Growth and yield of lychee cultivars in subtropical Queensland

C. M. Menzel, K. R. Chapman, B. F. Paxton and D. R. Simpson

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

Summary. Four lychee (*Litchi chinensis*) cultivars (Bengal, Gee Kee, Tai So and Wai Chee) were grown in subtropical coastal southern Queensland. Yields after 8 years varied from 0·1 to 28·5 kg/tree (equivalent to a maximum of 6·6 t/ha at a density of 230 trees/ha). Wai Chee was superior to Gee Kee under all conditions and to Bengal and Tai So when flowering was reduced after warm wet winters or when fruiting was reduced during hot, dry springs.

Introduction

The lychee (*Litchi chinensis*) was introduced into Queensland in 1854 and a small industry has existed along coastal northern Queensland for the past 50 years (see Stephens 1935). Recent interest in the crop, both for local consumption and export to south-eastern Asia, has led to expansion of production in northern Queensland and establishment of plantings in central and southern Queensland and northern New South Wales, although current production is low compared with other tropical fruits (Australian Bureau of Agricultural Economics 1984).

A major problem limiting expansion of lychee production in southern Queensland has been low and irregular yields. Trees often display poor flowering in spring because the winters are not cool or dry enough to induce satisfactory vegetative dormancy. Excessive vegetative flushing or hot dry weather in spring can also eliminate flowers and young fruit.

Only limited information is available on the performance of lychee cultivars in Australia. Paxton and Chapman (1980) recorded yields of up to 120 kg for 10-year-old Bengal trees in southern coastal Queensland. This paper describes the growth and cropping of four cultivars over 8 years in that area.

Materials and methods

Potted marcots (cvv. Bengal, Gee Kee, Tai So and Wai Chee) were planted in April 1977 on a fertile loam at Nambour (27°S). Trees were placed at 4·8 m intervals in rows 9·0 m apart (equivalent to a density of 230 trees/ha) in eight randomized blocks with external guards on the perimeter of the site.

Tai So and Wai Chee are commercial cultivars from China, whereas Bengal is a seedling selection from the Indian cultivar Purbi, selected in Florida. Gee Kee was found growing on the property of C. Gee Kee in Babinda in North Queensland. It was imported from a village in China, but its origin has not been adequately established. It resembles the Chinese cultivar Seong Sue Wai, but does not match in some characteristics, including time of fruit maturity. Gee Kee may be a seedling of Seong Sue Wai.

Irrigation was by minispray twice weekly. The amount of water applied was based on foliage ground cover (soil area covered by each tree) and replacement of 80% of class A pan evaporation; rainfall less than 5 mm was considered ineffective. After 1979, water was withheld (except to prevent tree death) from April to August.

In 1978 each tree received 92 g nitrogen, 9 g phosphorus and 12 g potassium and in 1979 received 46 g nitrogen, 29 g phosphorus and 12 g potassium. No fertilizer was applied in 1980 or 1981. Each tree received 400 g nitrogen, 115 g phosphorus and 790 g potassium in 1982 and received 138 g nitrogen, 38 g phosphorus and 115 g potassium in 1983 and 1984, split 2 weeks before and after harvest.

Trees were cinctured with a hacksaw after maturation of the post-harvest flush in February 1981 and April 1982. A cut 2 mm wide and 2 mm deep removed the layer of bark and cambium 10 cm above the base of the trunk.

The climate at Nambour is subtropical with no arid months (Table 1). Average annual rainfall is 1779 mm, 42% falling in summer. Temperatures range from an average daily minimum in July of 6·9°C to an average daily maximum in December of 28·7°C. Temperatures above 35°C are occasionally experienced in spring, usually accompanied by dry westerly winds.

