Effect of cincturing on growth and flowering of lychee over several seasons in subtropical Queensland

C. M. Menzel and D. R. Simpson

Queensland Department of Primary Industries, Maroochy Horticultural Research Station, P.O. Box 5083, Sunshine Coast Mail Centre, Nambour, Qld 4560, Australia.

Summary. The effects of autumn cincturing on vegetative flushing and incidence of flowering of 2 lychee (*Litchi chinensis*) cultivars (Bengal and Tai So) were investigated over 1–3 years at 8 sites in subtropical southern Queensland. Cultivars at these sites varied in the level of natural vegetative dormancy in winter (3–100% of terminal branches) and flowering in spring (0–100% of terminal branches). There was a strong correlation between percentage flowering (y) and the level of dormancy (x) in the 1–2 months prior to floral initiation ($y = 8{\cdot}8 + 0{\cdot}83x$; $r = 0{\cdot}89$, $P < 0{\cdot}001$).

Cincturing increased flowering by 40–800% in trees that would have flowered poorly in spring (<70%), but had no significant effect ($P > 0{\cdot}05$) on flowering in trees that would have bloomed profusely (70–100%), provided trees were adequately fertilised and actively flushing after harvest. This was shown by the relationship, $y = 899 - 23{\cdot}0x + 0{\cdot}14x^2$; $r = -0{\cdot}96, P < 0{\cdot}001$), where y is the percentage change in flowering after cincturing and x is the percentage flowering in control trees. Cincturing reduced or delayed flowering if nutrition was not maintained. It is concluded that trees to be cinctured should be adequately fertilised and complete a significant vegetative flush after harvest.

Introduction

A major limitation to the commercial expansion of lychee (*Litchi chinensis*) in eastern subtropical Australia is low and erratic yields because of poor flowering in spring (Menzel and Paxton 1986*b*). Lychee trees require 2–3 months of vegetative dormancy prior to floral initiation in winter. This dormancy is typically induced by cool dry weather, although it can be artificially induced by treatments such as cincturing (Menzel 1983).

Young (1977) found that lychee flowering was not reduced after 2 consecutive years of cincturing in Florida. Menzel and Paxton (1986*b*) showed that cincturing increased the level of flowering of lychee trees in subtropical Queensland (lat. 27°S.) capable of less than 70% bloom, but decreased flowering in those capable of 70–100% bloom if the cincture cut did not remain open for 2–3 months. This paper describes the effect of cincturing on growth and flowering of lychee cultivars in the same area over 1–3 years, using a cincture cut of sufficient width (3 mm wide by 3 mm deep) to prevent premature callusing during winter. No other research has been reported on cincturing of lychee over more than 2 consecutive years.

Materials and methods

The sites, cultivars and dates of cincturing are listed in Table 3. Trees at Palmwoods, Woombye and Beerwah were cinctured for 4 years, while those at Eudlo were cinctured for 3 years. All the other trees were cinctured once (see Tables 1 and 3).

Although no specific climatic data were available during the experiment, Beerwah, Kandanga and Glasshouse Mountains are relatively drier and cooler during winter than the other sites. Soil types are sandy loam on a clay subsoil at Woombye, Beerwah and Mooloolah, deep sandy loam at Diamond Valley, shallow clay at Eudlo, Glasshouse Mountains and Kandanga, and deep clay at Palmwoods. Elevation above sea level is less than 50 m at all sites.

Trees were cinctured after maturation of the post-harvest vegetative flush. The method was similar to that described by Menzel and Paxton (1986*b*), except that all the lower major branches were cinctured rather than the whole trunk. Ten cm above the ground, a cut with a hacksaw 3 mm wide and 3 mm deep was made to remove a layer of bark and cambium down to the central hardwood. The cut was covered with a saturated paste of copper oxychloride to limit disease infection. Adjacent, uncinctured trees were left for comparison as controls. The treatment trees were arranged in randomised complete blocks with 6 trees per treatment.

