND METHODS

Cymbidium Sazanami 'Harunoumi' was used as a plant material. This cultivar was chosen for its cultural easiness and high susceptibility to high temperature injury of inflorescences. Plants with two or three bulbs were potted into clay pots (15 cm in diameter) containing sand-bark mixtures (3:1) in February, 1972. They were grown outdoors during May through October, thereafter in a greenhouse maintained at 5°C through 25°C. In mid-summer the temperature shifted between 20°C and 35°C in the open air and light intensity was reduced to about 50% of sun light intensity (approximately 50 klux) by covering the plants with a single layer of black plastic net with 1 m clearance. Overhead irrigation was carried out once a day, except in mid-summer twice a day in the morning and evening and in winter once or twice a week. Hyponex solution (about 1%) was fed at weekly intervals and rape cake (about 20 g per pot) was also fed three times at the time of lead-bulb development. Transplanting was conducted every other year.

Developmental stages of inflorescences were represented by the use of measuring the length of flower stalks, but the whole length of inflorescences was used for young ones with a small flower stalk enveloped by sheaths.

In August, 1973, the plants with inflorescences at relatively young stages were placed in two air-conditioned glass-houses in a phytotron, one group of plants at a high day/night temperature of 30/25°C, the other group at a low day/night temperature of 14/10°C, for 20, 40 or 60 days. The plants submitted to both temperature conditions for the required days were replaced to the other temperature, respectively, and kept there throughout the experimental period. The light condition of the glass-house in the phytotron depended on natural daylight and day length. Low temperature pretreatment for 60 days was duplicated to clarify, in detail, the relationships between developmental stages of inflorescences and temperature effects.

In late October, 1976, inflorescences at younger stages of development were selected from the plants grown outdoors where a temperature was between 5°C and 25°C and then treated at high temperature. In this experiment the effect of high temperature was examined on such inflorescences. This high temperature treatment was conducted in an artificially illuminated room of the phytotron (approximately 5 klux at leaf surface level, 12 hr light period).

The number of inflorescences used is counted by the number of symbols in each figure shown in Results.

RESULTS

Effects of transfer from high to low temperature

The effect of high temperature pretreatments on the development and flowering of inflorescences are shown in Fig. 1. Most inflorescences treated for 20 days normally developed and flowered after they were transferred to the low temperature condition. In 40 day-treated inflorescences, relatively longer or well-developed ones at the beginning of the treatment, were almost impossible to grow and only smaller inflorescences developed normally to anthesis after transfer to

Fig. 1 Effects of high temperature pretreatment for 20 days (A), 40 days (B), or 60 days (C) on the development and flowering of inflorescences at different developmental stages. After the treatment plants were grown under low temperature conditions. Each number on the abscissa shows the length of inflorescences at the beginning of the treatment. Open circle, number of florets flowered; closed circle, length of flower stalks at completion of experiments. This legend was also applied to the other figures.

low temperature. On the contrary, almost all the inflorescences of the 60 day-treatment except the youngest one died with neither flower stalk elongation nor floral development. Furthermore regardless of the difference in the length of the high temperature treatment, the flower stalks of damaged inflorescences similarly resulted in length less than 5 cm.

Effects of transfer from low to high temperature

As shown in Fig. 2, the effect of low temperature pretreatments on stalk elongation and flowering increased in proportion to the period subjected to the low temperature treatment. In the plants treated for 20 days all of their inflorescences suffered death after transfer to high temperature, regardless of their stages or length. In the 40 day-treatment, flower stalk elongation showed a tendency to increase in proportion to the length of inflorescences at the treatment. But even in the well-developed stalks, their length resulted in less than half of normal flowering stalks. Furthermore, the number of florets that normally flowered was very low. Note that the elongation of the flower stalks, whose flower buds dropped, occurred mainly at the lower half of them. Namely, the upper half of the stalks bearing flower buds was greatly suppressed in elongation. In the 60 day-treatment, most of the inflorescences developed normally and flowered except the youngest ones. The number of florets which normally flowered comprised about 20. The flower stalks, of which florets flowered normally, elongated well to 40-50 cm in length.

Similar results were obtained in the other 60 day low temperature pretreatment (Fig. 3). These results showed again that the effect of low temperature

Fig. 2 Effects of low temperature pretreatment for 20 days (A), 40 days (B), or 60 days (C) on the development and flowering of inflorescences at different developmental stages. After the treatment plants were grown under high temperature conditions. Each number on the abscissa shows the length of inflorescences at the beginning of the treatment.

Fig. 3 Effects of low temperature pretreatment for 60 days on the development and flowering of inflorescences at different developmental stages (duplicated experiment of Fig. 2-C). Each number on the abscissa depicts the length of flower stalks at the end of the low temperature treatment.

on the stalk and flower bud development in this cultivar was dependent on the developmental stage of inflorescences at the time of low temperature treatment.

Furthermore, when the plants were kept outdoors at the temperature between 5°C and 25°C till late October and thereafter treated at high temperature, the results were also obtained in a similar manner as the plants pretreated at low temperature for 60 days (Fig. 4).

