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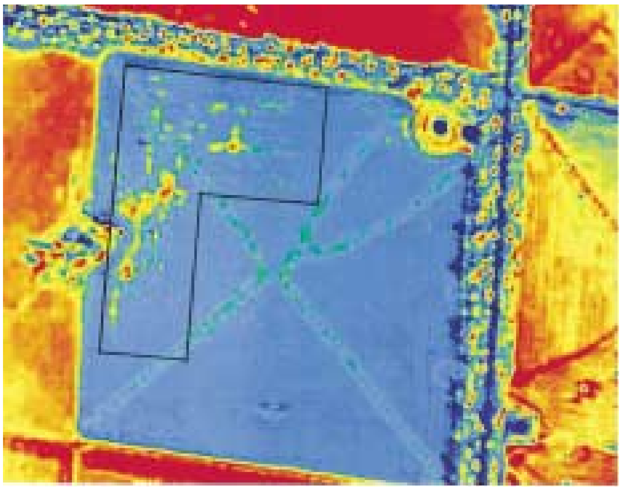

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Yield comparisons and cropping patterns of Kensington Pride mango selections

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Abstract. Thirty-three trees were identified from commercial orchards in Queensland during the 1990–91 and 1991–92 seasons to investigate the potential of improving the agronomic and fruit quality aspects of Kensington Pride mango. These selections were grafted and planted in a replicated field trial in the Burdekin district for comparative evaluation. Cropping characteristics were recorded annually until the trees reached 10 years of age. Small yield variations were observed between the selections, with no significant differences between the top 19 selections. No single selection had outstanding yields, however 2 selections had significantly lower yields than the rest.. These findings indicate the difficulty in significantly improving Kensington Pride mangoes through selection from existing commercial germplasm.

Sixteen of the best performing selections from the field trial were used as a top group to investigate the cropping characteristics of the cultivar. The average annual increase in yield and fluctuations from this average were modelled. The first significant crop was 15.7 kg per tree in year 4 and modelled yields increased by 23.3 kg per tree per year thereafter to year 10. There were significant annual fluctuations from the modelled trend with yields varying from between –44.7 to +35.7% of the expected yield. As fruit number per tree increased, average fruit weight decreased by 0.14g for every extra fruit.

Additional keywords: *Mangifera indica*, clonal selection.

Introduction

Kensington Pride has been the leading commercial mango cultivar in Australia over the last 50 years. The cultivar originated in the Bowen district of Queensland in the late 1800s (Stephens 1963; Meurant 1986; Johnson 2000) where it was recognised for its superior flavour and low fibre content. Kensington Pride soon spread to all mango growing districts of Australia, replacing the more fibrous Common cultivar to become the dominant commercial variety. Kensington Pride is polyembryonic, that is, the seeds have nucellar embryos that are genetically the same as the maternal parent, enabling them to be propagated from seed (Sturrock 1967). This attribute probably assisted in Kensington's rapid spread as a commercial variety. However, some polyembryonic cultivars of mango have a viable zygotic embryo (Sturrock 1967). Schnell and Knight (1991) reported the number of zygotic off types differing between cultivars, with up to 64% in Golek and as few as 0% in the Israeli cultivar, 13-1. The percentage of zygotic off types in Kensington Pride is unknown and the variation in phenotypes seen in commercial orchards, comprised of seedlings and grafted trees, may be partly due to genetic variation from the propagation of zygotic embryos.

Although Kensington Pride has maintained its dominance as the preferred commercial cultivar, its shortcomings have been recognised and erratic fruiting is the foremost of these limitations (Beal 1981; Whiley *et al*. 1989). Deficiencies in aspects of fruit quality have also been noted (Peterson 1982; Johnson *et al*. 1989; Catchpoole and Bally 1990; Bally 1995). Despite these shortcomings the superior flavour of Kensington has maintained its commercial appeal over many introduced varieties from around the world (Beal 1981; Winston 1984, 1993; Wright and Bally 1984). The continued dominance of Kensington and its low productivity has led many people to believe a program of genetic improvement was necessary to overcome some of the shortcomings of the variety (Watson and Winston 1984; Whiley *et al*. 1993).