Trees were managed as commercial crops with respect to irrigation, nutrition, weed and pest management

Table 1. Date and duration of cincturing
All other cultivars were cinctured once in 1986

Site and cultivar	Years of cincturing	Years of observation reported in this paper
Palmwoods		
Bengal	1983–86 (4 years)	1984–86[A]
Woombye		
Tai So	1983–86 (4 years)	1985–86[AB]
Eudlo		
Bengal	1984–86 (3 years)	1985–86[B]
Tai So	1984–86 (3 years)	1985–86[B]
Beerwah		
Tai So	1983–86 (4 years)	1984–86[A]

[A]Results for 1983 are reported in Menzel and Paxton (1986*b*).
[B]All trees were cinctured in 1984.

(Menzel and Simpson 1986). The exceptions were cv. Bengal at Palmwoods where fertiliser was not applied after harvest in January 1985 and in cvv. Tai So and Bengal at Glasshouse Mountains where fertiliser was not applied after harvest in January 1986.

A monthly (March–October) record was kept of vegetative dormancy and flowering (panicle formation) in the terminal branches until the end of fruit set. Trees were also assessed monthly for healing of the cincture and given a rating from 0 to 10 as described in Table 2.

Dormancy and flowering data are expressed as a percentage of the terminal branches on a tree, recorded as an average of visual estimates by 2 observers working independently.

The significances of cincturing on flowering were determined by *t*-tests, with each cultivar, site and year being analysed separately. The data on dormancy have been analysed by 2-way ANOVA (cincturing×month) for each cultivar, site and year. Both sets of data were transformed by inverse sine before analysis. Means have been back-transformed for presentation in tables.

Results

1984

Cincturing increased the percentage of terminal branches in flower of cv. Bengal at Palmwoods, but had no significant effect on percentage flowering in cv. Tai So at Beerwah (Table 3). These responses were reflected by the changes in the percentage of terminal branches dormant after cincturing (Table 4). Cincturing had no significant effect on the times of panicle emergence or fruit set of cv. Bengal or Tai So.

The cinctures began to heal soon after panicle emergence (May) in cv. Tai So, and healing ratings increased from (mean ± s.e.) 6·8 ± 0·4 in May to 7·5 ± 0·3 in October. In contrast, healing of the cinctures in cv. Bengal was delayed until after fruit set (September) and healed from 0·0 ± 0·0 in May to 2·8 ± 0·4 in October. The early recovery in cv. Tai So was not associated with vegetative flushing during winter.

1985

Cincturing prolonged vegetative dormancy and increased the percentage of branches which flowered in cvv. Bengal and Tai So at Eudlo (Tables 3 and 4). Cincturing had no significant effect on the level of flowering for cv. Bengal at Palmwoods and cv. Tai So at Woombye and Beerwah (cincturing delayed panicle emergence by 8–10 weeks in cv. Bengal). With the exception of the first cultivar, these responses were associated with small changes in the level of dormancy. Although the uncinctured trees of cv. Bengal at Palmwoods flushed during winter, they produced small shoots atypical of healthy trees.

Most of the cinctures did not begin to heal until fruit set (September–October), with healing ratings increasing from 0·2 ± 0·2–1·0 ± 0·3 in June to 2·3 ± 0·2–4·3 ± 1·0 in October. The exception was cv. Bengal at Eudlo where healing began soon after panicle emergence (June) with healing ratings of 2·7 ± 0·2 in June and 5·5 ± 0·8 in October.

1986

The only instances in which cincturing increased percentage flowering were in cv. Bengal at Eudlo and cv. Tai

Table 2. A description of the ratings for healing of the cinctures

Rating	0	1	2	3	4	5	6	7	8	9	10
% of Circumference with callus formation	0	<10	10–40			40–70			70–100		
Callus thickness[A]	0	1, 2 or 3	1	2	3	1	2	3	1	2	3

[A]1, Sunk below bark level; 2, level with bark; 3, swollen above bark level.