Table 1. Climatic data during fruit production of lychee cultivars planted at Nambour in April 1977

Year and parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1980												
Mean min. daily temperature (°C)	20·4	21·3	16·1	15·1	14·7	8·5	6·4	9·3	10·1	15·5	16·1	17·8
Mean max. daily temperature (°C)	31·5	28·7	28·6	26·6	23·6	21·7	20·6	22·6	27·1	26·9	28·4	28·0
Total monthly precipitation (mm)	178	228	19	47	361	20	67	40	0	122	46	238
Total monthly pan evaporation (mm)	176	144	136	113	85	68	84	91	144	132	153	170
1981												
Mean min. daily temperature (°C)	18·8	22·3	18·1	15·0	12·5	8·5	7·9	6·4	10·7	11·8	17·1	20·1
Mean max. daily temperature (°C)	28·1	29·4	28·7	26·7	26·7	21·2	21·3	22·6	25·1	25·0	26·0	29·7
Total monthly precipitation (mm)	133	341	110	216	196	67	42	39	13	31	247	289
Total monthly pan evaporation (mm)	161	97	154	114	85	86	76	114	136	155	130	178
1982												
Mean min. daily temperature (°C)	21·3	21·3	19·4	15·0	11·5	5·7	5·7	9·2	10·6	11·4	15·0	17·8
Mean max. daily temperature (°C)	29·0	28·8	28·2	25·3	23·9	20·4	20·5	21·7	24·1	25·9	27·3	30·0
Total monthly precipitation (mm)	590	173	228	104	167	3	14	107	40	51	22	84
Total monthly pan evaporation (mm)	150	121	113	101	70	73	75	85	107	149	166	175
1983												
Mean min. daily temperature (°C)	18·5	18·3	18·4	15·2	14·4	10·3	10·4	9·2	13·2	15·2	16·6	16·2
Mean max. daily temperature (°C)	28·8	29·5	28·6	25·7	23·6	20·7	20·3	21·7	26·0	26·0	26·4	26·9
Total monthly precipitation (mm)	246	56	129	212	368	534	94	87	93	111	297	160
Total monthly pan evaporation (mm)	164	155	133	95	68	59	57	92	112	135	108	157
1984												
Mean min. daily temperature (°C)	19·0	18·4	17·1	14·4	10·9	11·2	8·8	6·9	8·8	14·0	16·1	18·3
Mean max. daily temperature (°C)	28·0	28·0	27·9	25·0	22·9	21·0	19·9	22·7	24·6	24·1	27·7	30·1
Total monthly precipitation (mm)	156	74	71	98	37	138	188	12	21	190	67	126
Total monthly pan evaporation (mm)	136	130	123	91	78	57	70	101	118	136	144	166
Long-term average (25 years)												
Mean min. daily temperature (°C)	19·1	19·5	17·9	15·0	11·6	9·1	6·9	7·5	10·1	13·4	16·1	17·9
Mean max. daily temperature (°C)	28·6	28·2	27·2	25·9	23·1	21·4	20·7	22·1	24·2	26·0	27·4	28·7
Total monthly precipitation (mm)	284	277	247	137	122	82	91	48	45	111	155	180
Total monthly pan evaporation (mm)	174	129	132	115	87	77	82	102	128	150	158	182

Results

Trees established quickly and grew vigorously. Foliage ground cover per tree increased from an initial 0·2 m^2 in 1977 to 15 m^2 by 1984.

Environmental conditions during fruit production were close to long-term averages, with the following exceptions: winter 1980, drier; winter 1981, slightly drier; winter 1982, drier and cooler; spring–early summer 1982, drier; and winter 1983 and 1984, wetter and warmer than average.

All cultivars produced their heaviest and first appreciable crop in 1981–82 (Table 2). In 1982–83, yields of Bengal and Wai Chee were significantly higher than those of Gee Kee and Tai So, whereas in 1983–84 and 1984–85 yields of Wai Chee were higher. The relative order for total

Table 2. Marketable fruit yield (kg/tree) of lychee cultivars planted at Nambour in April 1977

Values are the means of eight trees. Means for each year followed by different letters are significantly different ($P<0{\cdot}05$)

Cultivar	1980–81	1981–82	1982–83	1983–84	1984–85	Accumulated yield
Bengal	2·5	28·5c	11·2b	0·5a	0·5a	42·9
Gee Kee	0·4	6·5a	1·8a	5·8b	0·6a	15·1
Tai So	1·6	24·5bc	1·0a	0·2a	0·1a	27·4
Wai Chee	0·7	21·3b	14·5b	12·4c	13·3b	62·2

Table 3. Flushing, flowering and fruiting of lychee cultivars planted at Nambour in April 1977
Values are the means of eight trees, with 30 replicate terminal branches recorded each year. Means for each year followed by a different letter are significantly different ($P<0\cdot05$).

