Influence of gibberellin treatment on flowering and fruiting patterns in mango

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Summary. The potential for using gibberellins (GAs) to modify time of flowering and fruit maturity in mango was investigated. Winter spraying of mango trees grown in the coastal subtropics of Queensland (latitude 27°S) with gibberellin A_3 (GA_3) or GA_4 solutions caused a delay in flowering time of up to 4 weeks, depending on cultivar (Kensington Pride, Glenn, Early Gold) and concentration (50–200 mg/L). There was also a general reduction in number of panicles, particularly at higher GA concentrations. Similar experiments with GA_3 on cvv. Kensington Pride and Keitt in tropical North Queensland (latitude 17°S) did not show any effect either on time or extent of flowering.

Fruit yield was highly correlated with the proportion of terminal buds that flowered. Consequently, GA treatments caused significant yield reductions in cv. Kensington Pride, especially at 200 mg/L where only 23% of terminal buds flowered. Fruit size was inversely related to yield, and yield was influenced by tree size. Delayed flowering also resulted in later fruit maturation, by up to 2 weeks. With Early Gold, late-flowering panicles retained 3 times more fruit than those which flowered early, which was possibly related to differences in night temperatures before or at anthesis.

Delays in flowering time, which lead to somewhat lesser delays in fruit maturation, can be achieved with suitable GA treatments, but concentration and timing of application are critical if flowering and, hence, yields are not to be reduced. The potential use of this treatment in commercial mango orchards is discussed in relation to extending the fruit production season.

Introduction

Mango (*Mangifera indica* L.) is a major fruit crop, with most production occurring in India, and lesser centres throughout tropical and subtropical regions. Species diversity is reflected in the enormous number of named varieties. In most mango-growing countries, the industry is based on a restricted number of cultivars, giving a spread of cropping times and range of fruit types. However, in Australia, a single cultivar, Kensington Pride, accounts for over 90% of production. The result, with production centred in 2 areas of North Queensland, is a concentrated harvest time with potential gluts in years of good yield. In the longer term, growing a wider range of cultivars may minimise the problem, but a short-term solution is also needed. There have been limited plantings of early season cultivars in subtropical Australia, but these tend to flower during winter when low temperatures are not conducive to successful fruit set. Delaying flowering in these cultivars may result in better yields. In the tropics, most plantings other than Kensington Pride are late cultivars.

Flowering in mango, as with several other tropical tree fruit species, is influenced by temperature (Singh 1960; Chacko 1986). Induction requires several weeks at low temperatures, typically 15–19°C day, 10–13°C night (Shu and Sheen 1987; Whiley *et al.* 1989; Núñez-Elisea and Davenport 1994, 1995; Schaffer *et al.* 1994). At tropical latitudes where such low temperatures are never experienced, water stress may sometimes be an effective alternative stimulus for floral induction (Chacko 1986; Rameshwar 1989). Erratic flowering is still frequently observed in the dry tropics (Schaffer *et al.* 1994) and in years where the dry season has been interrupted by unseasonal rainfall, subsequent flowering in the Northern Territory has often been poor, resulting in low yields (E. K. Chacko pers. comm.).

Gibberellin A_3 (GA_3) applied to mango trees has a dramatic inhibitory effect on floral development. High concentrations (10^{-4}–10^{-1} mol/L in lanolin) applied directly to apical buds of cv. Dashehari caused 15–95% inhibition of flowering depending on concentration, and also resulted in a 2- to 4-week delay in flowering time at the lower doses (Kachru *et al.* 1971). Tomer (1984) sprayed whole trees with 25–200 mg GA_3/L and found variable degrees of flower inhibition depending largely on cultivar. No information on flowering time in relation

to treatment was given. A similar experiment on cv. Taimour resulted in no inhibition of flowering but did show a 2- to 4-week delay in flowering (Shawky *et al.* 1978). Inhibition of flowering in axillary buds of deblossomed shoots was noted by Núñez-Elisea and Davenport (1991). Application of inhibitors of gibberellin (GA) biosynthesis such as paclobutrazol tends to have the opposite effect: increasing the proportion of terminals initiating flowers and causing earlier anthesis (Kulkarni 1988; Winston 1992), as well as reducing the period of juvenility (Salomon and Reuveni 1994).

Gibberellin treatment of other tree species also inhibits or delays flowering (Brian *et al.* 1959). In apple, GA_3 applied in the summer before floral initiation is strongly inhibitory (Guttridge 1962; Looney *et al.* 1985). In apricot, preinduction treatment reduced the number of flowers by 40% (Southwick *et al.* 1995*b*). In sweet orange, flower number was reduced dramatically by GA_3, and there was a much greater proportion of leafy inflorescences (Moss 1970), similar to increases in panicle leafiness found in mango by Kachru *et al.* (1971). Application of GAs after floral initiation has a different effect—promoting extension of the inflorescence axis (Kachru *et al.* 1971; Rajput and Singh 1983), and sometimes enhancing fruit set (Rajput and Singh 1983).