Table 3. The effect of cincturing on flowering of lychee cultivars
Data are the means of six trees expressed as a percentage of terminal branches. Trees were cinctured after maturation of the post-harvest flush

Site and cultivar	Date of cincturing	Tree age (years)	Flowering (%) Control	Flowering (%) Cinctured	Month of fruit set Control	Month of fruit set Cinctured
Palmwoods						
Bengal	1 May 1984	9	20·9	76·0**	Sept.	Sept.
	3 April 1985	10	18·1	19·2	Oct.	Oct.
	5 March 1986	11	90·7	94·2	Sept.	Sept.
Woombye						
Tai So	26 March 1985	8	71·6	93·0	Sept.	Sept.
	6 March 1986	9	76·4	66·0	Aug.	Aug.
Eudlo						
Bengal	3 April 1985	8	0·0	86·6**	Oct.	Oct.
	2 April 1986	9	8·7	92·0**	Sept.	Sept.
Tai So	26 March 1985	8	44·0	99·7**	Sept.	Sept.
	2 April 1986	9	76·8	91·7	Aug.	Aug.
Beerwah						
Tai So	15 March 1984	5	100·0	95·1	Aug.	Aug.
	26 March 1985	6	90·8	70·0	Sept.	Sept.
	2 April 1986	7	95·6	83·9	Aug.	Aug.
Mooloolah						
Tai So	5 March 1986	4	61·5	90·0	Sept.	Aug.
Diamond Valley						
Tai So	10 March 1986	4	6·5	95·6**	Sept.	Aug.
Glasshouse Mts						
Bengal	2 April 1986	5	84·8	80·1	Sept.	Oct.
Tai So	2 April 1986	5	73·6	94·7	Aug.	Sept.
Kandanga						
Tai So	23 March 1986	6	89·4	97·7	Sept.	Sept.

**Differences between control and cinctured trees highly significant at $P<0 \cdot 01$.

So at Diamond Valley (Table 3). These responses were reflected by the changes in the percentage of terminal branches vegetatively dormant (Table 4). Cincturing altered the timing of flowering by only 1–3 weeks (Table 3). The exceptions were cvv. Bengal and Tai So at Glasshouse Mountains where cincturing delayed flowering and fruit set by 6–8 weeks, and cv. Tai So at Diamond Valley where cincturing accelerated panicle emergence by 10–12 weeks. Cultivars Tai So and Bengal at Glasshouse Mountains were low in vigour because of lack of fertilisers and did not flush vegetatively after harvest.

The cinctures began to heal around the time of panicle emergence (April–July) for cv. Bengal at Eudlo and Glasshouse Mountains and for cv. Tai So at Eudlo, Diamond Valley and Beerwah, with healing ratings increasing from $0 \cdot 6 \pm 0 \cdot 2$–$1 \cdot 8 \pm 0 \cdot 2$ in June to $5 \cdot 0 \pm 0 \cdot 3$–$6 \cdot 2 \pm 0 \cdot 4$ in September. In contrast, healing did not begin until late in panicle development (July–August) or just prior to the time of fruit set (August–September) in cv. Bengal at Palmwoods and cv. Tai So at Woombye, Mooloolah, Glasshouse Mountains and Kandanga, with healing ratings of $0 \cdot 0 \pm 0 \cdot 0$–$0 \cdot 5 \pm 0 \cdot 2$ in June and $2 \cdot 5 \pm 0 \cdot 2$–$6 \cdot 1 \pm 0 \cdot 5$ in September.

Effect of cincturing on panicle size and flower number
Cincturing did not affect final panicle size or flower number per panicle. The exceptions were cv. Bengal at Palmwoods in 1985 and cv. Tai So at Glasshouse Mountains 1986, when cincturing reduced panicle length and flower number by about 50% compared with control trees. Cincturing had no significant effect on the proportion of male and female flowers at any site.