Part of the debate over the genetic improvement of Kensington has been over the method to use: selection or cross breeding. Watson and Winston (1984) suggested that the industry practice of obtaining seed from processors for new plantings was regressive selection as much of the fruit supplied to processors was of inferior fruit quality. They suggested an extensive selection and evaluation program could overcome some of the variation seen in the variety. Iyer

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and Dinesh (1997) agree, suggesting clonal selection within cultivars is worth pursuing. In Kensington Pride, Johnson (1995) identified the selection 'KRS' as having a higher cumulative yield than 6 other selections in the same experiment and Mayers *et al*. (1984) reported the selection Grosszmann as having superior resistance to Bacterial Black Spot. In other polyembryonic cultivars, Singh and Chadha (1981) reported a clonal selection in the Indian cultivar Dashehari being more regular bearing and being less susceptible to malformation. Chaikiattyos *et al*. (1999) selected an improved clone of the Thai variety Kaew Sisaket with improved yield and fruit quality. In 1990, a project was set up to identify and select possible superior Kensington Pride clones and compare their performance in a single location under a single management regime. Bally *et al*. (1996) conducted early genetic evaluation of the selected trees in this project and found very little genetic variation between them. Fifteen of the selections did not differ in a single marker of the 107 scored, and only 2 (WEAN2 and ML2N1) out of the 31 tested displayed 5% dissimilarity. They concluded that only limited improvements were likely through selection alone and the introduction of genes through cross breeding may be the best way to improve the cultivar.

This paper reports on the yield characteristics of the same Kensington Pride selections. It reports on a comparative evaluation of yield and its components of the selections and then discusses the cropping patterns of the higher yielding selections over the first 10 years after field planting.

Materials and methods

During the 1990 and 1991 seasons, 33 potentially superior selections of the mango variety Kensington Pride were identified from responses to requests made to growers in Queensland's major mango-growing districts. Trees were selected on their reputed superior fruit quality and bearing or pest and disease tolerance (Bally *et al*. 1996). Although Kensington Pride is the most widely grown variety in Australia, no single selection can be considered as an industry standard, however the 3 named selections, Spooner, Bambaroo and Grosszmann included in the experiment have been selected and named in the past; Grosszmann for its bacterial black spot resistance, Spooner and Bambaroo for their blush colour. These selections were grafted onto uniform Kensington Pride rootstocks from a single source and planted in a field experiment at the Queensland Department of Primary Industries Ayr Research Station in the Burdekin delta (19°37´S, 14°22´E). The experimental site had a uniform soil with a 0.15–0.45 m dark clay loam fine sandy to light clay A horizon over a neutral brown to brown silty clay to light medium clay B horizon (McClurg 1986).

The experiment was designed as a randomised complete block design with 3 single tree replicates each of 33 Kensington Pride selections and 2 non-Kensington varieties. Trees were planted at a 10 by 10 m spacing. Two non-Kensington varieties were included, R2E2 as an industry standard being the second most widely grown variety and Royal Red a new local variety included to generate some comparison data with the industry standard varieties.

Fruit number and total yield per tree were measured for 8 years from the third year after field planting to year 10.

Statistical analysis

Comparative evaluation of the yields of Kensington seedlings was carried out by 2 methods. The first was an analysis of variance of the average yield, fruit weight and fruit number over the 7 years of cropping (year 4 to year 10). This analysis gives the performance of the strains over the whole period rather than on a year-to-year basis. Testing (l.s.d.) was performed to determine where the difference (if any) lay. The second analysis using a mixed model estimated by REML (Verbyl *et al*. 1999) was used to assess the year-to-year differences between the strains. This model was used to accomodate the non-independent errors (induced by repeatedly measuring the same experimental units). The l.s.d. was produced by using the average standard error of differences between strains.

A top group was formed by choosing the strains that did not seem to differ in average yield over the 10 years as well as strains that did not differ from the highest increasing yield strains on a year-to-year basis. Once this top group had been formed, a mixed model established by REML was constructed to assess the cropping on a year-to-year basis. This gave an indication of the production patterns of a developing orchard (up to 10 years) based on the best strains of Kensington Pride.

A mixed model using REML estimation was used to assess the relationship between average fruit weight per tree and fruit number produced by a tree. This model contained terms to adjust for the age of the tree as well as allowing for the error structure induced by repeatedly sampling the same trees.

Results

Comparison of Kensington Pride selections

Some trees started cropping in the third year after field planting (1993). Fruit numbers, however were low (about 5 kg per tree) and many trees did not have a crop. Analysis of the average tree yields over 7 years, from year 4 to year 10 after field planting, indicated that there were significant (P<0.001) differences between selections (Table 1). However no single selection stood out as having the highest average annual yield. There was no significant yield difference at the 5% level between the top 19 selections and l.s.d. groups had large overlap. Neither R2E2 nor Royal Red were in the top l.s.d. (P = 0.05) group. Two selections, TE1NT and WH1NT had significantly (5%) lower yields than all other selections

The yield by time (tree age) interaction in the mixed model varied significantly (P = 0.024) between selections, indicating the annulised rate of yield increase differed between selections. However, l.s.d. (P = 0.05) groups were large with 25 selections in the top group (Table 2).