Gibberellin treatments have not been assessed in mango orchards in Australia. This paper describes the effects of GA treatments on flowering, harvest time and yield in Kensington Pride and other cultivars at different locations in Queensland.

Materials and methods

Plant material

Mango trees used were located in commercial orchards at Eumundi and Palmwoods, south-eastern Queensland (27°S), and at the Queensland Department of Primary Industries research station at Southedge, North Queensland (17°S). Cultivars used were Glenn and Early Gold, grafted onto Kensington Pride seedling rootstocks (Palmwoods 1989–90), Kensington Pride seedling trees (Eumundi 1990–91), and Keitt and Kensington Pride grafted onto Kensington Pride seedling rootstocks (Southedge 1990–91). All trees were 3–5 years old and about 1.5–2.5 m high.

Experimental treatments

Experiment 1 (Palmwoods). Ten different GA treatments were used on cv. Early Gold and 7 on cv. Glenn, with 5 trees per treatment. Treatments consisted of spraying the whole tree with a solution of GA_3 (Grocel formulation, ICI) or GA_4 (Abbott Chemical Co.) at concentrations of 0, 50, 100 or 200 mg/L in deionised water to which was added Tween-20 (0.1% v/v). Gibberellin A_4 was used only on cv. Early Gold. First treatments were given on 31 May 1989, and repeat sprays of GA_3 only were applied to 3 sets of trees 14 days later. Trees were sprayed to runoff which required about 500 mL per tree. This was equivalent to 25, 50 and 100 mg GA per tree for the 3 concentrations, and double these amounts for trees sprayed twice.

Experiment 2 (Eumundi) and experiment 3 (Southedge). Four treatments were used: 0, 50, 100 and 200 mg GA_3/L, with 7 trees per treatment at Eumundi and 5 at Southedge. Treatment method was similar to that used at Palmwoods except wetting agents were Agral 600 (0.1% v/v) at Eumundi and Shirwet 100 (0.15% v/v) at Southedge. Treatment dates were 13 May 1990 at Eumundi and 23 May 1990 at Southedge. Spray volumes were 700 mL per tree at Eumundi and 500 mL at Southedge.

Data collection and analysis

Five terminal branches facing each point of the compass (N, E, S, W) were tagged. Floral development was assessed on these 20 tagged terminal buds, starting at the first visible break of dormancy (swelling of terminal buds) and continuing at 7- to 14-day intervals until all flowering had finished. Categories of development were: no development; budbreak, reproductive state not distinguishable; vegetative shoot; and floral shoot, pre-, during or post-anthesis. Before harvest of mature fruit, fruit on tagged shoots were counted, and total fruit per tree were counted and weighed (experiments 2 and 3 only). Minimum trunk circumference between ground and first branch was measured at harvest on all trees at Eumundi, allowing trunk cross-sectional area to be used as an indication of relative tree size.

For each tree and each treatment, the following variables were measured: flowering—percentage of terminal buds that flowered; time of anthesis; duration of anthesis for each tagged panicle; fruiting—final fruit number and weight per tagged panicle; final fruit number and weight per tree; and time of fruit maturity and ripening.

Results

Experiment 1 (Palmwoods)

Flowering. First identifiable panicles were seen in July, about 40 days after first treatments. Almost all the GA treatments had a delaying effect on flowering time of both cvv. Early Gold and Glenn (Fig. 1), up to 22 days with the highest dose (2 x 200 mg GA_3/L). This treatment also caused a reduction in panicle initiation, down to 72% in cv. Early Gold and 51% in cv. Glenn (Fig. 2). All other treatments gave ≥85% and ≥96% flowering, respectively, for the 2 cultivars. No significant differences were found between effects of GA_3 and GA_4. Single sprays of 50 mg/L of GA_3 or GA_4 had a negligible effect on Early Gold flowering. Terminal buds that did not produce

