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# Effect of Temperature on Growth and Flowering of *Phalaenopsis amabilis.*

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## Abstract

At a continuous high temperature of 28°C, adult plants of *Phalaenopsis amabilis* continued to form foliage leaves at the shoot apex, but did not produce flower-stalks. In order to bring the plants into reproductive growth, low temperatures below 25°C were required daily more than 12 hours. After exposure to the low temperature for 6-8 weeks, the plants emerged flower-stalks mainly from the axils of the 3rd and/or 4th nodes below the uppermost leaf. Some of the growing flower-stalks shorter than 5cm, on which the primordia of the 1st and 2nd florets had been initiating, became abortive, when the high temperature was subsequently applied. While, the high temperature applied after the stalks reached to 10cm, where the 1st and 2nd florets began to differentiate petals, was not harmful to the further development, but rather accelerated the growth of the stalks.

## Introduction

Under temperature conditions common in commercial green houses in Japan, flower-stalks of *Phalaenopsis amabilis* emerge from the axils of leaves in autumn and flower during winter months. Accurate control of flowering time is of concern to growers, since the flower is primarily a corsage flower in special demand at certain times of the year.

ROTER (1952)[1] observed, with *Phalaenopsis amabilis* plants grown in the 65°F greenhouse, that continuous short days stimulated flowering and caused new inflorescence to develop throughout the year. WENT (1953)[2] suggested that the plants, grown in a 700 ft. c. light intensity and at a constant temperature of 20°C, formed more inflorescences at an 8-hour photoperiod than at a 16-hour photoperiod. RÜNGER (1971)[3] reviewed that *Phalaenopsis amabilis* and *Phalaenopsis schilleriana* require short days and also cool temperatures to develop flower. On the other hand, NISHIMURA and KOSUGI (1972)[4] reported that the emergence and the subsequent growth of flower-stalks in *Phalaenopsis amabilis* were stimulated by cool temperatures, but no clear effect of daylength was noticed.

The aim of the work reported in this paper was to examine the temperature responses to the growth and flowering behavior of *Phalaenopsis amabilis* under natural daylength.

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## Materials and Methods

Several years old unnamed hybrid seedlings of white flower were used. They were planted in sphagnum moss in unglazed pots and grown in the greenhouse at a temperature of 15 °C minimum under conditions of light and nutrition common in commercial greenhouses, except during a period of temperature treatments. The effect of different temperatures on the development of flower-stalks was determined by moving the plants from the greenhouse to growth chambers of 20°C, 25 °C, and 28 °C under natural daylength. For the experiment aimed to retard or inhibit the plants from entering into reproductive growth, low plastic clad tunnels warmed to 28°C minimum by a heating-cable were equipped in the greenhouse. In order to determine the effect of length of the daily period of the high temperature, the tunnels were cooled by switching off the heater and blowing outside air (maximum 25 °C; minimum 15 °C) by a centrifugal fan at specified times.

By weekly measurements of the plants, time of emergence of axillary buds from the base of leaf-sheaths, number of unfolded leaves, and time of flowering were recorded. Date of flowering was taken when the first floret was open. When a flower reached a marketable stage, length of flower-stalks and number of florets per stalk were measured. Determination of developmental stages of florets was made by observing the apical parts of flower-stalks with the use of a binocular microscope. The material of the observation was excised from the plants in the greenhouse at different stages of growth in length, and fixed in FAA.

## Results

*Formation and development of flower-stalks in the greenhouse.*

The first external indication of the growth of flower-stalk is the emergence of the axillary bud from the base of leaf-sheath. The axillary buds develop into flower-stalks,