DISCUSSION

Effects of both high and low temperatures on the development of inflorescences increased in proportion to the duration of the treatments (Figs. 1 and 2). Therefore it seems apparent that temperature effects on the growth of inflorescences were additive. However, even in any treatment of this experiment, temperature induced greatly different effects among inflorescences of different length at the treatment (Figs. 1-B and 2-B, C). Tulips treated by high temperature had exhibited similar results as above.^{6,7)} This may indicate the existence of temperature sensitive stage, in which the inflorescence is susceptible to high-temperature injury and requires low or not so high temperature for its normal development (Fig. 4). This temperature seems to be below 20°C, 14°C day/10°C night being more effective.¹⁹⁾ On the other hand, *Cymbidium lowianum* required temperatures ranging between 20°C or 23°C day and 14°C or less night.¹⁸⁾ After the inflorescences continue to grow over the stage sensitive to temperature, high temperature no longer injures the inflorescences and low temperature does not have a promotive effect on the development of inflorescences. This hypothesis in relation to the stage sensitive to temperature seems to explain the results obtained in the present investigation. The length of flower stalk at 3-7 cm roughly corresponded to this stage (Figs. 2-A and 3). In addition, temperature effects were proportional to the duration of the treatment during this stage (Figs. 1 and 2).

This dependency on the developmental stage was shown to be similar in several blind phenomena caused by high temperature and other factors.^{2,4,9,12,20)} In general, the meiotic stage of pollen mother cells is more susceptible to high temperature and other unfavorable conditions. Several workers reported that a sensitive stage was correlated with meiosis.²¹⁻²³⁾ However in *Cymbidium Sazanami* 'Harunoumi' the pollen mother cells entered into the meiotic prophase at 6 cm of stalk length and remained at this phase till 15 cm.²⁴⁾ Therefore the meiotic

Fig. 4 Development and flowering under high temperature conditions of inflorescences exposed to fluctuating temperature between 5°C and 25°C. Each number on the abscissa shows the length of flower stalks at the beginning of the treatment.

stage does not seem to be the stage sensitive to temperature. The details in respect of the temperature sensitive stage in *Cymbidium* will be presented in a subsequent paper.

The requirement of low temperature for dormancy release of seeds or buds and for floral induction or bolting is well known.^{25,26)} In this experiment low temperature (14/10°C) for 60 days affected two processes, one being the elongation of flower stalks and the other floral development (Fig. 3). In the inflorescences whose flower stalks were below 5 cm in length at the completion of the low temperature pretreatment, no flower buds opened while their flower stalks elongated to about 20 cm in length. The elongation beyond this level, which was observed in well-developed and flowered inflorescences, seems to be related with normal floral development. Similar results have been reported for various flowering plants in SACHS' review.²⁷⁾

Low temperature used in this experiment was much higher than that in dormancy release and other low temperature requiring developmental processes. But in *Cymbidium pumilum* hybridized as a mother plant of the cultivar used here this temperature (14/10°C) was too high and lower temperature was required.²⁸⁾ Several *Cymbidium* orchids susceptible to high temperature injuries, such as *Cym. Mary Pinchess* and *Cym. Minneken*, also have *Cym. pumilum* as their parent. In addition, the other parent of *Cym. Sazanami* seems not to have low temperature requirement. Therefore *Cym. Sazanami* 'Harunoumi' may inherit the character of low temperature requirement from *Cym. pumilum* to some extent.

The treatment of low temperature (14/10°C) for 60 days was required for normal development of inflorescences (Fig. 3). This may be due to the existence of acropetal gradient (advanced to younger) in the flower bud development. If so, the duration of low temperature required by the individual flower bud may be shortened to 40 days (Fig. 2-B) or less.

Though the low temperature treatment successfully resulted in overcoming the abortion of inflorescences occurring under high temperature conditions in mid-summer, the effect of low temperature was dependent on the developmental stage of inflorescences. This stage dependency is to be kept in mind in applying the present results to practical cymbidium growing.

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<和文抄録>

Cymbidium の花序の発育に関する研究

I. 発育ステージによる温度の影響の差異

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Cymbidium Sazanami 'Harunoumi' の花序の発育に及ぼす温度の影響をファイトトロンを用い調べた。種々の発育ステージにある花序を高温（昼 30°C, 夜 25°C）および低温（14°C, 10°C）でそれぞれ 20, 40, 60 日間処理し、高温処理したものは低温条件下に、低温処理したものは高温条件下に移した。その結果、高温処理の場合、20 日間ではほとんど花序に影響を与えず開花も正常であったが、40 日処理では発育の進んでいた花序にアボーションが発生した。さらに 60 日間処理では発育ステージにかかわらず大部分の花序がアボーションを起した。一方、低温処理の場合には発育ステージが進んでいるほど花茎は伸長したが、20 日間および 40 日間処理では開花に至らず、60 日間の処理が開花誘起には必要であった。高温ならびに低温の影響が、いずれも処理時の花序の発育ステージにより、大きな差異を示したことから、温度に感受性のある発育ステージの存在が示唆されている。