Fruit number per tree, per year were significntly different when the average over the yielding period was considered (Table 3). No significant difference was observed between the top 13 selections. The annual increase in fruit number per tree was also significant, with no significant difference between 27 selections with the fastest rate of increase.

Average fruit weight significantly varied between selections over the 7 years measured. Amongst the Kensington selections, the l.s.d. groups were large, with no significant difference at the 5% level between the top 22 selections (Table 4). Average fruit weight generally decreased slightly over time, and the rate significantly varied between accessions. Again, l.s.d. groups were very large with 22 selections in the top group.

The 2 non-Kensington cultivars, R2E2 and Royal Red had significantly larger fruit than the Kensington selections and from each other (R2E2 = 806.9 g and Royal Red = 550.1 g, Table 4), however they both produced low fruit numbers (R2E2 = 89.3 and Royal Red = 85.0, Table 3).

Discussion of selection comparisons

Although significant differences were seen in yield, fruit number and fruit weight between selections, l.s.d. groups were large and overlapping with no significant difference between the top 19 highest yielding selections. Two selections (TE1NT and WHIN2) had significantly lower yields than the other selections (Table 1). TE1NT was selected for its round fruit shape and strong blush colour and was genetically similar to the other selections. WHIN2 was selected for its colour, flavour and lack of jelly seed. No genetic information is available for WHIN2 as it was not included in the genetic analysis (Bally *et al*. 1996). This result was not unexpected after the genetic analysis of the selections found they were very similar (Bally *et al*. 1996). The cultivar, Royal Red performed poorly in comparison to the Kensington selections. There were 25 Kensington

Table 1. Mean yields for 31 Kensington Pride selections and 2 non-Kensington varieties over 7 years, from 4 to 10 years after field planting

Means followed by the same letters are not significantly different at $P = 0.05$

Kensington selection	Mean yield (kg/tree.year)	l.s.d. groups
RORNT	95.73	a
REHNT	95.14	ab
VC4N2	94.05	abc
TE2NT	93.75	abc
WI2NT	90.73	abcd
MG1N2	89.45	abcd
GR1N2	88.81	abcd
WI1NT	85.45	abcde
BAMBAROO	83.51	abcdef
GROSMAN	82.10	abcdef
KRAN1	81.20	abcdef
NU1N2	80.13	abcdef
HA2N2	79.87	abcdef
TOBNT	79.68	abcdef
NASNT	78.88	abcdefg
MA1NT	78.61	abcdefg
ML2N1	77.86	abcdefg
NUCNT	77.48	abcdefgh
KANNT	77.45	abcdefgh
M18N2	76.21	bcdefghi
WI3NT	76.02	cdefghi
SPOONER	73.85	defghi
ML1N1	73.19	defghi
MA2NT	72.70	defghi
GR2N2	69.30	efghi
NU2N2	67.45	efghij
FITN2	67.00	efghij
R2E2[A]	66.65	efghij
WALNT	65.12	fghij
HA1N2	60.27	ghij
WEAN2	58.51	hij
GAMN1	57.65	ij
ROYAL RED[A]	48.57	j
TE1NT	16.55	k
WHIN2	16.31	k
l.s.d. = 18.98		

[A]Not Kensington Pride.

Table 2. Rate of yield increase in Kensington selections between the 4th and 10th year after planting

Means followed by the same letters are not significantly different at $P = 0.05$

Kensington selection	Rate of yield increase (kg/year)	l.s.d. group
BAMBAROO	28.86	a
GR1N2	27.02	ab
KRAN1	26.00	ab
VC4N2	25.54	ab
MG1N2	25.50	ab
TE2NT	24.43	abc
M18N2	23.94	abc
RORNT	23.54	abc
WI2NT	23.52	abc
KANNT	22.85	abcd
ROYAL RED[A]	22.39	abcd
NU2N2	21.89	abcd
GR2N2	21.38	abcd
NU1N2	21.36	abcd
GROSMAN	21.22	abcd
SPOONER	21.22	abcd
ML2N1	21.15	abcd
NUCNT	20.38	abcd
WI3NT	20.30	abcd
WI1NT	20.16	abcd
TOBNT	19.95	abcd
ML1N1	19.92	abcd
R2E2[A]	19.06	abcd
MA2NT	17.93	abcd
NASNT	17.48	abcd
HA1N2	17.26	bcd
HA2N2	17.23	bcd
REHNT	16.83	bcd
FITN2	16.76	bcd
WALNT	15.91	bcd
MA1NT	15.50	bcd
WHIN2	13.45	cd
WEAN2	13.23	cd
GAMN1	11.90	cd
TE1NT	1.27	e
l.s.d. = 11.75		

