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Effect of temperature on the flowering biology and fertilization of mangoes (*Mangifera indica* L.)

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Abstract

'Haden', 'Irwin', 'Keitt' and 'Local' mangoes were treated with three temperature regimes to investigate the influence of temperatures on the flowering biology and fertilization. Compared to 25°C/19°C, warm temperature (31°C/25°C), hastened growth rates of panicles and flowers, shortened flowering duration and life span of individual flower. It also decreased numbers of hermaphrodite and male flowers. But warm temperature increased the rates and percentages of anther dehiscence and fertilization. In contrast, cool temperature (19°C/13°C), lingered growth rates of panicles and flowers, extended flowering duration and life span of flowers. It also increased numbers of hermaphrodite and male flowers. Sex ratio was statistically not different among the plants under the three temperature regimes. The highest number of hermaphrodite and male flowers occurred at the first one third and the half time, respectively, of the entire flowering period.

Keywords: Mango, flowering, temperature, sex ratio, fertilization

Introduction

Mangoes are grown widely in tropical and subtropical areas around the world. Biennial bearing (Mukherjee, 1953), unfruitfulness (Young, 1942; Shü, 1983) and low percentage of successful crosses in hybridization (Mukherjee, *et al.*, 1968; Singh, *et al.*, 1977; Singh, *et al.*, 1980), have long been a problem for mango production and breeding. In order to overcome the low fruit set problem in both the fields of production and breeding, more knowledge on floral biology and reproductive physiology of the mango is important. Torre (1931), Sturrock (1969), Shü (1982) and Pimentel *et al.* (1984) have made some fundamental descriptions of the floral biology (*e.g.* flower development, sex distribution, sex ratio, percentage of hermaphrodite flowers and natural pollination of mango under field conditions). Spencer and Kennard (1955) and Pimentel *et al.* (1984) reported the stigma receptivity of the mango. Spencer and Kennard (1955), Shen and Huang (1979), Tseng and Chang (1983) and Young (1955) showed temperature effect on pollen germination. The reports of Chen (1979), Ou (1983) and Pimentel *et al.* (1984) depicted the diverse factors affecting the fruit set of mangoes. Evidence concerning the effects of temperature on the flowering biology and fertilization of mangoes, however, is still limited. Therefore, we initiated a study to expand the existing knowledge and to serve as a basic reference for field management and academic studies in the future.

Materials and Methods

Plant materials: Four cultivars, 'Haden', 'Irwin', 'Keitt' and 'Local', economically important to Taiwan were used in this experiment. Forty uniform three-year-old trees, 25 'Haden' and 5 each for the other three cultivars, of the four cultivars were grown in 35 cm pots and put in the field. Only 'Haden' was used to investigate flowering duration, life span of a single flower, number of hermaphrodite, male and total flowers and percentage of fertilization.

Growth conditions: As soon as the flower buds on the trees initiated, the trees were transferred into three growth rooms with day/night temperature regimes at 31°C/25°C, 25°C/19°C and 19°C/13°C with ±1°C accuracy. The light source was provided with twenty 40W (10 Toshiba FL-40SRB and 10 FL-40SD) fluorescent tubes plus six 60W incandescent lamps with a light intensity of about 50 $\mu^{-2}m^{-2}$ at plant top level. The illuminating time was controlled to 12 hours (from 08:00 to 20:00). The day/night relative humidity under the above-mentioned condition was 72%/80%, 78%/88% and 82%/90% for 31°C/25°C, 25°C/19°C and 19°C/13°C, respectively. The average maximum and minimum temperatures during the flowering period of mangoes in the major production areas in Taiwan have been 27°C and 12.8°C, respectively (Central Weather Bureau, 1998). However, temperatures higher than 27°C during the day and lower than 12.8°C during the night happened occasionally. The three temperature regimes, 31°C/25°C, 25°C/19°C and 19°C/13°C, in the present study was chosen on the basis of the above-mentioned climate condition in Taiwan.

Flowering biology: Mango trees in the three growth rooms were recorded for flowering duration, growth rate of panicles, growth rate and life span of a single flower, number of hermaphrodite, male and total flowers, rate and percentage of anther dehiscence.

Percentage of fertilization: Mango trees normally flower continuously with the peak at about sunrise (six a.m.; Torres, 1931; Spencer and Kennard, 1956). From the previous observation, dehiscence of anthers of both male and hermaphrodite flowers occurs a few hours after flowering. To ensure that there were no suspended pollens in the growth rooms, hermaphrodite flowers of these trees were emasculated at or before anthesis and were marked with labels. The male flowers were pinched off several times a day. A sufficient number of the flowers of the four cultivars were picked from the orchard in the early morning. These flowers were placed separately, with each variety on two layers of filter papers in one petri dish. Two layers of silica gel were placed under the filter papers. The anthers of the detached flowers were forced to dehiscent under incandescent lamps at a distance of about 10 cm. The dehiscent anthers were then used directly as pollen sources for hand pollination.

