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The Relationship between Vegetative and Reproductive Development in the Mango in Northern Australia

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Abstract

Vegetative and reproductive growth was recorded on mature mango trees (cultivar Kensington) over two years in northern Australia. There were four vegetative growth flushes during each year, but not all shoots grew during each flush. Observations on the flowering of shoots of known age showed that the older shoots produced most inflorescences. Microscopic examination of terminal buds showed that floral initiation occurred within a month of the commencement of the flowering flush under these tropical conditions. The main vegetative growth flushes occurred prior to flowering between March and May, and during flowering and early fruit development in July and August.

Introduction

Most cultivars of mango exhibit some degree of irregular bearing (Singh 1978). Low yields may be due to insufficient flower buds or to excessive fruit drop, but in all cases the relationship between vegetative and reproductive development is important (Mukherjee 1953; Chacko *et al.* 1982; Chacko 1985). Vegetative growth cycles of mango trees have been described by a number of workers (Singh and Khan 1939; Singh 1959; Rao and Khader 1979), but flushing patterns often vary with location and season. Information on the relationship and timing of floral initiation and development in relation to the vegetative growth cycles is important for crop management (Sen 1944; Bondad and Lingsangan 1979). Reports on floral initiation and development from various mango growing areas indicate that floral initiation occurs only a few weeks before anthesis with no dormancy period (Sen and Mallik 1941; Mustard and Lynch 1946; Ravishankar *et al.* 1979; Lin and Chen 1981). The developmental period between floral initiation and anthesis appears to depend largely on temperature, with a longer period in subtropical than tropical areas (Ravishankar *et al.* 1979). Observations in a warm temperate climate at Merbein, Vic. (latitude 34° S., longitude 142° E.) on some experimental mango trees indicate a very long period between floral initiation in April–May, and flowering in October–November (D. McE. Alexander, personal communication, 1985). Uneven differentiation is also common with differences between trees in the same orchard and between different parts of a single tree (Lin and Chen 1981).

The mango industry in northern Australia is relatively new but is expanding rapidly (Luxton 1982; Scholefield and Blackburn 1985). Low yields in the major cultivar, Kensington, appear related to excessive vegetative vigour and poor

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flowering. In this study we have characterized the vegetative cycles of the Kensington mango in northern Australia in relation to floral initiation and fruit development.

Materials and Methods

Trees of *Mangifera indica* L. cv. Kensington were located in a commercial orchard planted in 1970 at a density of 100 trees per ha at Humpty Doo near Darwin, N.T. (latitude 12° S., longitude 131° E.). A total of between 76 and 99 vegetative shoots were labelled on each of five trees in July 1981. Observations were made at weekly intervals to determine times of vegetative and reproductive growth between July 1981 and July 1983. All trees behaved similarly and the results were combined.

Terminal buds from labelled shoots were sampled between March and July 1982 at Humpty Doo and from similar trees at Bowen, Qld (latitude 20° S., longitude 148° E.) and during May and June 1983 at Humpty Doo. Dates of sampling and number of buds sampled at each date are shown in Table 1. The outer bracts were removed, and each bud was bisected and fixed in 3% glutaraldehyde in 0·025 M phosphate buffer pH 7·0. The tissue was dehydrated through alcohols and embedded in glycol methacrylate (Feder and O'Brien 1968). Sections were cut at 5 μm and stained with periodic acid–Schiff's reagent and toluidine blue O.

Yields, fruit numbers and average fruit weights were measured for the experimental trees in 1981, 1982 and 1983.

