

Yield and Fruit Quality of Longan (*Dimocarpus longan* Lour.) Cultivars on the Atherton Tableland of Tropical North Australia

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Abstract

The yield and fruit quality of 18 longan (*Dimocarpus longan* Lour.) cultivars imported from China (3), Taiwan (2), Thailand (5), Florida (4), and Hawaii (3) and 1 local selection were evaluated on the Atherton Tableland of North Queensland, Australia (Lat. 17°S) between 1982 and 1991. Cropping was irregular with the best yields in years with extended winter periods with mean daily minimum temperature < 12°C although the degree of cropping could not consistently be related to winter temperatures. Mean yields on older trees (data from tree ages of 3 to 13 years) were 3 to 79 kg and 7 to 35 kg on younger trees (data from 3 to 9 year old trees). 'Chompoo II' (78.8 kg/tree), 'Beow Keow' (57.8) and 'Chompoo I' (45.7) were the heaviest yielders of the older trees. 'Fuhko 2' (35.0 kg/tree) and 'Duan Yu' (32.6) yielded best of the more recently planted cultivars. Average fruit weights ranged from 5.3 to 11.0 g with 'Beow Keow,' 'Homestead,' 'Kay Sweeney' and 'Kohala' the only cultivars to have average weights > 10 g. Brix ranged from 16 to 21° except for 'Chien Liou' (10.3°). Most cultivars were crisp in texture with a sweet taste. Mean flesh recovery (% aril) varied from 57 to 70% with most cultivars in the low to mid 60s. 'Kay Sweeney' had the best recovery. 'Beow Keow,' 'Dang,' 'Duan Yu,' 'Fuhko 2,' 'Haew,' 'Kay Sweeney,' and 'Kohala' were the only cultivars to have > 80% of fruit of commercial size (> 22 mm diameter). 'Kay Sweeney' (early season), 'Kohala' (early), 'Fuhko 2' (mid) and 'Beow Keow,' 'Haew,' 'Dang' and possibly 'Chompoo I' (all late) are the recommended cultivars for commercial planting.

Introduction

The longan (*Dimocarpus longan* Lour.), a member of the *Sapindaceae* family, is an evergreen tree native to southern China and areas of southeast Asia (10). As a result of propagation by seed over hundreds of years there are over 300-400 cultivars, although only 30-40 are important commercially.

Longans today are a major crop in Thailand and to a lesser extent in the Fujian and Guangdong provinces of China and in Taiwan (2, 3). The main cultivar in Fujian Providence is 'Fu Yan,' a processing type while 'Wu Yuan' and 'Xi Xia' are the important selections in Guangdong (3, 12). 'Yang Tao Ye' and 'Chau On Diao' are the major cultivars in Taiwan (3). Thailand is the world's largest producer with 27,000 ha (3) which is somewhat surprising as the first longans were introduced from China to Thailand as late as 1896 (2). Thai production is mainly centred around the Chiangmai/Chienrai area of northern Thailand (18°N) (10). The six main cultivars in order of maturity are 'Daw,' 'Dang,' 'Chompoo,' 'Haew,' 'Beow Keow' and 'Baidum.' 'Daw' is the most widely planted cultivar although 'Haew,' 'Beow Keow' and 'Chompoo' command better prices (2).

Longan is a minor crop in Hawaii and Florida but is not substantially grown commercially elsewhere.

Longans were probably first introduced to north Queensland last century via Chinese miners. There are numerous backyard trees scattered throughout coastal north Queensland as well as on the Atherton Tableland. Many of these trees yield heavily but most are of poor quality with large seeds and thin flesh. Although trees have been in north Queensland and other areas of eastern Australia since last century (1), commercial plantings have only been made since 1980. Currently several plantings (< 10,000 trees in

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total) are being made on the Atherton Tableland of north Queensland.