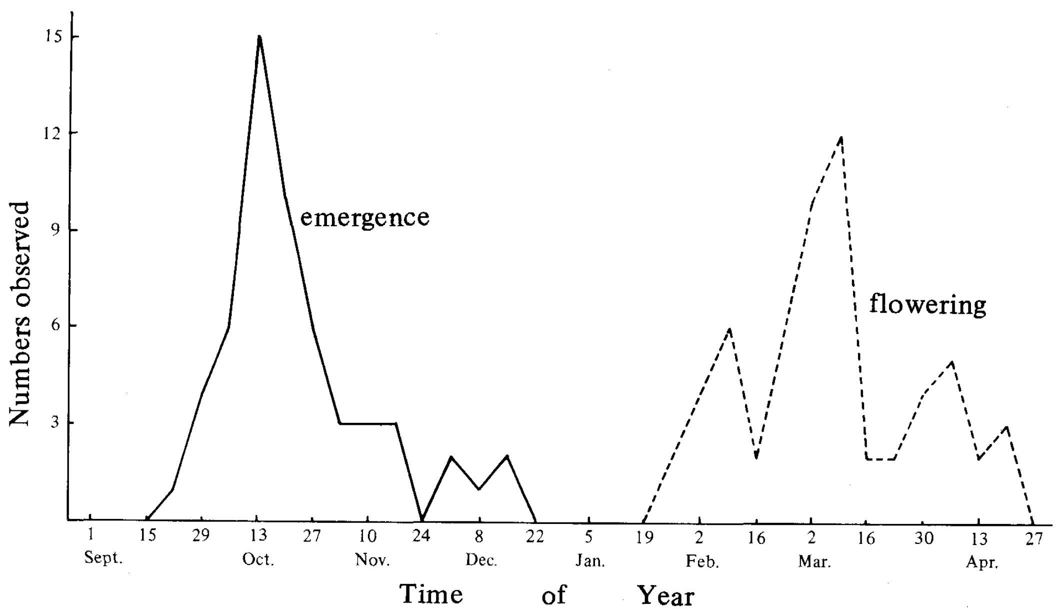


Fig. 1. Frequency distribution of time of flower-stalk emergence and flowering in the greenhouse.

which induce several florets. Fig.1 shows the number of emerged buds and flowered stalks from 50 plants in the greenhouse at different times of year. Temperatures in the greenhouse during the observation period are shown in Fig.2. The bud emergence began from the latter part of September where the average temperature fell down to 22°C.

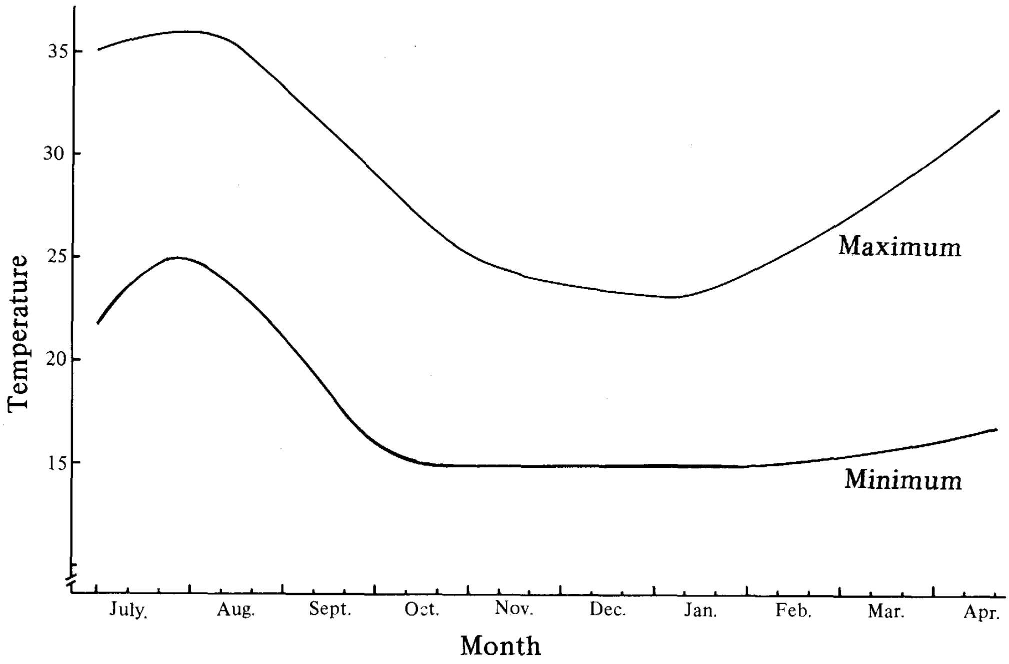


Fig. 2. Changes in the greenhouse temperature. The greenhouse was maintained at minimum 15°C by heating from November to March.