Flowers were artificially pollinated at anthesis. To avoid nutrient competition, only about 10 flowers were kept on one tree and only 2 panicles were kept on one tree. The pollinated flowers were harvested 24 hours after pollination. After harvesting, the flowers were fixed in FAA and the same procedures as described in previous papers were undertaken (Shu, 1982). After softening with NaOH and staining with aniline blue (Kho and Baer, 1968), the flowers were dissected into two parts: ovules and styles and were observed under a fluorescent microscope. Flowers with pollen tube in the ovule were counted and expressed as percentage of fertilization.

Rate and percentage of anther dehiscence: Two hundred and twenty five flowers each for the four cultivars were picked from the field in the early morning. Three replicates of three treatments for each variety were initiated. Twenty-five flowers for one variety at one temperature were placed on two layers of filter papers in one petridish with silica gel placed under the filter papers. The petridishes were placed in three ovens maintained separately at. 31, 25 and 19°C. The rates and percentages of anther dehiscence were recorded at intervals of 15 to 30 minutes for a period of 2, 3 and 4 hours for the 31°C, 25°C and 19°C treatments, respectively.

Results

The biology of mango flowers under the three temperature regimes is shown in Table 1. Significant difference was found in flowering duration of 'Haden' under the three temperature regimes. The flowering period under moderate temperature of 25°C/19°C was 23 days. Warm temperature, *i.e.* 31°C/25°C, shortened the duration of flowering to only 12 days. While cool temperature, *i.e.* 19°C/13°C, extended the duration of flowering to 36 days. The life spans of a single flower for 31°C/25°C, 25°C/19°C and 19°C/13°C were 5 days, 8 days and 17 days, respectively (Table 1).

There were totally 775 flowers, with 132 hermaphrodite, 643 male and a sex ratio of 0.21 in the 31°C/25°C treatment. More flowers were recorded in the 25°C/19°C treatment, with hermaphrodite 178, male 774, total 952 flowers and a sex ratio of 0.23. However, neither the numbers of hermaphrodite, male and total flowers nor the sex ratios of the above two temperature regimes was statistically different (Table 1). Low temperature treatment, 19°C/13°C, had a total number of 2,969 flowers, with hermaphrodite 466 and male 2,503 flowers and a sex ratio of 0.17. The flower numbers of the 19°C/13°C treatment were statistically higher than the 31°C/25°C and 25°C/19°C treatments.

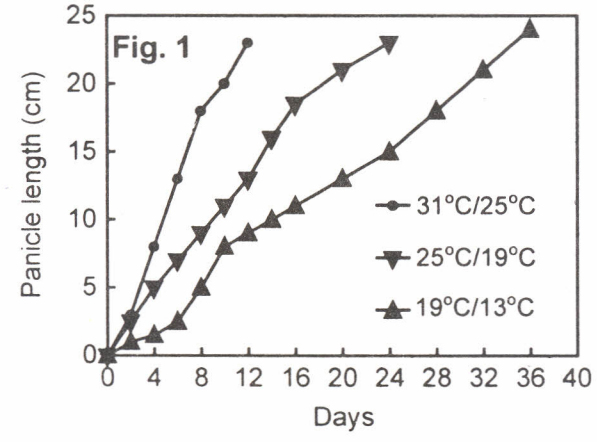
Table 1. Flowering biology and fertilization percentage of 'Haden' mango trees grown under three temperature regimes

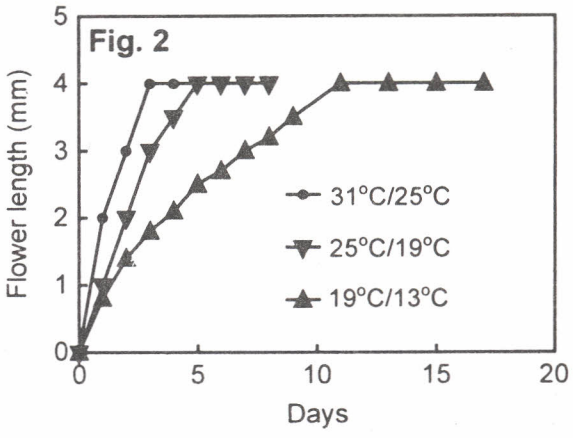
Reproductive behaviour	Temperature (day/night)		
	31°C/ 25°C	25°C /19°C	19°C/13°C
Flowering duration (day)[z]	12 c[y]	23 b	36 a
Life span of a single flower (day)	5 c	8 b	17 a
Number of flowers			
Total	775 b	952 b	2969 a
Hermaphrodite	132 b	178 b	466 a
Male	643 b	774 b	2503 a
Hermaphrodite flowers(%)	0.17 a	0.19 a	0.16 a
Sex ratio	0.21 a	0.23 a	0.17 a
Fertilization(%)[x]	24.8 a (100)[u]	17.6 b (120)	3.8 c (80)
Number of flower fertilized[t]	32.7 a	31.3 a	17.7 b