Relationship between flowering in spring and vegetative dormancy in winter
There was a strong correlation between percentage flowering on terminal branches (y) and percentage of terminal branches that were dormant in the 1–2 months preceding panicle emergence (x) for both cinctured and uncinctured trees, taken together:

Table 4. Effect of cincturing on the percentage of terminal branches dormant in lychee cultivars
Means for each site, cultivar and year followed by different letters are significantly different ($P<0{\cdot}05$). Data are the means of six trees

Site, cultivar and year	March		April		May		June		Month of panicle emergence	
	Control	Cinctured	Control	Cinctured	Control	Cinctured	Control	Cinctured	Control	Cinctured
Palmwood, Bengal										
1984					12·8a	94·1c	59·6b	87·0c	June	July
1985			5·7a	93·8b	4·1a	81·5b	97·4b	97·4b	May	August
1986			100·0	97·0	98·6	99·4	85·3	98·2	June	June
Woombye, Tai So										
1985			80·1c	94·9c	46·3ab	79·8c	40·3a	36·0a	May	May
1986	89·8	93·0	73·5	71·8	71·7	85·1	57·1	61·1	April	April
Eudlo, Bengal										
1985			31·9b	94·4cd	0·6a	92·3cd	83·6c	98·4d	June	June
1986			80·0b	79·8b	72·6b	88·7b	12·9a	73·2b	July	June
Eudlo, Tai So										
1985			47·8a	82·2b	35·8a	86·5b	51·8a	39·9a	May	May
1986	85·0c	90·0c	29·7a	65·5bc	53·0b	55·6b	34·1ab	15·8a	April	April
Beerwah, Tai So										
1984			98·7c	85·2c	13·5b	19·1b	2·2a	8·5a	May	May
1985			57·0a	95·5c	79·5ab	93·5c	61·3a	85·5bc	May	May
1986			100·0b	99·1b	96·7b	99·7b	14·2a	34·5a	May	May
Mooloolah, Tai So										
1986			89·0b	98·6b	84·1b	79·5b	46·0a	41·8a	May	May
Diamond Valley, Tai So										
1986	92·0c	97·9c	13·5a	72·8c	83·4c	73·3c	66·8bc	21·7ab	July	April
Glasshouse Mts, Bengal										
1986			100·0	98·8	99·8	100·0	99·6	99·6	July	July
Glasshouse Mts, Tai So										
1986			100·0c	98·0bc	100·0c	93·1b	95·7bc	39·0a	June	June
Kandanga, Tai So										
1986			79·2b	99·5b	74·5b	89·2b	31·8a	22·0a	May	May

$$y=8{\cdot}8+0{\cdot}83x \quad (r=0{\cdot}89;\ P<0{\cdot}001)$$

Trees that were dormant in winter flowered better than trees that had flushed, with only 1 exception (cv. Bengal after cincturing at Palmwoods in 1985, possibly because of inadequate nutrition).

Relationship between percentage change in flowering of terminal branches after cincturing and level of flowering in control trees

There was an inverse correlation between the percentage change in flowering after cincturing (y) and the percentage flowering in control (uncinctured) trees (x):

$$y=899-23{\cdot}0x+0{\cdot}14x^2 \quad (r=-0{\cdot}96;\ P<0{\cdot}001)$$

Cincturing increased flowering in those trees that would have a low bloom in spring (<70%), but had no effect or slightly reduced flowering in those trees that would have flowered profusely (70–100%). The exception was cv. Bengal at Palmwoods in 1985, where cincturing did not improve flowering when few control trees flowered.

Discussion

This experiment confirms earlier work that cincturing can promote flowering in lychee (Nakata 1956; Menzel and Paxton 1986*b*). Our work also shows that increased flowering can be obtained for up to 4 years after cincturing provided tree vigour is not allowed to decline because of inadequate nutrition.

As has been noted earlier in this environment (Menzel and Paxton 1986*b*), in Hawaii (Shigeura 1948) and in Florida (Young 1956) there was a strong correlation between the incidence of flowering in spring and the level of vegetative dormancy in winter. Although the best flowering was obtained when trees were dormant for 3 months prior to floral initiation, some trees flowered profusely after only 1 month of vegetative dormancy (e.g. cv. Tai So at Woombye and Eudlo in 1986).