The peak of emergence was in the middle of October followed by a gradual decrease toward the year end. Flowering was first noticed late in January, and the peak was in the beginning of March, i.e. about 2 and a half months after the peak of the bud emergence. Throughout the season, most of the plants bore 1 or 2 flower-stalks and a few produced 3 stalks.

Table 1. Frequency of flower-stalk emergence from different positions of node.

| Node number from the uppermost leaf downwards | Node number from the previous flower-stalk upwards | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | 1 | 5 | 11 | 8 | 4 | 2 | 31 |
| 4 | 2 | 4 | 11 | 8 | 6 | 1 | 32 |
| 5 | | 1 | 2 | 2 | | | 5 |
| 6 | | | | | | | |
| Total | 3 | 10 | 24 | 18 | 10 | 3 | 68 |

Observation was made in the same plants as Fig. 1.

Table 1 shows the position of nodes bearing flower-stalks. Formation of flower-stalks centered on the 3rd and 4th nodes from the uppermost unfolded leaf downwards. From the view based on the position of the previous season's stalks, it is found that new stalks could be formed on every node above the remnant of the old flower-stalk, up to the 5th node. However, the 3rd and 4th nodes mainly produced the stalks.

*Emergence and flowering of flower-stalks at different temperature regimes.*

The plants, which had been grown in the greenhouse, were removed to 20°C, 25°C and 28°C from June 19 onwards, and the development of flower-stalks was observed (Table 2). Fifteen plants were used in each temperature regime. Promotion of flower-stalk emergence was shown in both the plants at 20°C and at 25°C, with a little earlier

Table 2. Effects of different temperature regimes on emergence and flowering of flower-stalks.

| Temper-ature | Percentage of flowered stalks | Mean dates of | | Length of flowered stalk | Number of florets per stalk |
|---|---|---|---|---|---|
| | | emergence | flowering | | |
| 20°C | 100% | July 31 ± 10* | Nov. 21 ± 14* | 45.4cm | 5.5 |
| 25 | 100 | Aug. 3 ± 17 | Oct. 22 ± 20 | 45.5 | 7.1 |
| 28 | 0 | – | – | – | – |

*: Deviation of days from the mean date.

emergence in the former plants. The mean time of the emergence in them was the end of July or thereabout, i.e. about 2 and a half months earlier than that in the control plants left in the greenhouse (cf. Fig.1). In consequence, early flowering was brought about by both the plants. Prior to others, the plants at 25°C began to flower around the latter part of October. At 20°C, the mean flowering date was one month later and the number of florets per stalk was smaller than the plants at 25°C. All the plants kept at 28°C formed no flower-stalks for any length of time (Fig. 3).

*Effect of high temperature on growth and flowering.*

The results of the experiments described above suggest that the critical temperature, which inhibits this cultivar from entering into reproductive growth, is between 25°C and 28°C. The following experiment was undertaken to inquire about the influence of transferring the plants to lower temperatures after different durations of the high temperature period. Table 3 indicates the dates of flower-stalk emergence and flowering in the plants, which were kept at 28°C from summer on and returned to the greenhouse (minimum temperature 15°C) on Novermber 14, December 26, and February 6 of the next year. Twenty plants each were used in the experiment. Comparative increase in the leaf number among them is shown in Fig.4. All of the plants began to push out flower-stalks 6 to 8 weeks after they were replaced in the greenhouse condition, but the increasing in the leaf number of them ceased at that condition. The longer the period of the high temperature, the later the date of flower-stalk emergence and the more the number of leaves.