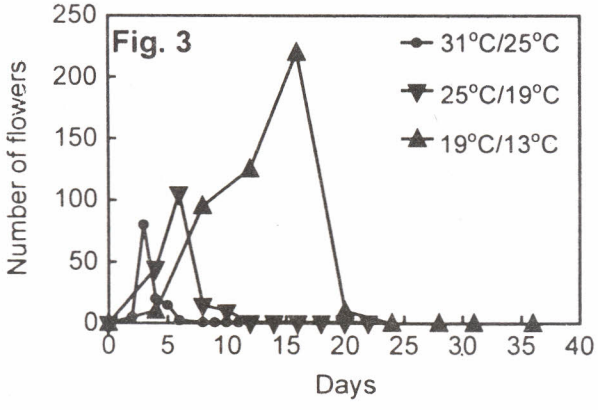
[z]from visualization of flower bud to fading.
[y]mean separation in lines by Duncan's multiple range test, $p < 0.05$.
[x]penetration of pollen tubes into ovary 24 hours after hand pollination.
[u]the number in parenthesis indicate flowers observed.
[t]percentage of fertilization multiply number of hermaphrodite flower.

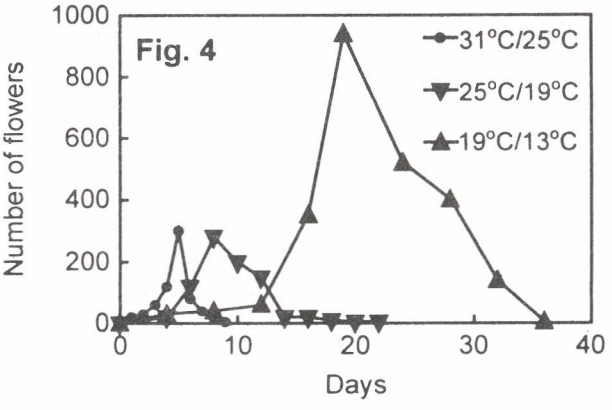
It took only 12 days for the panicles to grow to the length of 23 cm under the 31°C/25°C treatment. While it took 24 and 35 days for the panicles to reach the same length under 25°C/19°C and 19°C/13°C temperature regimes, respectively (Figure 1). Similar to the panicles, the growth of a single flower, expressed as longitudinal length, is faster in the warm temperature treatment and slower in the cool temperature treatment (Figure 2). The time for a single flower to reach its maximum length of 4 cm was 3, 5 and 11 days for 31°C/25°C, 25°C/19°C and 19°C/13°C, respectively.

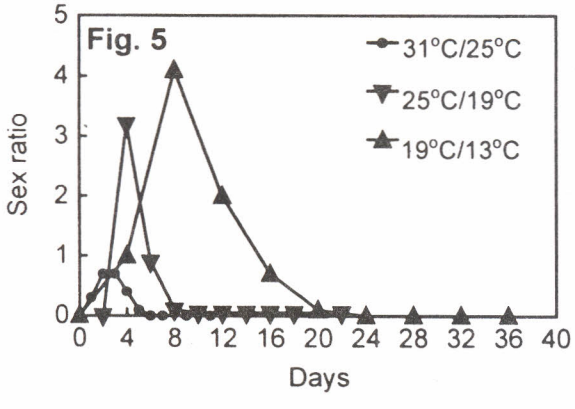
Figures 3, 4 and 5 show the distribution patterns of flowers (hermaphrodite and male) and sex ratio of the mango panicles against development days under the three different temperature regimes. The distribution patterns of hermaphrodite flowers under the three temperature regimes were quite similar. There were few hermaphrodite flowers at the very beginning of the flowering period on a panicle.