In recent glasshouse experiments, we found that flowering in lychee can occur at temperatures above those required for vegetative dormancy (about 11·0°C) provided the trees are not flushing at the time (data not presented). Cultivars flowered after 6–8 weeks at 15/10, 20/15 and

20/20°C day/night temperatures, but remained vegetative at 25/20, 30/10 and 30/25°C. It is not possible at the moment to separate the direct and indirect effects of cincturing on lychee flowering. The main effect of cincturing may be to induce vegetative dormancy. Once trees are dormant they may then flower after exposure to temperatures below 20°C.

Cincturing suppressed or delayed flowering if the tree was in poor health or had not produced a flush of growth after harvest (cv. Bengal at Palmwoods in 1985 and cvv. Bengal and Tai So at Glasshouse Mountains in 1986). Tissue analysis showed that nitrogen, calcium, magnesium, iron, zinc, copper and boron levels in the leaves of these trees were below those considered optimum for lychee production under subtropical Queensland conditions (Menzel and Simpson 1987) and generally lower than comparable trees at Eudlo. Our results indicate that trees to be cinctured should be adequately fertilised and should have had a strong post-harvest flush. This agrees with results reported for lychee in Hawaii (Nakata 1953). Ample supplies of nitrogen (and other nutrients) after harvest would be expected to increase the level of carbohydrate reserves necessary for panicle and flower development during winter and spring (Tromp 1983).

When trees were fertilised regularly, the beneficial effect of cincturing on flowering was more obvious when trees were expected to bloom lightly. In trees which were about to flower heavily, flowering was not affected or slightly reduced. A similar response was recorded in lychee (Menzel and Paxton 1986*b*), avocado (Malo 1971), and olive (Lavee *et al.* 1983). When the results of the present trials are considered with the previous observations of Menzel and Paxton (1986*b*), cincturing resulted in an increase of flowering in 30% of cases, had no significant effect in 58% of cases and reduced flowering in 12% of cases.

Cincturing had only a small effect on panicle and flower differentiation and fruit set for most cultivars; fruit set was delayed or advanced by about 2 weeks in a few instances. The responses may have been very different if the trees were cinctured closer to the period of fruit set or with a deeper or wider cut. Most of the cinctures began to heal by the time of fruit set.

Because of early callusing and premature flushing of the trees during winter in the previous trial (Menzel and Paxton 1986*b*) we used branch-cinctures, rather than whole-trunk cinctures. This delayed the healing of the calluses and prevented a loss of flowering after cincturing.

No other cincturing trials with lychee have been extended to more than 2 years. Cincturing of olive (Ben-Tal and Lavee 1984) and orange (Erner 1986) over 4 years caused tree damage and reduced yield. Although there was no apparent loss of flowering in the present experiment after 4 years of consecutive cincturing, provided tree vigour was maintained, it is possible that repeated cincturing of the same tree might prove harmful. One method of reducing tree injury is to cincture trees in alternate years. Alternative methods are to cincture a proportion of the tree each year (as practised in Thailand) and manipulation of tree nutrition and vigour.

Nakata (1956) showed that half-tree cinctures in lychee reduced the yield of uncinctured branches. This suggests it may be more productive to cincture whole trees in alternate years. Ben-Tal and Lavee (1984) demonstrated that alternate bearing in olive trees over 4 years was less when half the branches were cinctured in alternate years compared with all branches cinctured annually or half the branches cinctured annually. Similar experiments are warranted in lychee.

Menzel and Paxton (1986*a*) speculated that improved flowering after cincturing in lychee is due to the accumulation of growth inhibitors. Growth inhibitors may counteract the flowering-inhibiting effects of gibberellin produced during active vegetative growth (Zhong and Wu 1983). Application of growth retardants may play a role with cincturing in restricting autumn flushing prior to floral initiation.

There is not always a close association between yield and the flowering response of lychees to cincturing. Excessive numbers of male flowers or flower or fruit shedding may result in a light crop after profuse flowering. In our experiments, heavy yields such as 60–80 kg per tree for a 10-year-old tree followed heavy flowering after cincturing in about 50% of orchards.

Increases in yield of 15–40 kg per tree at year 8–10 were recorded after cincturing in some orchards. At a density of 140 trees per hectare and a wholesale price of $A3.00 per kg, this is equivalent to an increase in gross return of $A6300–16 800 per hectare after cincturing. Increases in yield of younger trees at year 6 of between 4 and 10 kg per tree at the same spacings and prices would result in an increase in returns of $A1680–4200 per hectare.