Relation of the length of the daily period above 28°C to the development of flower-stalks was found using 12 plants in each plot, and the result is shown in Table 4. As hours of the high temperature extended, the flower-stalk emergence was delayed and the rate of the emergence decreased. In order to obtain a high rate of flower-stalks, plants should be kept at a cool temperature, at least 12 hours in a day for about 2 months.


Fig. 3. Development of flower-stalks in the plants grown at different temperature regimes. Photographed on October 21.
Control plant was kept at natural temperatures in the greenhouse.

Table 3. Emergence and flowering of flower-stalks in the plants subjected to natural low temperatures after different periods of high temperatures above 28°C.

| Start of low temp. | Mean dates of emergence | Mean dates of flowering |
|---|---|---|
| Control* | Oct. 16 ± 6** | Mar. 8 ± 27** |
| Nov. 14 | Jan. 6 ± 20 | Apr. 27 ± 23 |
| Dec. 26 | Feb. 18 ± 15 | June 3 ± 14 |
| Feb. 6 | Mar. 20 ± 5 | June 11 ± 8 |
| High temp. continued | – | – |

*: Plants were kept continually at natural temperatures in the greenhouse.
**: Deviation of days from the mean dates.

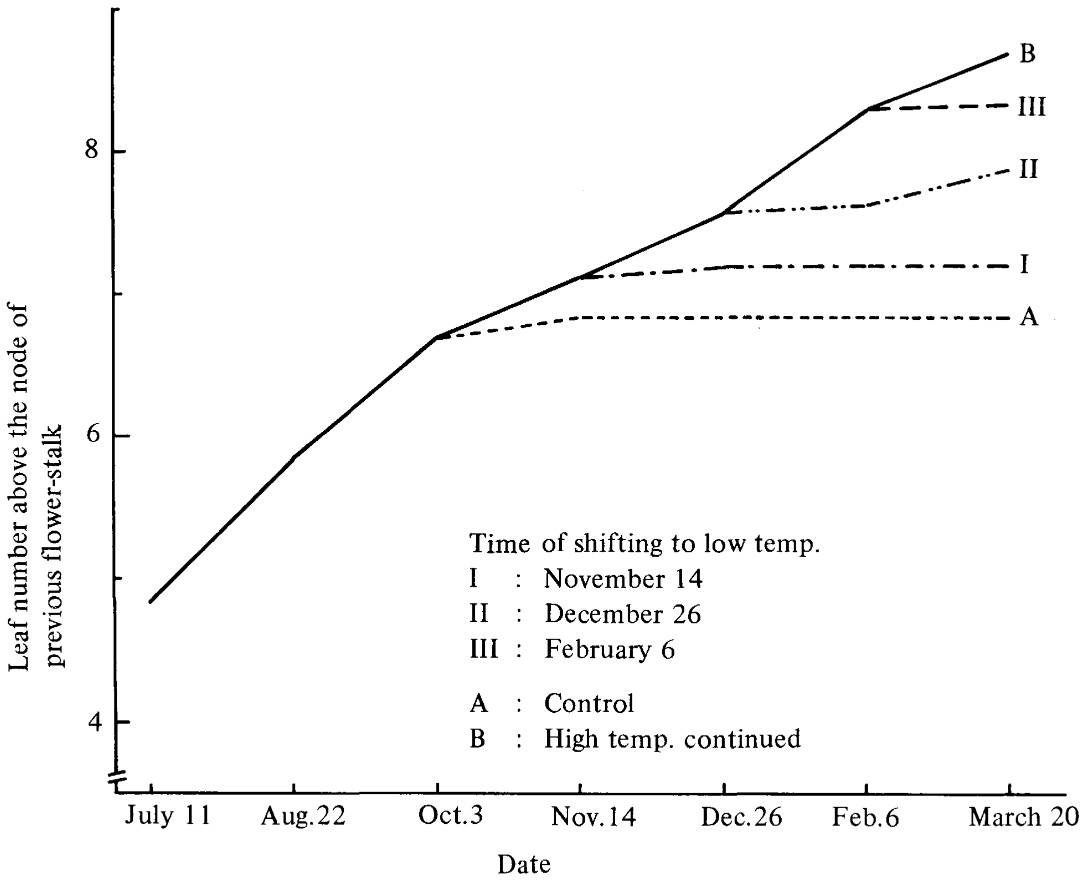


Fig. 4. Comparative increase in the number of leaves among the plants subjected to natural low temperatures after different periods of high temperatures above 28° C.