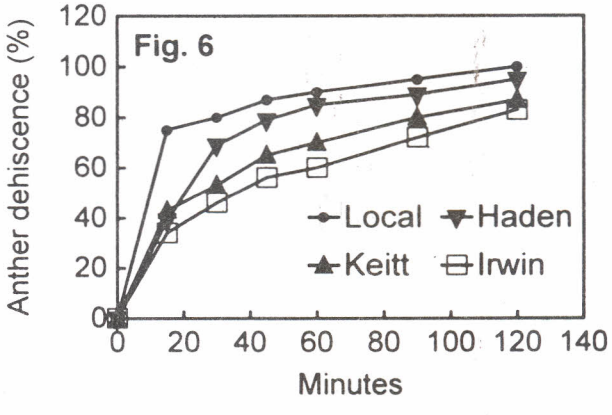


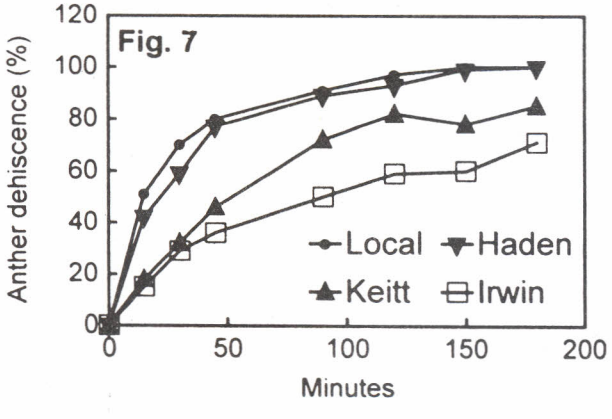


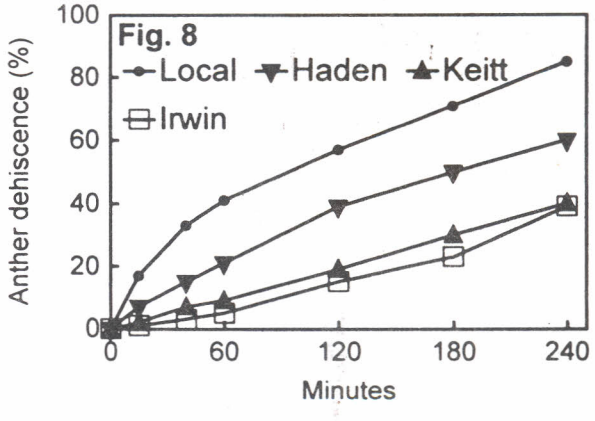












Growth of 'Haden' panicles (Fig. 1) and flowers (Fig. 2) under three temperature regimes. Number of hermaphrodite (Fig.3), male (Fig. 4) flowers and sex ratio (hermaphrodite/male) (Fig. 5) on 'Haden' panicles under three temperature regimes. Anther dehiscence (%) of male flowers of four mango varieties under three temperature regimes *viz.*, 31°C (Fig. 6), 25°C (Fig. 7) and 19°C (Fig. 6). Data presented in Figs. 1-5 are based on the means of three panicles.

However, more and more hermaphrodite flowers appeared during the later stages of flowering. The highest number of hermaphrodite flowers were found on the 3rd, 6th and 16th days, which corresponded to one third of the entire flowering periods, for the 31°C/25°C, 25°C/19°C and 19°C/13°C treatments, respectively (Table 1 and Figure 3). The distribution patterns of male flowers under three temperature regimes was slightly different from the hermaphrodite flowers. There were less male flowers than the hermaphrodite flowers at the early stage of the flowering period in a mango panicle. However, the highest numbers of male flowers were found on the 5th, 8th and 20th days, which was about a half of the entire flowering periods, for the three temperature treatments, respectively (Table 1 and Figure 4). The distribution patterns of the proportions of hermaphrodite to male flowers under the three temperature regimes were different from that of the hermaphrodite and male flowers. The highest numbers of hermaphrodite/male ratio were found early on the 2.5th, 4th and 8th days, which approximately corresponded to one fifth of the entire flowering periods, for the three temperature treatments, respectively (Table 1 and Figure 5).

Figures 6, 7 and 8 depict the rates and percentages of anther dehiscence of four mango cultivars under the three temperature regimes. In general, the rate and percentage of anther dehiscence were highest in 'Local', followed by 'Haden', 'Keitt' and 'Irwin'. The percentages of anther dehiscence was 100% for 'Local', 95% for 'Haden', 85% for 'Keitt' and 80% for 'Irwin' in 2 hours under 31°C/25°C (Figure 6). While the percentages of anther dehiscence under 25°C/19°C were 100% for 'Local' and 'Haden', 80% for 'Keitt' and 70% for 'Irwin' in 3 hours (Figure 7). Anther dehiscence rates under 19°C/13°C were 85% for 'Local', 60% for 'Haden' and 40% for 'Keitt' and 'Irwin' in 4 hours (Figure 8).