Year and cultivar	Percentage of terminal branches: Flushing[A]	Flowering[A]	Fruiting[B]
1982–83			
Bengal	22·9	77·1b	40·0b
Gee Kee	25·8	74·2b	26·5b
Tai So	50·6	49·4a	8·8a
Wai Chee	23·2	76·8b	49·6b
1983–84			
Bengal	96·2	3·8a	1·7a
Gee Kee	51·9	48·1b	27·7b
Tai So	85·4	14·6a	3·8a
Wai Chee	54·6	45·4b	26·6b
1984–85			
Bengal	51·9	48·1ab	0·0
Gee Kee	37·5	62·5ab	0·0
Tai So	53·7	46·3a	0·0
Wai Chee	5·8	94·2bc	23·6

[A] Recorded at the end of fruit set.
[B] Recorded at harvest.

accumulated fruit yield was: Wai Chee > Bengal > Tai So > Gee Kee. Variation between trees was high when yields were low.

In 1982–83, 1983–84 and 1984–85, a record was kept of flushing, flowering and fruiting of individual terminal branches in spring and summer (Table 3). Flowering was less (compared with Wai Chee) in Tai So in 1982–83, in Tai So and Bengal in 1983–84 and in Tai So in 1984–85. Fruiting was reduced in Tai So in 1982–83, in Tai So and Bengal in 1983–84 and in Tai So, Bengal and Gee Kee in 1984–85.

The relative order of fruit set and fruit maturity was: Tai So, Bengal, Wai Chee and Gee Kee (Table 4). The average dates of fruit set and harvest varied with year by 4 weeks, but only by a few days within branches of an individual tree or among trees of the same cultivar in the same year.

Cultivars varied in fruit size, 'chicken tongue' (shrivelled or aborted seed), fruit weight composition and sugar content (Table 5). Bengal was more susceptible to fruit splitting, poor flesh recovery (during dry weather) and insect and bird attack than the other cultivars.

Discussion

The low yields from young lychee trees in subtropical coastal southern Queensland compare with yields of up to 30 kg from trees of similar ages in northern Queensland (E. C. Winston, unpublished data 1982) and northern New South Wales (D. J. Batten, personal communication 1982). These cultivars were not biennial bearing, as is the case for cultivars in southern China (Chapman 1984). The highly variable yields from year to year (see also Paxton and Chapman 1980) reflected variations in seasonal weather conditions.

The major problem of lychee growing in coastal southern Queensland is irregular and low yield because of poor flowering (warm wet winters promoting vegetative flushing) and poor fruit set and retention (hot dry windy springs inducing water stress). Lychee crops best in regions with cool dry winters and warm wet humid summers. Floral initiation in late winter (June–July) is promoted by cool temperatures (daily maximum <23°C) and moisture stress (<50 mm rainfall per month), which induce vegetative dormancy (Menzel 1983; Chapman 1984). In 1983, Bengal and Tai So flushed continuously during autumn and winter, and comparison of climatic data from

Table 4. Date of fruit set and harvest of lychee cultivars planted at Nambour in April 1977
Values are the means of eight trees.