Table 4. Effect of length of daily period above 28°C on flower-stalk emergence.

| Daily period above 28°C | Percentage of emergence | Mean days from start of treatment to emergence |
|---|---|---|
| 0 hours | 100 % | 34 ± 8 S.E. |
| 6 | 100 | 44 ± 18 |
| 12 | 84 | 48 ± 17 |
| 14 | 46 | 78 ± 9 |
| 19 | 10 | 85 ± – |
| 24 | 0 | – |

Observation was discontinued on 90 days after the start of treatment.

*Stages of flower formation in relation to flower-stalk elongation.*

Flower-stalks at different stages of growth in length were sampled in succession, and flower formation on every node of the stalks was observed. The result is shown in Table 5. Primordia of the 1st and 2nd florets were already initiated on the stalks elongated to about 5cm. When the stalks were about 10cm long, the 1st and 2nd florets began to differentiate petals and, at the same time, the 3rd and 4th florets were in the stage of their own primordium formation or sepal differentiation. On the stalks from 21cm to 30cm, gynostemium (column) was observed in the 1st-4th florets, and the 5-6th florets were forming sepals and petals. When the stalks reached a length of 41-50 cm, the 1st-4th florets developed into the pollen formation stage, and the 7-8th florets attained from the petal formation stage to the anther formation stage.

With the object of determining the effect of high temperature treatment started from the different stages of the stalk elongation, 12 plants in the greenhouse were shifted to minimum 28°C at each time when flower stalks reached a length of 5, 10, 21-30, and 41-50cm (Table 6). The high temperature from the 5cm stage caused the abortion of florets or the stunted growth of the flower stalks. After the stalks elongated more than 10cm, every stalk normally developed into flower even at the high temperature. In that, the earlier start of the high temperature treatment resulted in earlier flowering. However, the shorter stalks and the fewer florets were brought about.

Table 5. Developmental stages of florets in relation to flower-stalk elongation.

| Length of flower-stalk (cm) | Order of florets on flower-stalk | Developmental stages of florets* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII |
| 1 - 5 | 1,2 | | 8 | 1 | 1 | | | |
| | 3,4 | 5 | 5 | | | | | |
| | 5,6 | 10 | | | | | | |
| 6 - 10 | 1,2 | | 1 | 1 | 6 | 2 | | |
| | 3,4 | 1 | 5 | 3 | 1 | | | |
| | 5,6 | 8 | 2 | | | | | |
| 11 - 20 | 1,2 | | 1 | 1 | 2 | 6 | | |
| | 3,4 | | 4 | 1 | 5 | | | |
| | 5,6 | 7 | 2 | 1 | | | | |
| 21 - 30 | 1,2 | | | | 2 | 6 | 2 | |
| | 3,4 | | | | 2 | 7 | 1 | |
| | 5,6 | | 3 | 4 | 2 | 1 | | |
| | 7,8 | 6 | 3 | 1 | | | | |
| 31 - 40 | 1,2 | | | | | 1 | 1 | 8 |
| | 3,4 | | | | | 1 | 3 | 6 |
| | 5,6 | | | | 1 | 2 | 6 | 1 |
| | 7,8 | | | 2 | 2 | 5 | 1 | |
| 41 - 50 | 1,2 | | | | | | 1 | 9 |
| | 3,4 | | | | | | 3 | 7 |
| | 5,6 | | | | | 4 | 5 | 1 |
| | 7,8 | | | | 3 | 5 | 2 | |

Five flower-stalks of each length were used for the observation.
*: Showing the respective stage of floret development as follows,
I : Primordia of floret not appeared,
II : Primordia of floret initiated,
III : Sepals differentiated,
IV : Petals differentiated,
V : Gynostemium differentiated,
VI : Anthers differentiated,
VII : Pollen formed.