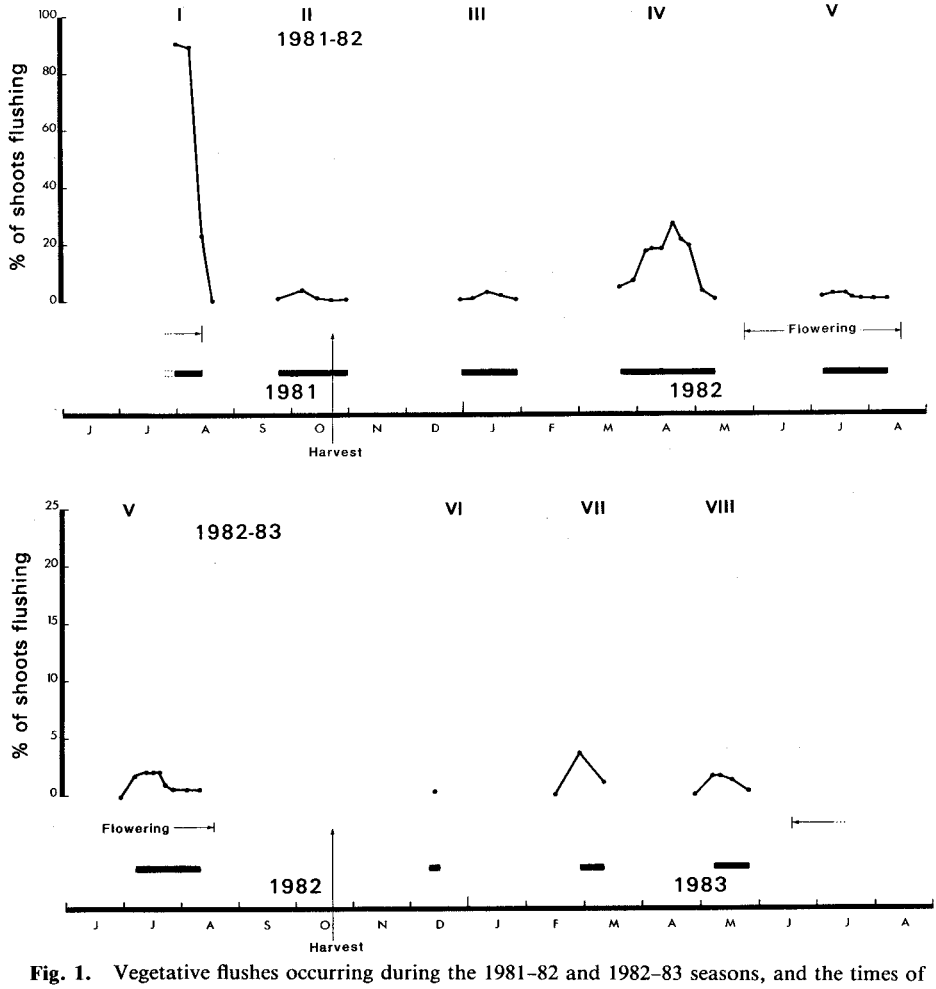


Fig. 1. Vegetative flushes occurring during the 1981–82 and 1982–83 seasons, and the times of flowering and harvest. Note the different scale for percentage of shoots flushing in 1982–83. Solid lines represent the period of flush.

Results

There were four vegetative flushes on the trees at Humpty Doo between the flowering period in July 1981 and July 1982 (Fig. 1). Not all terminal buds on the experimental shoots burst at each flush. Flushes I and IV were considered major flushes, with 91% and 46% respectively of the shoots flushing, while only 4·7%

Table 1. Mango buds sampled at Humpty Doo and Bowen in 1982 and 1983

Location	Date of sample	Number of buds sampled	Number vegetative	Number floral	Date of sample	Number of buds sampled	Number vegetative	Number floral
Bowen	15.iii.82	10	10	0	15.vi.82	10	10	0
	13.iv.82	10	10	0	23.vi.82	10	10	0
	10.v.82	10	10	0	28.vi.82	10	10	0
	7.vi.82	10	9	1				
Darwin	5.iii.82	5	5	0	29.vi.82	13	13	0
	15.iii.82	5	5	0	6.vii.82	8	8	0
	13.iv.82	5	5	0				
	21.iv.82	5	5	0	30.v.83	5	5	0
	28.iv.82	5	5	0	6.vi.83	5	5	0
	10.v.82	5	5	0	10.vi.83	5	4	1
	18.v.82	14	14	0	15.vi.83	10	8	2
	25.v.82	8	8	0	17.vi.83	10	8	2
	1.vi.82	14	14	0	20.vi.83	11	5	6
	8.vi.82	8	8	0	22.vi.83	10	9	1
	15.vi.82	14	14	0	24.vi.83	9	7	2
	22.vi.82	8	8	0	27.vi.83	7	5	2

and 4% respectively of the shoots grew during flushes II and III. Thus, at flowering 1982 the majority of the terminal shoots had originated in flushes I and IV, and 78% and 15% respectively of these shoots flowered (Table 2). Of the 187 terminal buds sampled for microscopy between March and July in 1982, none of those from the Humpty Doo orchard and one from Bowen was floral (Table 1).