Discussion

The flowering biology and fertilization of mangoes is influenced by many factors, such as environmental factors (Singh, 1966; Singh and Sharma, 1972; Shen and Huang, 1979; Tseng and Chang, 1983; Issarakraisila, *et al.*, 1992), variety (Popenoe, 1927; Pimental, *et al.*, 1984), blooming time (Singh, 1964; Singh, 1966), the physiological condition of tree (Singh, 1964; Wolstenholme and Mullins, 1982) and cultural practices (Shen and Huang, 1979; Tseng and Chang, 1983; Khader *et al.*, 1988). Among all the factors, temperature seems to be a quite decisive single factor on the reproductive behaviour of mangoes. A most recent review paper on the reproductive physiology of mangoes has detailed discussion on this topic (Davenport and Núñnez-Elisea, 1997). In the present study, temperature is found to be influential on growth rate of panicles, flowering duration, growth rate and life span of a single flower, numbers of hermaphrodite and male flowers, rates and percentages of anther dehiscence and fertilization percentage.

Sex ratio, sometimes being correlated to yield, is influenced by many factors (Davenport and Núñnez-Elisea, 1997). The sex ratios found under 31°C/25°C, 25°C/19°C and 19°C/13°C treatments in the present study were 0.21, 0.23 and 0.17, respectively (Table 1). Singh *et al.* (1966) and Singh and Sharma (1972) reported that cool temperature contributed to a reduction of hermaphrodite flowers, while warm temperature increased the percentage of hermaphrodite flowers in mangoes. Tseng and Chang (1983) indicated sex ratio of mango flowers decreased under 15°C condition. However, in the present study, the sex ratios under the three temperature regimes were statistically not different. The result is similar to the report of Issarakraisila, *et al.* (1992) that sex ratio was not affected by seasonal effects.

The percentage of fertilization of mango flowers treated under the three temperatures were 24.8, 17.6 and 3.8 for 31°C/25°C, 25°C/19°C and 19°C/13°C, respectively. Using the numbers of percentage of fertilization to multiply the numbers of hermaphrodite flowers on a panicle in Table 1, one can obtain 32.7, 31.3 and 17.7 of fertilized flowers on a panicle under 31°C/25°C, 25°C/19°C and 19°C/13°C, respectively. The numbers are quite high in terms of fruit setting or yield. However, as there are many factors influencing the growth and development of mango fruits (Davenport and Núñnez-Elisea, 1997), the high percentages of fertilization in the present study may not correspond to the final yield. According to the field observation in the experimental orchard, mangoes bear none to 5 fruits on a panicle. The observed numbers of fertilized fruits under the three temperature treatments in this study were at least 3 times to 6 times greater than that of the field observation. The possible reasons for this discrepancy could be genetic factor, competition among fruits, pest damage and others.

In summary, warm temperature shortened growth period of panicles and flowers, flowering duration and life span of the individual flower. It also decreased numbers of hermaphrodite and male flowers. But warm temperature increased the rates and percentages of anther dehiscence and fertilization. In contrast, cool temperature lengthened growth rate of panicles and single flowers, flowering duration and life span of a single flower. It also increased numbers of hermaphrodite and male flowers. However, cool temperature decreased the rates and percentages of anther dehiscence and fertilization. Sex ratio was statistically not different among the three temperature treatments. The highest population of hermaphrodite flowers occurred in the first one third period, while the male flowers appeared at the half time or later during the entire flowering period. Although there were more hermaphrodite flowers on the trees under the cool temperature than the 31°C/25°C and 25°C/19°C treatments, the fertilization percentage of the flowers was less in the 19°C/13°C treatment than the other two temperatures. The fact indicates that the mango, being a tropical fruit tree, is quite susceptible to cool temperatures.

The flowering season begins from December to March in Taiwan. The maximum and minimum temperatures during this period have been 27°C in March and 12.8°C in January, respectively, with occasional high temperature of more than 30°C and low temperature of lower than 10°C (Central Weather Bureau, 1997). According to the present study, warm temperatures did not affect pollination of mango flowers. However, cool temperature did reduced the percentage of successful pollination. Low temperatures also impair formations of hermaphrodite flowers (Yang, 1988) and pollens (Issarakraisila and Considine, 1994) and pollen germination (Shen and Huang, 1979; Tseng and Chang, 1983). It is thus suggested that special care or cultural practices, such as a temporary shelter to prevent low temperature damage or terminal panicle removing to induce axillary panicles (Shü, 1993), should be made to overcome the unfavourable temperatures.

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