In Thailand, China, Taiwan and Florida, cultivars with large fruit, high percentage aril recovery, good flavour, crisp flesh, high sugar content, regular and heavy yields and good shelf life are preferred. Most industries utilize several cultivars to extend the production season.

The Queensland Department of Primary Industries began introducing longan cultivars from Thailand, China, Taiwan, Florida and Hawaii in the late 1970s. The main introductions were made by B. J. Watson via Kamerunga Horticultural Research Station (Cairns, Queensland) and D. Batten via Alstonville Tropical Research Centre (Alstonville, New South Wales). This paper reports on performance results of longan cultivars on the Atherton Tableland.

Materials and Methods

Seventeen introduced and one local cultivar were planted at Walkamin Research Station (145°26'E, 17°7'S, 570 m elevation) on the Atherton Tableland of north Queensland between 1978 and 1987 (Table 1). The planting consisted of 'Beow Keow,' 'Chompoo I and II,' 'Dang,' 'Daw' and 'Haew' (ex-Thailand); 'Homestead,' 'Kay Sweeney,' 'Kohala' and 'Pon Yai' (ex-Florida); 'Fuhko 2,' 'Ila'o' and 'Wai' (ex-Hawaii); 'Chien Liou,' 'Duan Yu,' (ex Taiwan); 'Fa Hok Chai,' 'Saig Geeb,' 'Shek Yip,' (ex-China/Hong Kong) and the local 'Birch' (Cardwell large). Plant spacing was 9m x 9 m. The soil is described as a Euchrozem (Great soil group) or UF631 (Northcoate) or HAPLVDOX (USA System) (I. Heiner pers. comm.). Monthly maximum temperatures range from 22° to 30°C while minimums fluctuate between 12° and 20°C. Rainfall averages 1,033 mm, 67% of which falls in January-March.

A mixture of marcotted and grafted trees were planted. Most newer selec-

tions were grafted onto Kohala rootstock. Eight cultivars were represented by two trees each. Data were taken separately and averaged for this report. Other cultivars were represented by single tree plots. The two Chompoo introductions, 'Chompoo I and II,' appeared different and were treated as different cultivars.

Fertilizer on bearing trees was applied annually after harvest with rates varying with tree age. Irrigation was applied twice weekly by undertree sprinklers. Irrigation was withheld from late May until flowering in spring (August-October). Fertilizer and water rates approximated those recommended for lychee (6). Until 1986 no pruning was conducted, after which the more vigorous upright selections such as 'Kohala,' 'Homestead,' 'Kay Sweeney' and 'Fa Hok Chai' were topped at 3.5 m and lower branches were removed from all trees. No flower or fruit thinning occurred.

Detailed data were compiled annually from 1982 to 1991 on percent panicle emergence, time of flowering, fruit set, yield and fruit characteristics. Yield data were adjusted to compensate for major losses to parrots and fruit bats. Average fruit weights and percent flesh recovery (% aril) were determined on samples of 50 fruit taken at random. Mean Brix was determined with a Shibuya Number 11 handheld refractometer on 10-12 fruit individually. Fruit were given an overall quality rating based on size, flavour and texture. Data are presented as means (\pm) standard deviation.

Fruit were graded into five size categories by passing samples over wooden sieves having orifices of 32, 25, 22 and 19 mm diameter. Size 22 was considered the commercial minimum by the authors with only those > 25 mm being considered as top quality.

Results

Except for 'Pon Yai' and 'Wai' which had incompatible graft unions, all trees

established satisfactorily with most cultivars commencing flowering and cropping after three to four years in the field.