Table 2. The flush of origin, number of shoots and percentage of terminal buds which flowered in 1982 and 1983

(Flush of origin refers to the period of vegetative growth when the terminal shoot was formed — see Fig. 1)

Flush of origin	Number of shoots	% of terminal buds which flowered	Flush of origin	Number of shoots	% of terminal buds which flowered	Flush of origin	Number of shoots	% of terminal buds which flowered
	1982			*1983*			*1983*	
I	87	78	I	15	33	V	4	50
II	1	100	II	0	—	VI	1	0
III	1	100	III	0	—	VII	10	90
IV	92	15	IV	152	90	VIII	6	33

There was very little vegetative growth between July 1982 and July 1983, although four small flushes were recorded (Fig. 1). At flowering in July 1983 most of the experimental shoots had originated in April 1982 during flush IV, and 90% of these flowered (Table 2).

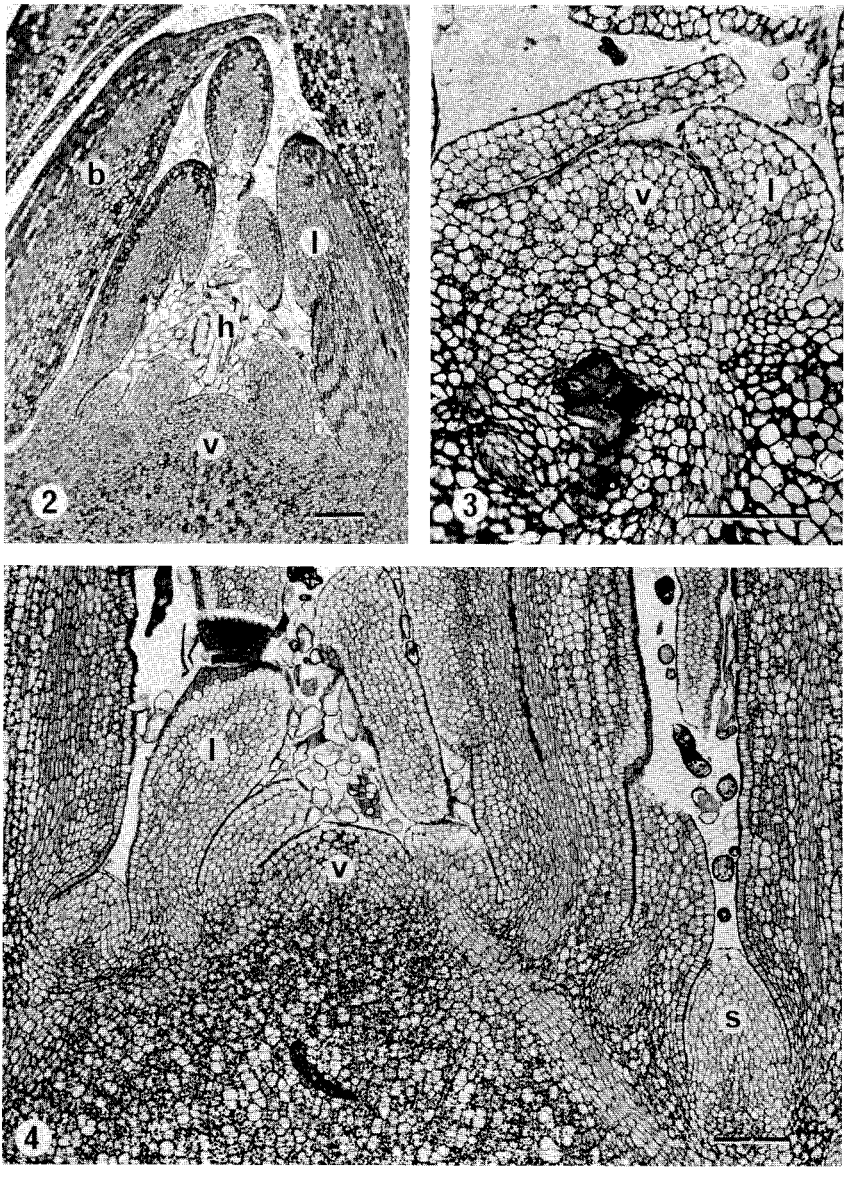


Fig. 2. Mango bud sampled at Humpty Doo on 18 May 1982 showing vegetative terminal meristem (v) with leaf primordia (l) with multicellular hairs (h) and surrounded by bud bracts (b). Bar represents 100 μm.

Fig. 3. Mango bud sampled at Humpty Doo on 24 June 1983 showing vegetative secondary axillary meristem (v) with leaf primordia (l). Bar represents 100 μm.