[A]Not Kensington Pride.

selections with significantly higher mean yields than Royal Red. Although Royal Red's average fruit size was large (550.1 g) the low fruit numbers per tree (85.0) reduced its overall yield. R2E2 had the highest average fruit weight (806.9 g) of all selections, although yields were lower than Kensington Pride selections because of low fruit numbers per tree. There were 7 Kensington selections with significantly higher mean yields than R2E2.

The large overlapping l.s.d. groupings amongst the Kensington selections indicates that the yielding potential of many of the selections is similar and identification of significantly superior yielding lines was not possible. A group of 16 Kensington selections can be considered to be the better performers — RORNT, BAMBAROO, REHNT, GROSSZMANN, VC4N2, KRAN1, TE2NT, NU1N2, WI2N2, HA2N2, MG1N2, TOBNT, GR1N2, ML2N1, WI1NT, NUCNT. All accessions in this group were in the top l.s.d. (P = 0.05) groups for average yield and yield increase over the 7 years measured. However, the large overlapping of l.s.d. groups suggests that this top group represents the better selections amongst a very uniform group.

This paper has only discussed the yield characteristics of selections, no detailed fruit quality evaluations have been carried out. However, in general very little difference was observed in fruit shape or colour during the annual

Table 3. Average fruit number per tree per year over the 7 years from the 4th to the 10th year after field planting

Means followed by the same letters are not significantly different at P = 0.05

Kensington selection	Fruit number (number/tree.year)	l.s.d. group
TE2NT	257.4	a
REHNT	254.7	ab
VC4N2	246.2	abc
MG1N2	240.6	abcd
WI2NT	234.6	abcde
KRAN1	229.1	abcdef
HA2N2	228.1	abcdefg
RORNT	227.6	abcdefg
NASNT	224.9	abcdefg
GR1N2	222.1	abcdefg
NU1N2	213.5	abcdefgh
WI1NT	213.1	abcdefgh
GROSMAN	207.6	bcdefghi
BAMBAROO	205.2	cdefghi
TOBNT	199.4	cdefghi
MA1NT	195.3	defghij
SPOONER	191.3	efghijk
GR2N2	188.1	efghijk
NUCNT	187.9	efghijk
M18N2	187.1	fghijk
ML2N1	184.8	fghijk
KANNT	184.2	fghijk
WI3NT	182.7	fghijk
ML1N1	181.4	ghijk
MA2NT	170.8	hijkl
FITN2	166.4	hijkl
NU2N2	160.6	ijkl
WALNT	153.8	jkl
GAMN1	153.0	jkl
WHIN2	152.6	jkl
HA1N2	147.9	kl
WEAN2	129.2	lm
R2E2[A]	89.3	m
ROYAL RED[A]	85.0	m
TE1NT	37.2	n
l.s.d. = 47.34		

[A]Not Kensington Pride.

Table 4. Average fruit weight over 7 years from the 4th to the 10th year after field planting

Means followed by the same letters are not significantly different at P = 0.05

Kensington selection	Average fruit wt (g)	l.s.d. group
R2E2[A]	806.9	a
ROYAL RED[A]	550.1	b
TE1NT	452.9	c
HA2N2	451.0	cd
MA2NT	449.5	cd
WALNT	448.6	cde
ML2N1	444.8	cde
M18N2	442.9	cdef
KANNT	441.9	cdef
RORNT	439.0	cdefg
WEAN2	439.0	cdefg
FITN2	434.3	cdefgh
NU2N2	433.3	cdefgh
WI3NT	428.1	cdefghi
WI1NT	426.2	cdefghi
BAMBAROO	425.5	cdefghi
GR1N2	422.4	cdefghi
VC4N2	418.6	cdefghij
MA1NT	417.6	cdefghij
NUCNT	417.1	cdefghij
TOBNT	415.2	cdefghij
WI2NT	412.9	cdefghij
GROSMAN	409.5	cdefghij
ML1N1	409.0	cghij
SPOONER	402.4	defghij
GR2N2	400.5	efghij
NU1N2	395.2	fghij
TE2NT	391.0	ghij
MG1N2	391.0	ghij
REHNT	390.0	hij
HA1N2	382.4	ij
KRAN1	382.4	ij
NASNT	380.5	ij
GAMN1	370.1	j
WHIN2	147.3	k
l.s.d. = 48.79		