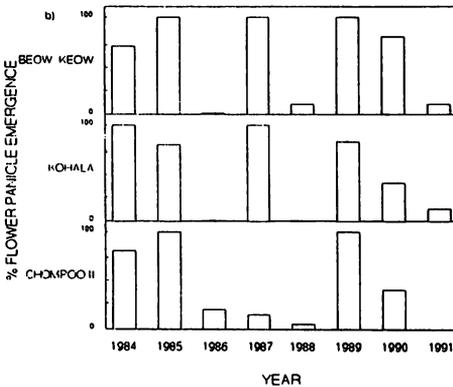
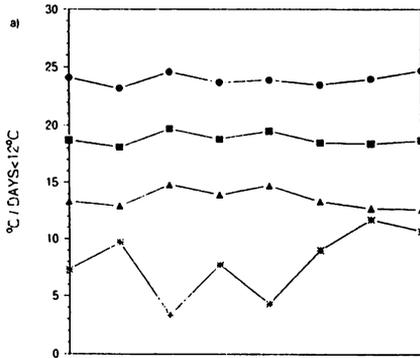


Figure 1. a) Average daily minimum ($\blacktriangle - \blacktriangle$), maximum ($\bullet - \bullet$) and mean ($\blacksquare - \blacksquare$) daily temperatures and number of days $< 12^{\circ}\text{C}$ minimum ($\circ - \circ$) in June, July and August combined, b) Estimated % flower panicle emergence: longan cultivars 'Beow Keow,' 'Kohala,' and 'Chompoo II,' 1984-1991 at Walkamin Research Station.

Flower panicles were evident in August, first flowers opened in early September, 50% flowering and fruit set occurred mid-September to mid-October. Flowering was completed by mid-October to mid-November. Fruit matured over the period late January to mid-March to early April. Phenological development was consistent from year to year.

Yield (Table 1)

All cultivars exhibited irregular cropping with distinct "on" and "off" years. At best there were four "on" years during the 9 year trial period. Only in 1991 did a number of cultivars have a significant return crop. In 1991 a significant proportion of the crop, especially on the Thai cultivars, was borne on panicles arising from old wood below where the previous season's panicle had been removed. In all other years, crops were borne on post harvest growth.

Highest yields occurred in 1990. Of the cultivars planted between 1978-1981 all but 'Homestead' had over 100 kg fruit/tree with 8 of the 10 cultivars planted between 1982-5 yielding in excess of 35 kg/tree.

Fruit Quality (Table 2)

Average fruit weight ranged from 5.3 g for 'Fa Hok Chai' to 11.0 g for 'Kay Sweeney.' 'Beow Keow,' 'Homestead,' 'Kay Sweeney' and 'Kohala' were the only selections to have average fruit weights in excess of 10 g. Except for 'Birch,' 'Fuhko 2' and 'Haew,' all cultivars had their lowest average fruit weight in 1990, the year of the heaviest crop (data not presented). 'Beow Keow' had a mean weight of 11.5 g in the other five years and 8.1 in 1990 while 'Chompoo I' had a mean weight of 6.4 in 1990 and 9.8 in the other five years of cropping. Similar weight reductions were noted for the other cultivars.

Table 1. Mean yield (kg/tree) and week of harvest of longan cultivars at Walkamin Research Station. Yields are means of 2 trees (\pm s.d.). Week of harvest is means of years (\pm s.d.).