Fig. 4. Mango bud sampled at Humpty Doo on 15 June 1983 showing vegetative terminal meristem (v) with leaf primordia (l) and floral secondary axillary meristems (s). Bar represents 100 μm.

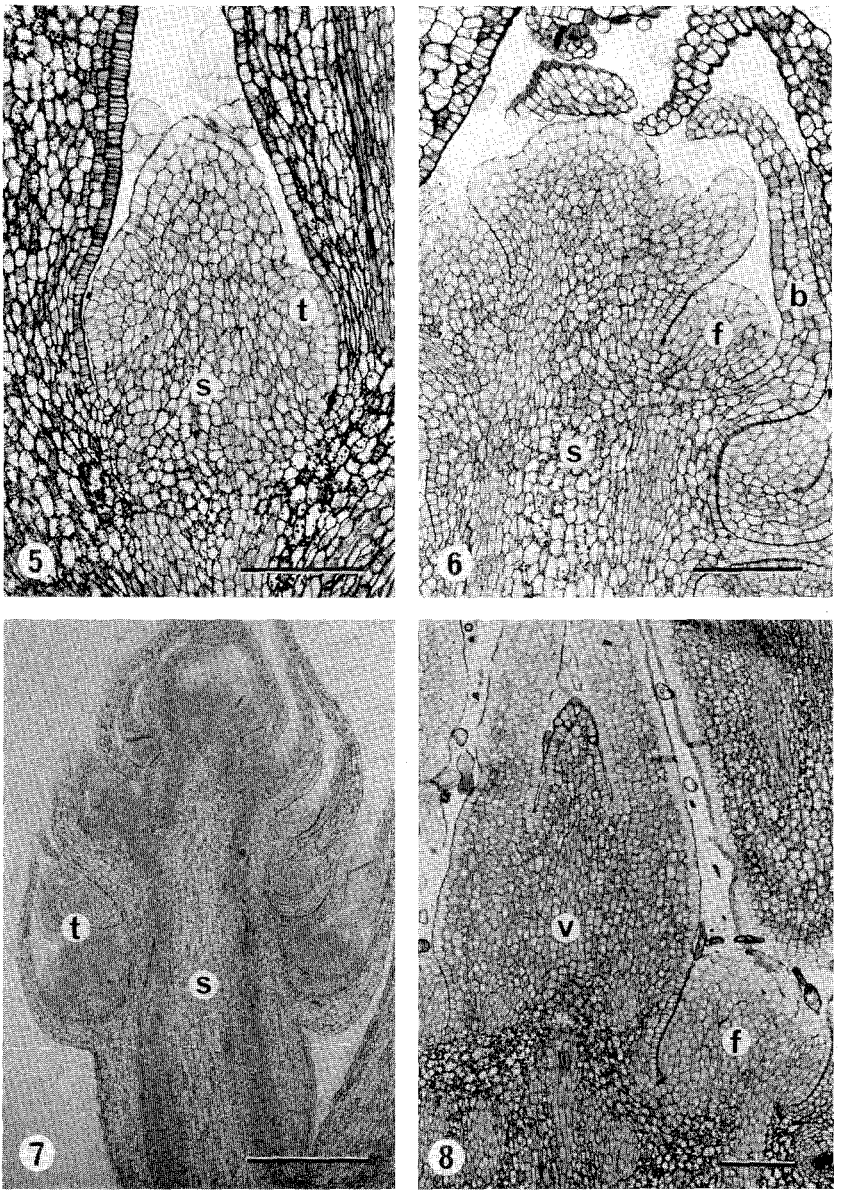


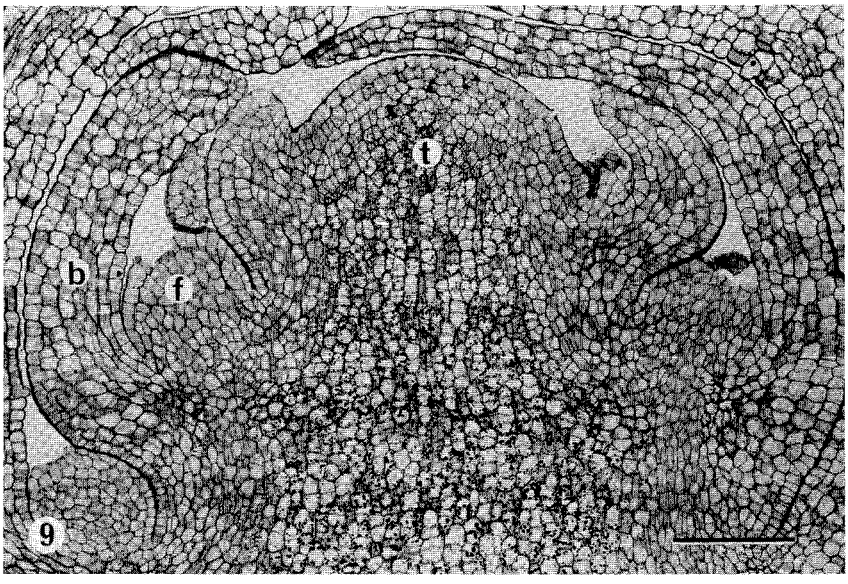
Fig. 5. Mango bud sampled at Humpty Doo on 20 June 1983 showing floral secondary axillary meristem (s) with tertiary meristems (t). Bar represents 100 μm.

Fig. 6. Mango bud sampled at Humpty Doo on 20 June 1983 showing floral secondary axillary meristems (s) with flower primordia (f) subtended by bracts (b). Bar represents 100 μm.

Fig. 7. Mango bud sampled at Humpty Doo on 20 June 1983 showing floral secondary axillary meristem (s) with tertiary meristems (t) which will develop into secondary and tertiary inflorescence branches respectively. Bar represents 500 μm.