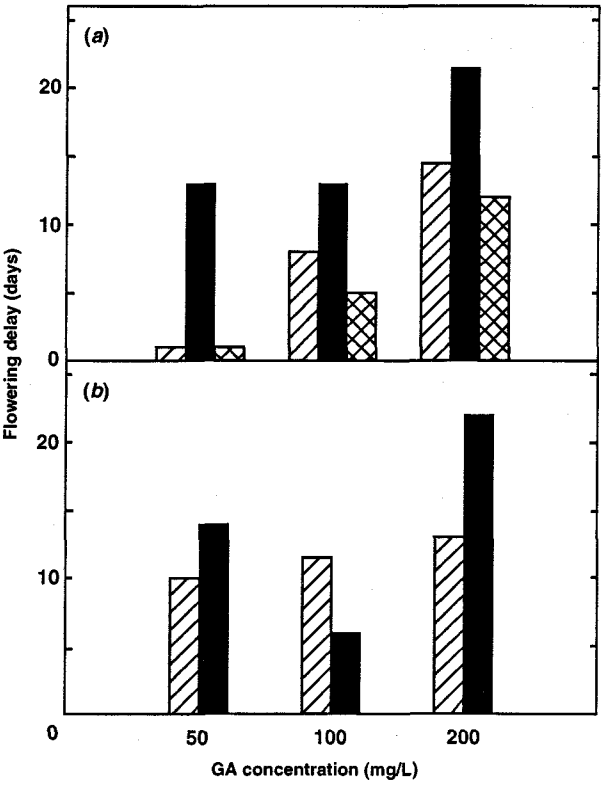

Figure 1. Experiment 1 (Palmwoods). Effect of gibberellin (GA) treatment on flowering time in (*a*) cv. Early Gold and (*b*) cv. Glenn. Numbers are calculated relative to control peak flowering, which was on 25 September for cv. Early Gold and 22 September for cv. Glenn. Treatments were: GA_3 sprayed once (hatched bars), twice (solid bars) or GA_4 sprayed once (cross-hatched bars, cv. Early Gold only).

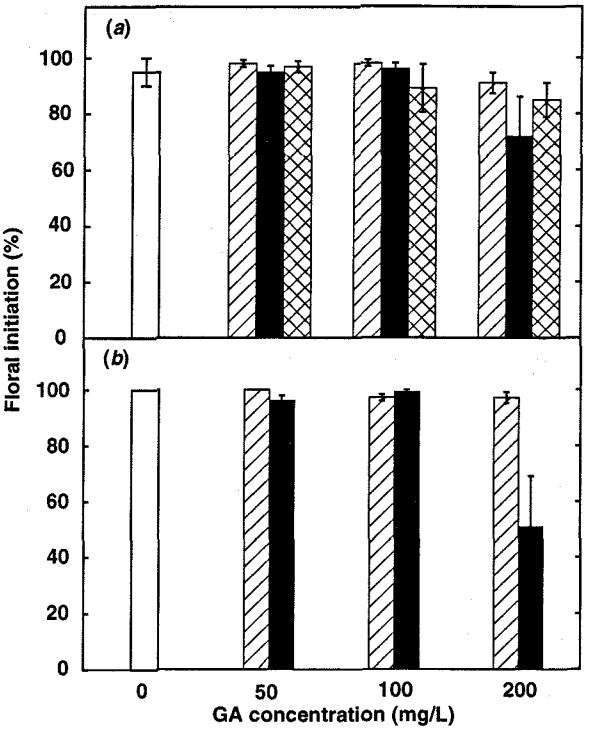

Figure 2. Experiment 1 (Palmwoods). Effect of gibberellin (GA) treatment on percentage of floral initiation in (*a*) cv. Early Gold and (*b*) cv. Glenn. Vertical bars are 95% confidence limits. Treatments were: water (open bars), GA_3 sprayed once (hatched bars), twice (solid bars) or GA_4 sprayed once (cross-hatched bars, cv. Early Gold only).

flowers either stayed dormant (1.2% in Early Gold; 1.9% in Glenn) throughout the experiment or later produced vegetative shoots (7.9% in Early Gold; 6.3% in Glenn, all from 2 x 200 mg/L treatment).

Fruiting. The experimental trees retained very few fruit: only 16 fruit from 640 panicles in cv. Glenn, and 101 from 909 panicles in cv. Early Gold. Analysis of effects of treatment on fruiting patterns was, therefore, impossible with Glenn and difficult with Early Gold. In the latter, fruit were produced from trees of all treatments but no significant effects of treatment on fruit numbers were noted.

Due to poor cropping, all trees were removed by the grower shortly after assessment of final fruit numbers, and hence no data were obtained on time of ripening to compare with time of flowering. Instead, by pooling Early Gold flowering and fruiting data across all treatments, it was possible to test fruiting against time of flowering. These data are expressed as mean fruit per panicle for each reading (Fig. 3), and show 3-fold more fruit per panicle in panicles that flowered last (mean