Cultivar	planted	Year										Mean week of harvest
		1983	1984	1985	1986	1987	1988	1989	1990	1991	Mean	
<i>Trees planted 1978-81</i>												
Beow Keow	1979	0.5	3.9	7.6	55.6	0.0	72.6	9.1	311.3	60.0	57.8	9.9 (2.0)
Chien Liou	1980	0.0 (0.0)	0.12 (0.12)	4.8 (1.5)	3.5 (3.2)	-	-	-	-	-	2.1	9.7 (1.2)
Chompo I	1978	42.9 (3.6)	5.6 (5.5)	62.0 (14.1)	9.9 (4.9)	0.5 (0.5)	33.3 (12.8)	13.2 (7.3)	243.3	1.0	45.7	10.8 (1.3)
Chompo II	1979	0.5	0.0	5.6	66.2	3.6	10.5	30.0	568.1	25.0	78.8	8.3 (10.7)
Dang	1978	22.3	0.6	16.6	4.0	1.0	29.5	13.9	219.8	0.0	34.2	10.4 (1.6)
Daw	1979	0.0	0.14 (0.14)	1.6 (1.4)	0.7 (0.1)	0.6 (0.5)	2.6	5.0	15.0	-	3.2	8.5 (1.1)
Haew	1979	9.9 (4.7)	0.2 (0.2)	19.7 (8.7)	4.5 (3.5)	0.7 (0.4)	13.7 (0.3)	4.3 (4.3)	145.8 (1.5)	52.5 (47.5)	27.9	10.8 (2.0)
Homestead I and II	1981	-	0.3 (0.3)	0.9 (0.6)	23.2 (20.8)	0.6 (0.6)	18.1 (4.0)	0.7 (0.7)	39.3 (18.1)	15.0 (0.0)	12.3	4.2 (0.9)
Kohala	1980	1.4 (0.9)	1.7 (1.1)	19.5 (0.5)	21.2 (21.2)	8.8 (8.8)	41.8 (1.8)	0.1 (0.1)	111.0 (8.2)	3.5 (0.5)	23.2	4.3 (1.0)
<i>Trees planted 1982-85</i>												
Birch (Cardwell large)	1984				0.4	0.0	5.0	0.0	44.4	-	10.0	8.7 (1.7)
Duan Yu	1982		0.7	22.0	3.8	0.1	54.4	0.0	147.1	-	32.6	6.4 (0.9)
Fa Hok Chia	1984						5.0	0.2	46.4	0.5	13.0	4.7 (1.7)
Fuhko 2	1984						7.6	10.5	92.0	30.0	35.0	8.8 (0.8)
Iao	1983					4.1	17.5	1.0	77.7	15.0	23.1	3.8 (1.1)
Kay Sweeney	1983/4				0.6 (0.2)	0.0 (0.0)	10.5 (5.5)	0.6 (0.4)	69.7 (10.1)	17.5 (2.5)	16.5	4.5 (1.2)
<i>Trees planted 1978-81</i>												
Pon Yai	1982			0.3 (0.3)	5.2 (4.7)	0.0 (0.0)	1.4 (0.4)	0.7	36.3	5.0	7.0	6.1 (0.7)
Saig Geeb	1985						3.8 (2.8)	0.3 (0.3)	47.4 (19.5)	1.0 (1.0)	13.1	5.8 (0.2)
Shek Yip	1983						1.7 (0.7)	0.3 (0.3)	21.7 (7.4)	7.0 (1.0)	7.7	7.0 (0.0)
Wai	1983						2.4	5.0	14.0	5.0	6.6	6.7 (0.5)

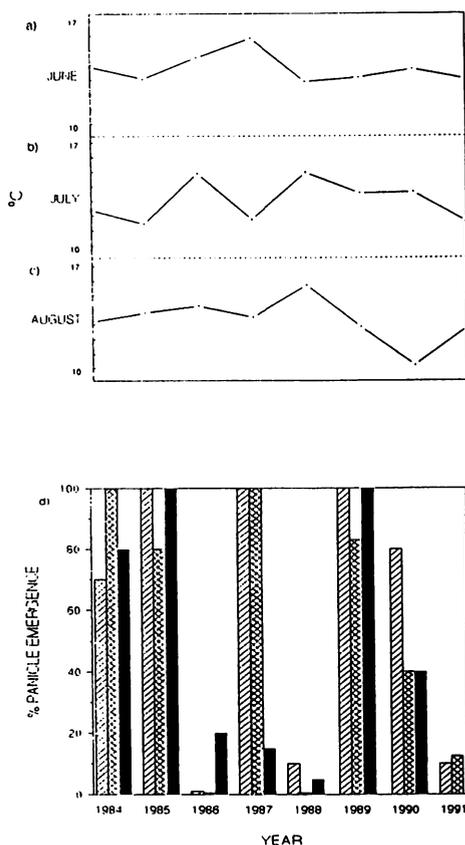


Figure 2. Mean daily minimum temperatures in (a) June, (b) July, (c) August and (d) Estimated % flower panicle emergence of longan cultivars 'Beow Keow' (▨), 'Kohala' (▩), 'Chompoo II' (■) and 'Chien Liou' (▤), 1984-1991 at Walkamin Research Station.