Cultivar	1980–81	1981–82	1982–83	1983–84	1984–85
Fruit set					
Tai So	2 Sept.	14 Sept.	14 Sept.	9 Sept.	15 Sept.
Bengal	16 Sept.	21 Sept.	20 Sept.	16 Sept.	22 Sept.
Wai Chee	23 Sept.	28 Sept.	14 Oct.	10 Oct.	29 Sept.
Gee Kee	30 Sept.	5 Oct.	21 Oct.	17 Oct.	15 Oct.
Harvest					
Tai So	12 Dec.	29 Dec.	11 Jan.	28 Dec.	27 Dec.
Bengal	22 Dec.	7 Jan.	15 Jan.	10 Jan.	10 Jan.
Wai Chee	1 Jan.	18 Jan.	1 Feb.	1 Feb.	31 Jan.
Gee Kee	8 Jan.	25 Jan.	8 Feb.	7 Feb.	6 Feb.

Table 5. Fruit quality of lychee cultivars planted at Nambour in April 1977
Analysis based on 1 kg samples of ripe fruit harvested from eight trees in 1981–82.

Cultivar	Fruit size (g)	Chicken seed[A]	Fruit composition (% fresh weight): Skin	Seed	Aril	Total soluble solids (%)	Fruit shape	Skin colour	Skin texture	Aril texture	Aril flavour	Comments
Bengal	20·8	3·1	26·1	17·2	56·7	17·3	cone-shaped	bright red	very rough	juicy	very sweet	poor marketing type
Gee Kee	14·6	81·3	21·1	6·3	72·6	18·9	round	dark red	very rough	juicy	sweet (spicy)	poor marketing type
Tai So	18·7	13·3	19·0	15·5	65·5	17·0	egg-shaped	bright red	slightly rough	firm	sweet-acid	poor marketing type
Wai Chee	17·1	45·2	23·7	8·1	68·2	18·6	round	strong red	smooth	very juicy	sweet	suitable for export

[A]Shrivelled or aborted seed.

Nambour and the lychee-growing areas of China (Menzel and Paxton 1985) suggests that this was due mainly to heavy rainfall, although high temperature was probably another factor.

Profuse flowering alone did not guarantee a high yield because flowers and young fruitlets abscissed readily (Table 3). High temperatures, low humidities and strong winds have been implicated as the major reason for flower and fruit drop in lychee, since these factors lowered leaf water potential even when the soil was held close to field capacity (Menzel 1984; Menzel *et al.* 1986). It is not clear which factors are involved in reproductive failure because they are correlated in spring weather at Nambour. Other factors such as poor pollination (Menzel 1984), nutrient deficiencies (Menzel *et al.* 1983), competitive vegetative flushing (Menzel and Paxton 1985), pest damage (Rogers and Blair 1981) or disease (D. J. Batten, personal communication 1985) may also be involved.

The cooler and drier inland areas (e.g. Gayndah, Beerwah, Childers and Esk) provide better conditions for flower initiation than the coastal lowlands and subcoastal mountains in subtropical Queensland. Cultivars perform similarly at Maleny, Mt Tamborine and Nambour (C. M. Menzel and D. R. Simpson, unpublished data 1984). Despite the slightly cooler days and much cooler nights at the elevated sites, the generally higher rainfall results in vigorous flushing of most cultivars during winter. Heavier textured soils at the mountain sites also reduce water and nutrient stress, with light applications of water or nitrogen resulting in vigorous vegetative growth. Fruit maturity is delayed at the elevated sites so that late cultivars (e.g. Wai Chee) are not harvested until March or April, thus considerably lengthening the production season.

Late-maturing, less-vigorous cultivars appear to provide more consistent lychee production in coastal subtropical Queensland, as suggested by Paxton and Chapman (1980). Lower yields of Tai So and Bengal (early vigorous cultivars) were due to poor flowering and fruit retention (Table 5). Wai Chee was superior to Bengal and Tai So, however, only in years with warm wet winters or dry springs. Wai Chee was superior to Gee Kee mainly because of superior fruit retention. It is likely that the 5 years of cropping recorded was inadequate to indicate differences in yield potential between all cultivars. Cultivars selected in Florida, Hawaii and Thailand may bear more regularly in our environment than the heavily selected Chinese cultivars, although recent experience (C. M. Menzel and D. R. Simpson, unpublished data 1985) with some of these cultivars (Groff, Peerless, Amboina, Sampao Kaow and Kaloke Bai Yaow) indicates that not all are suitable for coastal areas. Cultivars with different maturity times should be tested in a range of environments to extend the production season.