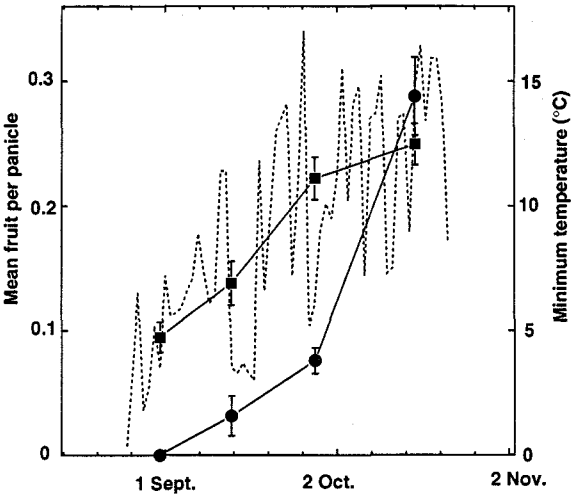

Figure 3. Experiment 1 (Palmwoods). Influence of flowering time on number of fruit set per panicle in cv. Early Gold (●). Night minimum temperatures are also plotted as mean minimum for period centred on flowering reading (■); daily minimum (dotted line). Bars are ± s.e.

Table 1. Experiment 2. Fruit data (mean ± s.e.) from cv. Kensington Pride

Means within each column followed by the same letter are not significantly different at $P = 0.05$

GA_3 concentration (mg/L)	No. of fruit/ tree	No. of fruit/ panicle	Yield (kg/tree)	Mean fruit weight (g)	Maturation date
0	44.0 (± 3.6)a	0.52 (± 0.13)a	19.5 (± 0.8)a	406 (± 13)a	5 Feb. (± 1)a
50	24.3 (± 7.0)b	0.50 (± 0.19)a	10.8 (± 3.6)b	449 (± 24)ab	11 Feb. (± 3)ab
100	21.3 (± 5.0)b	0.39 (± 0.08)a	9.5 (± 2.5)b	458 (± 28)ab	10 Feb. (± 2)a
200	12.9 (± 4.6)b	0.34 (± 0.17)a	6.3 (± 2.3)b	484 (± 33)b	18 Feb. (± 1)bc

peak 16 October) compared with those that flowered early (peaks 31 August–29 September).

Since cool temperatures are thought to be a cause of low rates of fruit set in mango, mean and daily minimum temperatures are included in Figure 3. These show a steady rise in the mean minimum through flowering, from 5 to 12°C. Absolute minimum values for the dates either side of the 4 flowering assessments plotted were 1, 3, 5 and 7°C, respectively.

Experiment 2 (Eumundi)

Flowering. This experiment was conducted on the industry-standard cultivar, Kensington Pride. Again, all GA treatments resulted in changes in the pattern of flowering. The delaying effect of GA treatment on peak flower opening was similar at all concentrations, ranging from 25 to 28 days (Fig. 4*a*). All GA concentrations caused reductions in floral initiation, most severely at high doses, with only 23% of terminal buds bearing panicles after treatment with 200 mg GA_3/L compared with 99% in controls (Fig. 4*b*). Substantial tree to tree variation was observed in the extent of floral initiation, with 5–95%, 20–95% and 0–60% of terminals flowering, respectively, for the 3 GA concentrations. Control trees showed 90–100% flowering.

Fruiting. Fruit production was assessed on tagged shoots and the whole tree. Productivity across all treatments, expressed as yield per unit trunk cross-sectional area, was linearly correlated with extent of panicle production (Fig. 5; $R^2 = 0.867$, $P<0.0005$). Fruit numbers on tagged shoots were also correlated with total fruit number per tree (data not shown; $R^2 = 0.634$,

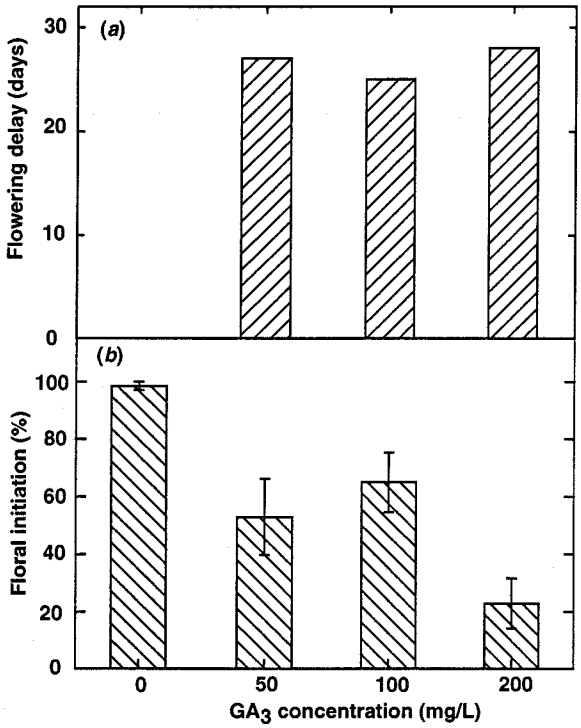

Figure 4. Experiment 2 (Eumundi). Effect of gibberellin A_3 (GA_3) treatment of cv. Kensington Pride on (*a*) flowering delay calculated relative to timing of anthesis in control trees (peak 28 September) and (*b*) floral initiation. Vertical bars are ± s.e.