Mean flesh recovery (% aril) varied from 57.3% for 'Birch' to 70.2% for 'Kay Sweeney'. Most cultivars had recoveries between 60 and 65%.

Most cultivars were crisp-fleshed, the only exceptions being 'Chien Liou' and 'Duan Yu' (ex-Taiwan), 'Wai' (ex-Hawaii) and 'Birch' (local). Cultivars were sweet with a Brix of 16-21°, except for 'Chien Liou' (10.3°). The Thai cultivars in general had the best flavour and eating quality. The early season 'Kohala', 'Homestead' and 'Kay Sweeney' (ex-Florida) while having

an acceptable eating quality were considered inferior flavour-wise (sweetness) to 'Beow Keow', 'Chompoo I and II', 'Dang', 'Daw and Haew' (ex-Thailand) and 'Fukho 2', 'Ila'o' and 'Wai' (ex-Hawaii). 'Saig Geeb' and 'Shek Yip' lacked sufficient juice.

Fruit Size

Fruit were graded into five size categories:- Size 1 (> 32 mm); Size 2 (25 to 32 mm); Size 3 (22 to 25 mm); Size 4 (19 to 22 mm) and Size 5 (< 19 mm). Very few fruit fell into the size 1 category with only 'Kay Sweeney' having a significant number in this category (6%). Most fruit were sizes 2 and 3 although considerable cultivar variation occurred (data not presented). Size distribution of most lines were similar each year except for 1990 when most cultivars had their highest yield. In 1990 sizes were markedly reduced on 'Beow Keow', 'Chompoo I and II', 'Dang', 'Duan Yu', 'Ila'o', 'Kohala' and 'Pon Yai'. 'Kay Sweeney' also had a heavy crop but size was unaffected. Fruit size of 'Haew' and 'Homestead' were likewise unaffected but neither had more than a moderate crop when tree size was taken into account. With the 1990 figures excluded, only 'Beow Keow', 'Duan Yu', 'Kay Sweeney' and 'Kohala' had >50% of fruit Size 2 or larger. 'Birch', 'Chien Liou', 'Fa Hok Chai', 'Ila'o', 'Pon Yai' and 'Shek Yip' exhibited considerable year to year variation in size as they had a high proportion of fruit with small seeds and thus much reduced size in some years. 'Fukho 2' in 1990 and 1991 gave uniform size fruit (data not presented). The fruit were borne in open panicles and were clean compared with other cultivars which had tighter clusters.

Discussion

Yields

Cultivar differences in fruit yields were evident. 'Beow Keow', 'Chompoo I and II', 'Dang' and 'Haew' were the best yielders of the older group of

Table 2. Fruit characteristics of longan cultivars at Walkamin Research Station. Data are means of years (\pm s.d.).