Fig. 8. Mango bud sampled at Humpty Doo on 27 June 1983 showing vegetative (v) and floral (f) secondary axillary meristems within the same terminal bud. Bar represents 100 μm.

Sixteen of the 72 buds sampled for microscopy during May and June 1983 were floral (Table 1). The earliest floral buds were sampled in early June, less than one month prior to anthesis. The vegetative bud consisted of bud scales enclosing a flat dome of meristematic tissue which had produced some leaf primordia (Fig. 2). Small axillary secondary meristems were present in the axils of the bud scales and



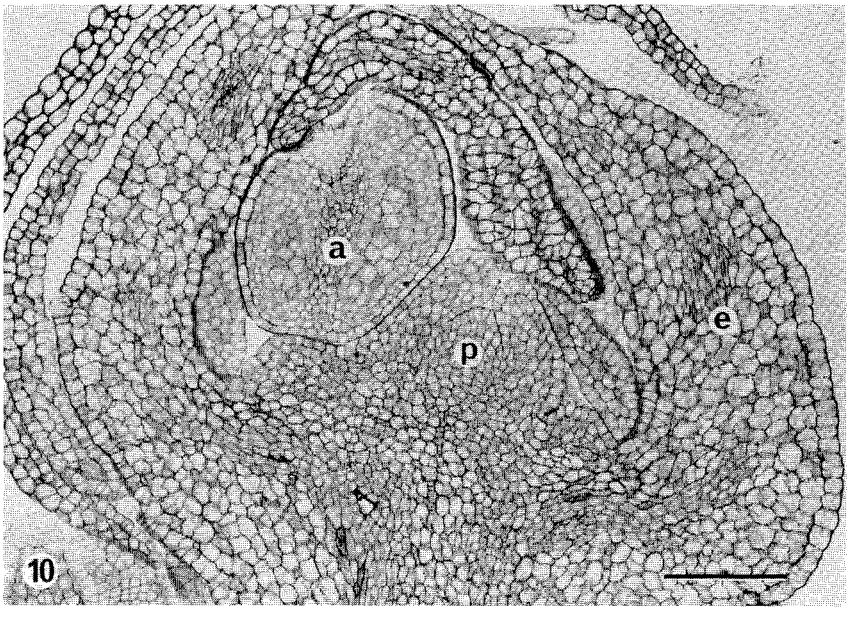


Fig. 9. Mango bud sampled at Humpty Doo on 20 June 1983 showing floral terminal meristem (t) with flower primordia (f) subtended by bracts (b). Bar represents 100 μm.