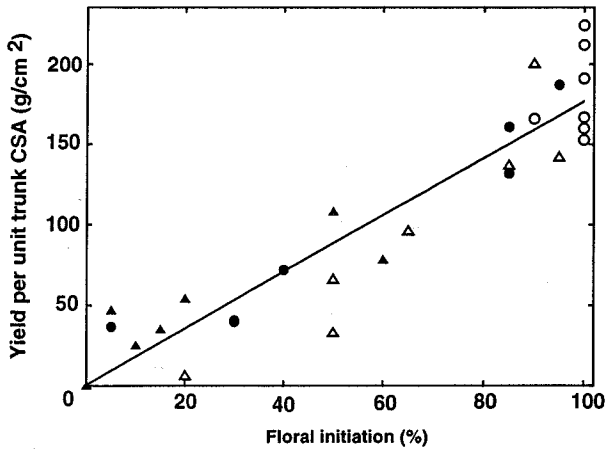

Figure 5. Experiment 2 (Eumundi). Relationship between floral initiation and yield, corrected for trunk cross-sectional area (CSA), in cv. Kensington Pride treated with gibberellin A_3: ○, control; ●, 50 mg/L; △, 100 mg/L; ▲, 200 mg/L. Each data point represents a single tree. Linear regression equation from data across all gibberellin treatments is:

Yield per unit trunk CSA = 1.762 x floral initiation % + 0.687

($R^2 = 0.867$, $P<0.0005$, $n = 28$).

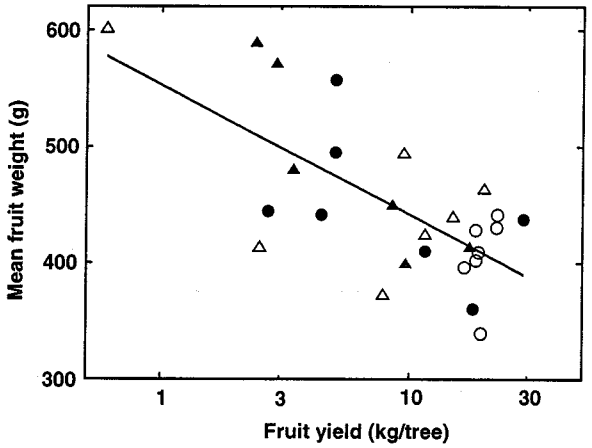

Figure 6. Experiment 2 (Eumundi). Relationship between yield and fruit weight in cv. Kensington Pride treated with gibberellin A_3: ○, control; ●, 50 mg/L; △, 100 mg/L; ▲, 200 mg/L. Each point represents a single tree. Linear regression equation from data across all gibberellin treatments is:

$$\text{Fruit weight} = -111.5 \times \log_{10}\text{yield} + 552.7$$

($R^2 = 0.469$, $P<0.05$, $n = 27$).

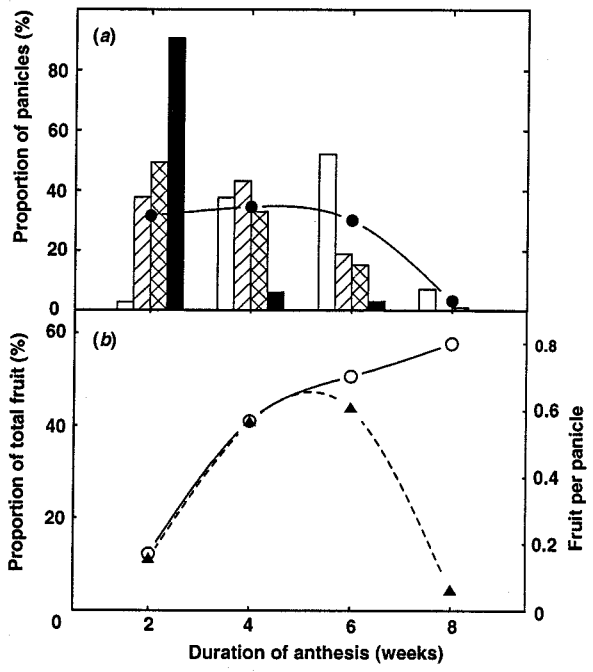

Figure 8. Experiment 2 (Eumundi). (*a*) Proportion of total number of panicles with different durations of anthesis in cv. Kensington Pride. Bars are individual treatments, line is mean for all panicles in the experiment. Gibberellin A_3 treatments were: control (open bars), 50 mg/mL (hatched bars), 100 mg/mL (cross-hatched bars), and 200 mg/mL (solid bars). (*b*) Relationship between duration of anthesis for each panicle and resultant number of fruit per panicle (○) and as a proportion of total fruit (▲).