Cultivar	Mean fruit			Flavor	Quality rating ^a
	Weight (g)	Aril (%)	Brix (°)		
Beow Keow	10.9 (0.7)	65.4 (0.4)	21.1 (0.3)	good, sweet, juicy, excellent	4
Birch (Cardwell large)	5.8 (1.2)	57.3 (1.5)	18.0 (2.3)	weak	1
Chien Liou ^o	8.5 (1.6)	58.4 (2.0)	10.3 (0.4)	lacking, watery	1
Chompoo I ^o	9.2 (0.5)	64.0 (1.0)	19.9 (0.5)	good, sweet	3
Chompoo II	8.3 (0.6)	62.6 (1.9)	20.6 (1.0)	good, sweet	2
Dang	9.0 (0.6)	62.9 (1.3)	20.1 (0.8)	sweet	3
Daw ^o	9.6 (0.4)	62.2 (1.1)	19.2 (0.5)	pleasant, sweet	3
Duan Yu	9.4 (0.8)	60.7 (1.1)	18.0 (0.6)	mild	2
Fa Hok Chai ^A	5.3	62.6	16.4		1
Fuhko 2	7.8 (0.3)	58.9 (1.2)	20.2 (1.2)	sweet, good	4
Haew ^o	9.1 (0.4)	63.0 (1.7)	20.5 (0.6)	sweet, good	3
Homestead ^o	10.2 (0.6)	64.3 (1.6)	16.2 (0.3)	mild	2
Ilao	8.9 (0.8)	67.4 (1.4)	20.6 (1.2)	sweet, good	2
Kay Sweeney ^o	11.0 (0.9)	70.2 (1.7)	16.4 (0.5)	mild	3
Kohala ^o	10.2 (0.6)	68.9 (1.4)	17.5 (0.3)	mildly sweet	3
Pon Yai ^o	8.7 (0.6)	64.4 (1.0)	20.2 (0.8)	sweet	2
Saig Geeb ^o	8.3 (1.1)	66.9 (0.7)	19.1 (1.6)	sweet, very dry	3
Shek Yip ^o	6.2 (1.3)	65.1 (0.4)	15.4 (0.6)	sweet, very dry	2
Wai	8.1 (0.3)	60.9 (0.1)	18.0 (1.2)	sweet	2

^aMean of 2 trees. ^A1 year only. ^bBased on size, flavour and texture 4 = excellent; 3 = good; 2 = fair; 1 = poor.

trees with 'Duan Yu' and 'Fuhko 2' the best yielders among those planted in 1982-5.

In 1990 most trees had markedly heavier crops than any other year, as nearly every terminal flowered and cropped. Crops were so heavy that several trees split and one fell over.

Yields of the better cultivars, excluding the exceptionally heavy crop in 1990, appear comparable with the averages of 14-28 kg per tree in Thailand, and 36 kg/tree in Fujian and 18 kg/tree in the Guangdong provinces of China (9). Yields are also comparable to Taiwan averages of 33 kg on 10 year old trees (9). Menzel *et al.* (9) reported that mature trees in Thailand can yield 120 kg and in Taiwan averages of 154 kg/tree can be obtained from 50 year old trees.

All cultivars cropped irregularly with good crops only about every 2nd or

3rd year during the trial period, which is consistent with data reported elsewhere (3, 4, 5). Campbell (4) stated that in Florida good crops occur about one year in four, while Watson (10) reported in Thailand that there is usually one poor, one fair and one excellent crop. Biennial cropping is also a problem in China (12).

Longan trees displayed similar cycles of fruiting across the district, supporting Campbell and Malo's (5) claim that climate is an important factor controlling flowering and cropping in Florida. The best flowering in Florida occurred after relatively cool winters (temperatures were not specified) with cultivar differences evident. Campbell and Malo (5) indicated that no research had been done to quantify the duration of "chilling" needed. However their Florida experience indicated that when temperatures in the 0-10°C range oc-

curred for relatively long periods in December to February (Southern Hemisphere, equivalent to June to August) and no frost injury occurred, then there was likely to be a good flowering. Flowering was usually poor after warm winters.