We conclude that cincturing could increase flowering on lychee trees capable of less than 70% bloom provided trees are adequately fertilised and have flushed actively after harvest. Although the incidence of flowering was not reduced by 3–4 years of continuous cincturing when nutrition was maintained, we recommend that trials are initiated to determine the potential of half-tree cinctures or cincturing of whole trees in alternate years.

Acknowledgments

We thank B. Barr, J. Brennan, B. Davidson, B. Dingeman, A. Greubel, D. Hertslet, C. Saunders and R. Weavell for use of lychee trees. Statistical analysis of dormancy data by C. Howitt and review of manuscript by B. J. Watson are gratefully acknowledged.

References

Ben-Tal, Y., and Lavee, S. (1984). Girdling olive trees, a partial solution to biennial bearing. II. The influence of consecutive mechanical girdling, on flowering and yield. *Rivista della Ortoflorofrutticoltura Italiana* **68**, 441–51.

Erner, Y. (1986). Girdling effects on yield over 4 years of citrus trees. *HortScience* **21**, 679.

Lavee, S., Haskal, A., and Ben-Tal, Y. (1983). Girdling olive trees, a partial solution to biennial bearing. I. Methods, timing and direct tree response. *Journal of Horticultural Science* **58**, 209–18.

Malo, S. E. (1971). Girdling increases avocado yields in south Florida. *Proceedings of the Tropical Region of the American Society of Horticultural Science* **15**, 19–25.

Menzel, C. M. (1983). The control of floral initiation in lychee: a review. *Scientia Horticulturae* **21**, 201–15.

Menzel, C. M., Chapman, K. R., Paxton, B. F., and Simpson, D. R. (1986). Growth and yield of lychee cultivars in subtropical Queensland. *Australian Journal of Experimental Agriculture* **26**, 261–5.

Menzel, C. M., and Paxton, B. F. (1986*a*). The effect of cincturing at different stages of vegetative flush maturity on the flowering of litchi (*Litchi chinensis* Sonn.). *Journal of Horticultural Science* **61**, 135–9.

Menzel, C. M., and Paxton, B. F. (1986*b*). Effects of cincturing on growth and flowering of lychee: preliminary observations in subtropical Queensland. *Australian Journal of Experimental Agriculture* **26**, 255–9.

Menzel, C. M., and Simpson, D. R. (1986). Lychee growing in subtropical Queensland. *In* 'The Potential of Lychee in Australia'. (Eds C. M. Menzel and G. N. Greer.) pp. 22–36. (Sunshine Coast Subtropical Fruits Association: Nambour, Qld.)

Menzel, C. M., and Simpson, D. R. (1987). Lychee nutrition: a review. *Scientia Horticulturae* **31**, 195–224.

Nakata, S. (1953). Girdling as a means of inducing flower-bud initiation in litchi. Hawaii Agricultural Experimental Station Progress Note No. 95, pp. 1–4.

Nakata, S. (1956). Lychee flowering and girdling. *Hawaii Farm Science* **4**, 4–5.

Shigeura, G. (1948). Blossom-bud formation and fruit setting in the litchi. Biennial Report of the Hawaii Agricultural Experimental Station, pp. 138–40.

Tromp, J. (1983). Nutrient reserves in roots of fruit trees, in particular carbohydrates and nitrogen. *Plant and Soil* **71**, 401–13.

Young, T. W. (1956). Responses of lychees to girdling. *Proceedings of the Florida State Horticultural Society* **69**, 305–8.

Young, T. W. (1977). Effect of branch girdling on yield of severely pruned 'Brewster' lychee trees. *Proceedings of the Florida State Horticultural Society* **90**, 251–3.

Zhong, Y. W., and Wu, S. Y. (1983). Effects of growth regulators on the induction of flowers of lychee (No Mi Chi). *Guangdong Agricultural Science* **5**, 17–19.

Received 13 April 1987, accepted 2 July 1987