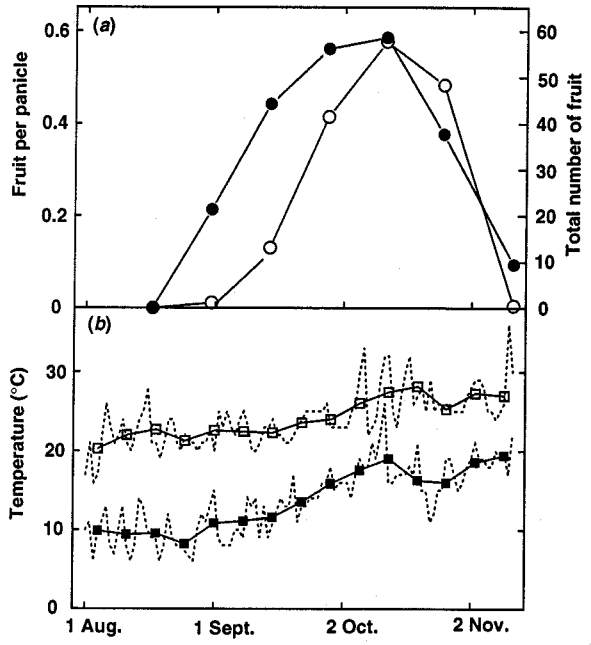

Figure 7. Experiment 2 (Eumundi). (*a*) Influence of date of anthesis on number of fruit borne per panicle (●) and total number of fruit (○) in cv. Kensington Pride. Data are combined from all gibberellin treatments. (*b*) Daily (dotted lines), and weekly (solid lines) maximum and minimum temperatures during anthesis.

$P<0.01$). Heaviest crops (mean 19.5 kg/tree) were borne on control trees, which also flowered most profusely. Similarly, lowest yields (mean 6.3 kg/tree) were obtained from trees treated with 200 mg GA_3/L (Table 1) which flowered least. Increased mean fruit size was correlated with decreased yield (Fig. 6; $R^2 = 0.469$, $P<0.05$). The number of undersized (<240 g) or 'nubbin' fruit was reduced dramatically by all GA treatments, representing only 1–3% of fruit compared with 23% in control trees (data not shown). This was equivalent to 0.5–1.5% of the yield in GA-treated trees and 8.3% in controls.

Time of anthesis for each panicle was compared with fruit per panicle from each assessment date and showed maximum potential to bear fruit in the middle of flowering (Fig. 7*a*). Ambient temperatures generally increased throughout flowering (Fig. 7*b*). Duration of anthesis for individual panicles was also calculated and showed that GA-treated panicles flowered for shorter periods, typically 2–4 weeks, compared with 4–6 weeks for controls (Fig. 8*a*). Panicles flowering for <4 weeks (i.e. 1 reading only) set fewer fruit compared with those that flowered for longer (Fig. 8*b*). Because the number of panicles that flowered for 8 weeks was very low, only a small proportion of the total fruit number resulted from such panicles (Fig. 8*b*). Time of fruit maturation was estimated from harvest dates for each tree: fruit were

harvested when skin colour changes were noted and/or mature fruit had started to abscise. All GA concentrations delayed fruit maturation (Table 1), but the maximum shift was 13 days, somewhat less than the delay in anthesis noted above.

Experiment 3 (Southedge)

Flowering. Compared with effects of GA treatments at Palmwoods and Eumundi, there was no significant influence of GA at any concentration on flowering intensity or flowering time in either of the cultivars examined, Kensington Pride and Keitt. Indeed, the overall flowering of Kensington Pride was very poor with only 28% of trees, and 37% of terminal buds on those trees, producing panicles. These low numbers precluded any further interpretation of the data. In Keitt, better flowering was achieved: 100% of trees and 83% of tagged panicles, but none of the GA concentrations altered the pattern significantly, in either timing, duration or intensity of flowering.

Fruiting. Of the few Kensington Pride trees that did flower, all produced some fruit, but no statistical analysis was possible (data not shown). In Keitt, as at Eumundi, there was a positive correlation (R^2 = 0.450, P<0.05) between percentage floral initiation and yield (Fig. 9). A heavy crop was obtained, averaging 32 kg per tree, but there was no apparent effect of GA treatment. Again, a negative correlation (R^2 = 0.482, P<0.05) was found between yield and fruit size (data not shown). GA treatment did not influence the time of fruit maturation in either cultivar (data not shown).