At Walkamin, inflorescences were evident in August with flowering occurring in September. The best panicle emergence generally occurred when June to August had extended periods of cool weather (daily minimum $< 12^{\circ}\text{C}$). There appeared no effect of mean and maximum temperatures on degree of panicle emergence (Fig 1 and 2). Except for 'Kohala,' there was a crop failure in 1987 (1986 winter). Temperatures in June, July and August were above normal with only ten days with minimum temperatures below 12°C and no extended cold period (i.e. > 3 to 4 days $< 12^{\circ}\text{C}$). In contrast 1990, the year of heaviest cropping, saw ten days of $< 12^{\circ}\text{C}$ in July 1989 and 12 in August even though the overall mean for July was 0.9°C above average. Most terminals initiated flowers. Many cultivars had a good return crop in 1991 following a cold winter (7 days in July and 20 in August $< 12^{\circ}\text{C}$). The crop, although not as heavy as the exceedingly heavy 1990 crop, occurred on trees which appeared to have depleted their reserves as evidenced by limited regrowth following harvest. After the cold winter, inflorescences developed even on older wood behind the previous year's panicle, indicating that longans can crop on older wood. Low temperatures failed to fully account for variation in cropping, suggesting other factors are also involved. For example, the 1990 heavy crop may have overridden effects of the cold winter in 1991. Winter conditions in 1991 were conducive to good flower induction, however, panicle emergence was $< 20\%$. No fertilizer had been applied following the previous harvest and plant reserves again appeared de-

pleted. Menzel *et al.* (9) stated that in Thailand, low winter temperatures appear to promote flowering with water stress being unimportant. At Nambour in southern Queensland, most cultivars flowered when mean daily minimum temperatures for the previous three months fell below 12°C . The results highlighted the difficulty of trying to define relationships between plant performance (yield) and climatic variability.

In 1987 'Kohala' had some crop when most other lines failed, collaborating early Florida reports which indicated 'Kohala' to be a more regular cropper than other cultivars (4, 5, 11). The other cultivars did not generally exhibit great variation in cropping ability, although 'Homestead' has yet to provide a heavy crop. 'Daw' flowered but did not set fruit, which was also noted at another trial site. This problem did not occur with any other cultivar and has not been mentioned in Thailand.

Fruit quality

Considerable differences exist in quality. 'Beow Keow,' 'Chompoo I and II,' 'Dang,' 'Daw,' 'Fuhko 2,' 'Haew,' 'Ilao,' 'Pon Yai,' 'Saig Geeb' and 'Shek Yip' were the sweetest and crispest cultivars. 'Homestead,' 'Kohala' and 'Kay Sweeney,' while crisp, are not as sweet. Knight *et al.* (7) stated there was a close relationship between TSS and subjective rating for flavour.

Fruit size

Fruit were smallest in 1990 when there was a heavy crop load. Knight *et al.* (7) found a relationship between individual longan fruit weights and yield per tree. Campbell and Malo (5) found fruit size to some extent genetically controlled and that some selections can have large fruit size even with a heavy crop. However, Campbell and Malo (5) further stated that when trees have a heavy crop load, fruit thinning, if done at an early enough stage, will increase fruit size. 'Beow Keow,' 'Dang,' 'Duan Yu,' 'Fuhko 2,' 'Haew,' 'Kay

Sweeney' and 'Kohala' were the only selections having > 80% commercial size fruit.

Acknowledgment

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Inbreeding in California Canning Clingstone Peach Cultivars

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Abstract

The inbreeding coefficients of commercially important canning clingstone peach [*Prunus persica* (L.) Batsch] cultivars developed in California were found to be relatively low based on pedigree analysis using the SAS INBREED procedure. However, coefficients of co-ancestry between the likely parents of future generations reveal an increasing probability of inbreeding. This increased probability is primarily the consequence of past usage of a small number of presumably unrelated parents in early crosses, and extensive use of their progeny as parents in subsequent crosses.

Introduction

Production of clingstone non-melting flesh peaches (*Prunus persica* (L.)

Batsch) in the central valley of California totalled 542,455 tons in 1992. Virtually all this production is for processing where requirements include high yields of good quality, uniform fruit, an absence of red anthocyanin pigmentation in fruit flesh (due to their water solubility and oxidative browning), and dependable supply of raw fruit from mid June through August. These needs, combined with the uniform, favorable growth environments in central California, have led to extensive utilization of locally-improved germplasm for the development of new cultivars.

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