Fig. 10. Advanced mango bud sampled at Humpty Doo on 20 June 1983 showing flower with developing petals (e), anther (a) and pistil (p). Bar represents 100 μm.

leaf primordia. These were generally inactive but in some cases had produced leaf primordia (Fig. 3). The apex was surrounded by multicellular hairs from the epidermis of the leaf primordia (Fig. 2). The first indication of the transition to flowering was elongation of secondary axillary meristems (Fig. 4). This transition occurred first in the secondary meristems distal to the apex and the terminal apex was generally the last meristem to produce floral rather than vegetative structures. The elongated secondary axillary meristems became the secondary branches of the mango inflorescence (Fig. 7). They produced tertiary meristems (Fig. 5) which either developed into flower primordia subtended by a bract (Fig. 6) or into tertiary floral branches (Fig. 7). In most buds all the axillary meristems became floral, but in two cases mixed buds were observed with both vegetative and floral axillary secondary meristems in the same bud (Fig. 8). The terminal apex of the bud was the last to produce flower primordia subtended by bracts (Fig. 9), but following the transition developed more rapidly than the axillary primordia. Floral organs at an advanced stage of development were present in partly burst floral buds harvested on 20 June 1983 (Fig. 10).

Table 3. Mean fruit number, fruit weight and yield from the five experimental mango trees

	1981	1982	1983
Fruit number per tree	144±12[A]	580±126	548±72
Fruit wt (g)	426± 5	304± 17	393± 8
Yield (kg) per tree	61± 6	174± 39	215±28

[A] ± standard error.

The 1981 yield was low, whereas larger crops of 17·4 and 21·5 t per hectare were produced in 1982 and 1983 respectively (Table 3). The 1984 yields (not presented) were low and comparable to those of 1981.

Discussion

Vegetative activity can vary greatly from year to year in the mango cultivar Kensington growing in northern Australia. This can effect flowering and yield in the same year or in the following season. Although shoots of ages varying from 2 to 11 months flowered in 1982, more of the older shoots flowered, and there was an indication that the flowers on older shoots set more fruit. Not all mango cultivars behave in this way. In the biennial bearing cultivars Dashehari and Langra growing in northern India, there was no effect of shoot age on flowering (Singh 1959) and flowers were initiated only in an 'on' year. Similarly, some of the regular bearing cultivars, such as Brindabani, appeared to initiate flowers irrespective of the vegetative growth cycles (Singh 1960, 1978). It is possible that the higher temperatures experienced in northern Australia may stimulate more vegetative growth than under northern Indian conditions.

The transition to flowering in mango trees observed in northern Australia was generally more rapid than that described in other mango-growing areas such as Florida (Mustard and Lynch 1946), the Dharwad area of India (Ravishankar *et al.* 1979) and China (Lin and Chen 1981). This is probably due to the high temperatures experienced in this tropical area. This very short development period

of approximately one month between initiation and anthesis led to problems in sampling of buds for microscopy in 1982. As a result, more intensive observations were made in 1983 during the month prior to anthesis. In the majority of buds observed all the axillary meristems as well as the terminal became floral. In some cases, however, some axillaries remained vegetative, resulting in mixed buds which upon bursting would form characteristic leafy inflorescences. Competition between leaves and developing fruits adversely affects yield of mixed inflorescences (Chacko and Kohli 1985). The reason for this incomplete transition is not known, but may be associated with the rapid floral development under these tropical conditions. It is possible that better flowering might result if tree development could be slowed down in some way during the period of floral initiation and development, or if flowering could be induced at a time when temperatures are lower.

The finding that older shoots initiate flowers most readily is in keeping with the concept that high reserves of starch are required prior to the transition to flowering (Singh 1960; Suryanarayana 1978; Chacko and Ananthanarayanan 1982). Young developing leaves are importers of photosynthates, whereas mature leaves are exporters (Chacko 1985; Chacko and Kohli 1985). Thus older shoots would be expected to have higher reserves of starch. Hormones have also been implicated in floral initiation in mango with the detection of high levels of auxins in floral shoots (Chacko *et al.* 1972). Gibberellins have been shown to inhibit flowering (Kachru *et al.* 1971), whereas ethylene and growth regulators such as CCC (2-chloroethyl trimethyl ammonium chloride), Alar and maleic hydrazide will promote flowering (Chacko *et al.* 1974; Rath and Das 1979).

This study has shown that the transition to flowering in the mango in northern Australia is very rapid and follows soon after a vegetative flush which can result in substantial growth in some years. This information is important for the timing of cultural practices which may increase yield. Flowering can be promoted by pruning (Rao and Khader 1979) and by application of potassium nitrate (Bondad and Lingsangan 1979). The latter treatment is used commercially to induce out-of-season cropping in the mango cultivar Carabao in the Philippines, although it has not been so effective in inducing flowering in other cultivars in other regions. It is hoped that similar treatments may be adapted to increase floral initiation and yield in mangoes grown in northern Australia.

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