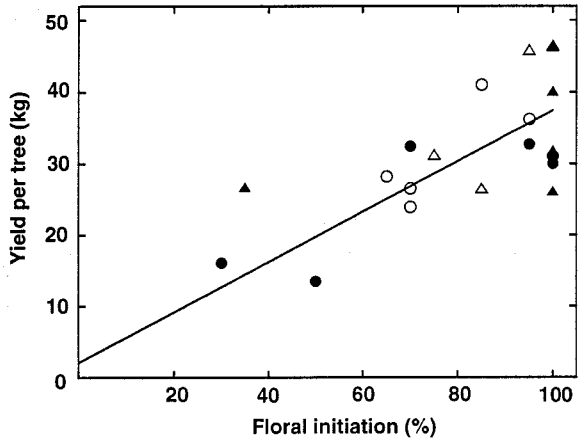

Figure 9. Experiment 3 (Southedge). Influence of flowering intensity on fruit yield per tree in cv. Keitt treated with gibberellin A_3: ○, control; ●, 50 mg/L; △, 100 mg/L; ▲, 200 mg/L. Each point represents a single tree. Linear regression equation from data across all treatments is:

Yield = 0.354 x floral initiation % + 2.08
(R^2 = 0.450, P<0.05, n = 22).

Discussion

All GA treatments were given before visible signs of bud swelling and thus were presumed to be before floral initiation. In separate experiments, scanning electron microscopy revealed no discernible floral structures until after bud swelling had commenced (N. Jarassamrit and C. G. N. Turnbull pers. comm.), consistent with recent findings of Núñez-Elisea *et al.* (1996). Overall, there were significant effects of GA treatment on flowering and fruiting patterns in experiments 1 and 2 at subtropical Palmwoods and Eumundi. In contrast, no effects of GA application were observed in experiment 3 at Southedge in tropical North Queensland. Data from the latter experiment indicate that responses to GA are unpredictable and may depend on condition of the trees at time of treatment and on environmental conditions during floral induction and development.

Change in flowering time and extent of floral initiation

The most consistent effect of GA treatments in experiments 1 and 2 was a delay in the timing of anthesis. Low GA concentrations (50 mg/L) had a negligible effect on cv. Early Gold, but single or double applications at 200 mg/L caused a flowering delay of 12–22 days in experiment 1 and 28 days in experiment 2. Very similar delays of 2–5 weeks have been shown in response to GA applications (Kachru *et al.* 1971; Shawky *et al.* 1978).

Gibberellin treatment sometimes reduced floral initiation. In experiment 1 (Palmwoods), flowering of both cvv. Early Gold and Glenn was reduced only with the highest doses, 2 x 200 mg/L. In contrast, flowering of Kensington Pride at Eumundi (experiment 2) was inhibited significantly by a GA concentration of 50 mg/L. Tomer (1984) demonstrated that concentrations as low as 25 mg/L strongly inhibited some varieties but not others, and showed that repeat sprays caused more inhibition. Other reports indicate that GA treatments usually result in some inhibition of flowering (Kachru *et al.* 1971; Shawky *et al.* 1978).

Kensington Pride flowers reluctantly in comparison with many of the Florida-selected cultivars such as Keitt, Glenn and Early Gold. On average, the inductive conditions experienced are probably nearer to the threshold for Kensington Pride, and therefore any other inhibitory factor, in this case GA application, may push the buds towards the non-floral state, exhibited as either extended bud dormancy, later flowering or vegetative flushing.

Response to different GA types

Unlike the flowering promotion by GA_4 in apple found by Looney *et al.* (1985), no differences were found here between the effects of GA_3 and GA_4 on the flowering pattern of cv. Early Gold at Palmwoods. Both GAs were inhibitory in a concentration-dependent

manner and the response to GA_4 is consistent with findings of Clemens *et al.* (1995). The reasons for species differences are unclear, as in all cases GAs were supplied before the estimated time of floral initiation. The relationship between GA structure and biological activity differs across species and among the various physiological processes influenced by GAs (King *et al.* 1987; Evans *et al.* 1994). It may be worth experimenting with substituted synthetic GAs, such as 2,2,-dimethyl GA_4 or C-16,17 dihydro-GA_5 which have flower-promoting activity in some species (Martin *et al.* 1993; Evans *et al.* 1994), yet are sometimes ineffective or even inhibitory to other GA-promoted processes such as stem elongation.

Flowering time–crop maturation time relationship

In experiment 2, there was a link between time of flowering and time of harvest of mature fruit, indicating a finite period required from pollination to fruit ripening. The delay in peak flowering was calculated to be 25–28 days, and in fruit maturation, 5–13 days. This indicates that relative times of flowering can be used as a reasonable predictor of relative times of harvest. The decrease in maturation delay when compared with flowering delay can probably be attributed to later flowering occurring during higher temperatures, thus accelerating the process of fruit development. A similar conclusion was reached by Shawky *et al.* (1978) who noted negligible delays in maturation date (0–4 days) even when flowering had been delayed by up to 34 days.