Table 6. Effect of high temperatures above 28°C during elongation of flower-stalks on flowering.

| Length of flower-stalk at start of high temp. | Percentage of aborted stalks | Mean days from flower-stalk emergence to flowering | Length of flowered stalk | Number of florets per stalk |
|---|---|---|---|---|
| Control* | 0.0% | 103 ± 8 S.E. | 61.8cm | 7.5 |
| < 5 cm | 15.4 | 59 ± 5 | 36.0 | 4.1 |
| 10 cm | 0.0 | 59 ± 5 | 47.2 | 6.8 |
| 21 - 30 cm | 0.0 | 65 ± 5 | 48.4 | 5.7 |
| 41 - 50 cm | 0.0 | 73 ± 5 | 59.1 | 6.8 |

*: Plants were grown continually in the greenhouse.

## Discussion

In order to cause the transition from a vegetative to a reproductive phase, the plants studied require relatively low temperatures below 25°C, after a certain period of growth, during which a succession of new leaves are formed at the shoot apex. At the continuous high temperature above 28°C, their vegetative development is active and the formation of leaves continues, but the formation of flower-stalks never occurs. Commonly, a continuous temperature of 15°C weakens growth. Even when day temperatures rise above 28°C, flower-stalks are developed in most of the plants, if the plants are exposed to a cool temperature more than 12 hours daily. In consequence of such temperature responses, flower-stalks do not start to develop until the advent of cool days of autumn in our district, where the summer temperature rises above the critical level. If the plants having flower-stalks of more than 10cm in length are transferred afterwards to above 28°C, flowering occurs, and even more rapidly. This shows that the high temperature is not harmful to the further development of flower-stalks, but rather it accelerates their growth.

Similar response to temperature was also observed in *Phalaenopsis schilleriana* grown in Indonesia by De Vries (1953)[5]. At Bogor (maximum temperature 29°-34°C; minimum temperature 24°-25° C), adult plants develop a stalk, which remains vegetative and develops an adventive plant. All of the plants develop stalks and are induced to flower when kept in Tjikopo (maximum temperature 26°-32°; minimum temperature 18°-20°C). Early and excellent flowering is obtained, if the plants grown at Bogor are moved to Tjikopo for 2 or 3 weeks and brought back to Bogor after the induction period.

It would seem likely that *Phalaenopsis* can belong to the CAM group. Sudo and Tsutsui (1978)[6] reported that the uptake of $CO_2$ in *Phalaenopsis amabilis,* which was increasing steadily during night, began to decrease in the early morning, and the night temperature at 20°C, which causes the floral induction, raised the $CO_2$ uptake much more than at 15°C or 30°C. Since the optimum temperature for the $CO_2$ uptake is analogous to that for the induction of reproductive growth, it is assumed that the plants kept at about 20°C can produce many quantities of carbohydrate, which appears to favor the reproductive growth.

Recently, after the results of our studies, flower promotion for autumn cropping has been attained commercially by keeping plants in an air-conditioning greenhouse (day temperature 24°C; night temperature 18°C) or transferring them to a place of high altitude from the middle of June onwards. After the cropping is finished, in that case, the plants must be replaced to high temperatures, so as to produce much foliage-leaves until the next year's application. Flower-stalks are mostly positioned on the 3rd and 4th nodes below the uppermost unfolded leaf. This means that plants at an induction time should have a goodly number of leaves extended after the flowering of the previous season.

Our studies were throughly conducted in the condition of natural day length, and no photoperiodic response was determined. We assume that the promotive effect of short day condition, which have been pointed out by some workers[1-3], may be additive to the low temperature effect and be revealed distinctly in the case when plant is kept at the critical temperature.

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