Market acceptance of lychee varies with cultivar (Chapman 1984). Only Wai Chee could be considered an acceptable marketing type and it is inferior to cultivars such as Souey Tung, Haak Yip, Kwai May Pink, Kwai May Red and Salathiel because it is very juicy. Fruit, however, will keep on the tree for up to 2 weeks after maturation. Tai So, Bengal and Gee Kee are poor marketing types because of small fruit, large seed, poor flesh recovery or unusual flavour.

Hardman (1982) demonstrated that yields of less than 40 kg/tree made lychee cultivation in northern Queensland uneconomic. Regulation of the annual growth cycle is essential for cropping, since conditions favourable for flushing are not always favourable for reproductive growth. Management factors influencing growth are water (Nakata and Suehisa 1969), nitrogen (Koen *et al.* 1981) and cincturing (Young 1977). Investigations to improve production in southern Queensland should include: introduction of superior cultivars; evaluation of genotype× environment interactions; studies on the effects of irrigation and overhead misting on reproductive development; nitrogen nutrition and leaf flushing; and long-term effects of cincturing on tree health and fruit production.

Conclusion

Lychee yields in coastal southern Queensland over 5 years reflected seasonal weather conditions. Heaviest yields occurred in years with cool dry winters and warm wet humid springs, which promoted successful flowering and fruiting. Wai Chee, a late-maturing, low-vigour cultivar, yielded more consistently than Tai So, Bengal or Gee Kee.

Acknowledgments

Statistical analyses were provided by D. Mayer.

References

Australian Bureau of Agricultural Economics (1984). Economic potential for selected horticultural crops in Australia: overview. Occasional paper of the Australian Bureau of Agricultural Economics, Canberra. No. 87, p. 33.

Chapman, K. R. (1984). Tropical fruit collecting in S.E. Asia and China. Queensland Department of Primary Industries, p. 123.

Hardman, J. R. (1982). The economics of litchi production in far north Queensland. Queensland Department of Primary Industries.

Koen, T. J., Langenegger, W., and Smart, G. (1981). Nitrogen fertilization of litchi trees. *Information Bulletin of the Citrus and Subtropical Fruits Research Institute* **107**, 9–11.

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

Menzel, C. M. (1984). The pattern and control of reproductive development in lychee: a review. *Scientia Horticulturae* **22**, 333–45.

Menzel, C. M., Banks, A. G., and Simpson, D. R. (1986). Effect of aerial and soil environment on leaf water potential of lychee: implications for irrigation scheduling and productivity. *Acta Horticulturae* (In press).

Menzel, C. M., and Paxton, B. F. (1985). Effect of temperature on growth and dry matter production of lychee seedlings. *Scientia Horticulturae* **26**, 17–23.

Menzel, C. M., Paxton, B. F., and Price, G. (1983). Lychee nutrient survey. *Research Report of the Maroochy Horticultural Research Station (Nambour)* **3**, 56–7.

Nakata, S., and Suehisa, E. (1969). Growth and development of *Litchi chinensis* as affected by soil moisture stress. *American Journal of Botany* **56**, 1121–6.

Paxton, B. F., and Chapman, K. R. (1980). Some litchi yields of interest at Maroochy Horticultural Research Station, Nambour. *Biennial Report of the Maroochy Horticultural Research Station* **2**, 34–7.

Rogers, D. J., and Blair, A. D. (1981). Assessment of insect damage to litchi fruit in northern Queensland. *Queensland Journal of Agricultural and Animal Sciences* **38**, 191–4.

Stephens, S. E. (1935). Litchi. *Queensland Agricultural Journal* **44**, 191–4.

Young, T. W. (1977). Effect of branch girdling on severely pruned Brewster lychee trees. *Proceedings of the Florida State Horticultural Society* **90**, 251–3.

Received 7 March 1985, accepted 30 July 1985