Effect of flowering duration and date on fruit number and yield

Measurements of the duration of flowering for each panicle indicated that anthesis in late-flowering panicles generally occurred over a compressed period. Perhaps the increasing mean temperatures, measured throughout flowering in experiments 1 and 2, resulted in reduced flower longevity.

In experiment 1, later flowering panicles of cv. Early Gold bore up to 3 times as many fruit as the earlier panicles. At the start of that experiment, night minimum temperatures were particularly low but increased substantially throughout anthesis (Fig. 3). Flowers developed under low temperatures have a high incidence of abnormalities such as pollen sterility (Issarakraisila and Considine 1994) or malformed stigmas (C. G. N. Turnbull pers. comm.), which may partly account for generally poor yields of early cultivars such as Glenn and Early Gold grown in the subtropics with very cool winters. Reduced activity of insect pollinators in cool weather may also be a contributory factor. However, results from experiment 2 were different: night temperatures over the whole flowering period were not as low (Fig. 7) and control panicles mostly flowered over a longer period than GA-treated ones (Fig. 8). Since panicles that flowered only for a short period tended not to retain many fruit, the trend was that later flowering (mostly GA-treated) panicles did not bear more fruit than those flowering earlier.

Floral initiation, yield, fruit size and tree size relationships

Trees with <100% flowering had lower yields and were unable to compensate by carrying more fruit on the smaller number of panicles (Figs 5 and 9). However, low-yielding trees had somewhat larger fruit (Fig. 6) which indicates that resource availability can influence fruit size, similar to findings in peach (Southwick *et al.* 1995*a*). Overall, the data suggest that long-distance resource redistribution within the cropping mango tree may not be very flexible, and yield is, therefore, sensitive to intensity of flowering. Girdled branches of macadamia carried heavier crops if greater leaf area (i.e. enhanced carbon availability) was present, resulting in dramatic changes in the numbers and size of fruit per inflorescence or branch unit (Trueman and Turnbull 1994). In lychee, starch levels become depleted in trees bearing a crop but increase in non-fruiting girdled branches (Menzel *et al.* 1995).

The high number of nubbin fruit on control trees may relate to resource supply constraints, as these trees consistently had the highest yields (Fig. 5). However, it is more likely that flower and fruit development on early-flowering control panicles was detrimentally affected by low temperatures before, during and after anthesis. Alternatively, a direct effect of GA on fruit set and development cannot be ruled out, although GA did not significantly reduce fruit per panicle in experiment 2 (Table 1). In experiment 3, several GA-treated Keitt trees had 90–100% flowering and some of the heaviest yields (Fig. 9). This indicates that GAs are not necessarily detrimental to fruiting provided flowering is not inhibited.

Failure to flower and lack of gibberellin response in experiment 3

Failure to flower is a characteristic of the cultivar Kensington Pride, with the incidence being greater at more tropical latitudes. The poor flowering of Kensington Pride in experiment 3 (only 28% of trees had any panicles) is a typical example and contrasts with the 100% flowering of Keitt trees in the same trial block.

So few Kensington Pride trees flowered that the data obtained are incomplete and more work is needed. The failure to elicit any response in Keitt is more difficult to explain, especially in light of the success at the subtropical sites. Keitt may be relatively insensitive to GA and, therefore, its flowering was unaffected. Of the 4 cultivars used by Tomer (1984), Keitt was the least responsive to GA_3 treatment, with no significant effect of a single application of 200 mg/L, the highest concentration used in experiment 3. However, Núñez-

Elisea and Davenport (1991) found an inhibitory response in Keitt with GA concentrations as low as 10 mg/L.

Conclusions and commercial implications

It was postulated initially that suitable timing and concentrations of GAs could delay flowering by a few weeks and this would flow through to later harvest dates. Certainly, GA treatment is effective in delaying flowering and hence ripening by up to 2 weeks. GA-treated trees also tended to bear larger fruit and the problem of nubbins was virtually eliminated. Problems lie, however, in the high probability of GA treatment also reducing floral initiation, especially with Kensington Pride, and this has a drastic effect on yield. The yield reduction probably outweighs any advantages from later maturation and larger fruit. It therefore seems unlikely that preinduction GA treatment can be developed into a commercially useful technique. Instead, GA may be suitable for preventing flowering and cropping in nursery stock and thus improving early tree growth, as reported by Sigler *et al.* (1981). Leaving GA treatments aside, it is clear from this work that good floral induction is an important prerequisite for maximum yields in mango.

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