[A]Not Kensington Pride.

harvesting. One exception was the accession WEAN2, which displayed darker green skin and a strong turpentine smell, and was selected for its late maturation. WEAN2 was 1 of the 2 selections that had a genetic dissimilarity of 5% (Bally *et al*. 1996). The other was ML2N1, that had a similar appearance to the other selections

The relative uniformity between the Kensington selections prevented the selection of better yielding genotypes and supports the earlier findings (Bally *et al*. 1996) that there is little significant genetic variation between selections.

These findings are somewhat at variance with those of Johnson (1995) who identified the Kensington Pride selection KRS as having significantly higher average yield than 6 other selections tested. However, as KRS was selected in a different region and was not included in this experiment, comparisons between the 2 are difficult.

General yielding patterns of Kensington Pride

The cropping characteristics of the top group of 16 trees have been analysed to gain an understanding of general cropping patterns of a young Kensington Pride mango orchard.

As trees grew from year 4 to year 10, there was a significant straight line trend in yield of 23.34 kilograms increase per tree per year. Around this trend, significant annual fluctuations were measured (Fig. 1). This irregular bearing pattern from year to year is typical of Kensington Pride and has been noted as one of the major limitations of the variety (Beal 1981; Johnson 1995; Whiley *et al*. 1988). The size and direction of these random fluctuations did not vary significantly between the selections in the top group. The reasons for the annual variations in yield cannot be fully explained by the observations made in the experiment. However, some of the variation may be explained by the number of terminals flowering. In 1998, a low-yielding year, the average percentage of terminals flowering was 22% compared with 91% in 1997 and 97% in 1999. Other factors such as previous crop load, tree health, pruning levels or disease may also have contributed to variations in yield. The effect of previous crop load was difficult to measure as the trees were less than 10 years old and were still increasing in size annually. The low-yielding year, 1998, demonstrated that in poor years, yields could be 47.7% below the expected annual average. The low and high yielding years were common to all trees in the experiment, including the non Kensington selections (R2E2 and Royal Red), suggesting that environmental and not genetic factors are mainly responsible for the variation.

Tree yields are a result of 2 factors, total number of fruit and average fruit weight. Fruit number per tree increased significantly over time with a linear relationship of 61.69 fruit per tree per year. Similar to yield, fruit numbers also had significant random fluctuations around the trend line from year to year (Fig. 2). The number of fruit per tree was the greatest contributor to yield as average fruit weight varied only slightly and was not significant However, there were significant random fluctuations in fruit size (Fig.3).

The analysis of the relationship between average fruit weight and fruit number per tree showed that as fruit number increases, individual fruit weight decreases. This

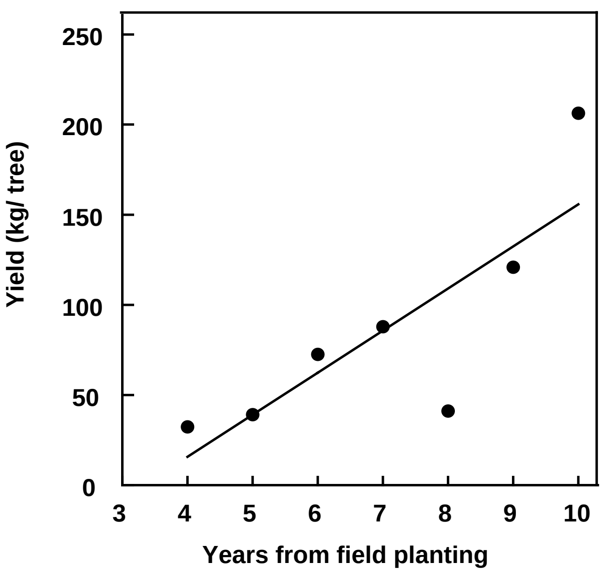

Figure 1. Annual yield of Kensington Pride. The data points are the fitted mean yields from 3 replicates of 16 selections. The line represents the modelled linear increase in yield per year (y = –77.69 + 23.30 × year, $P = 0.002$).

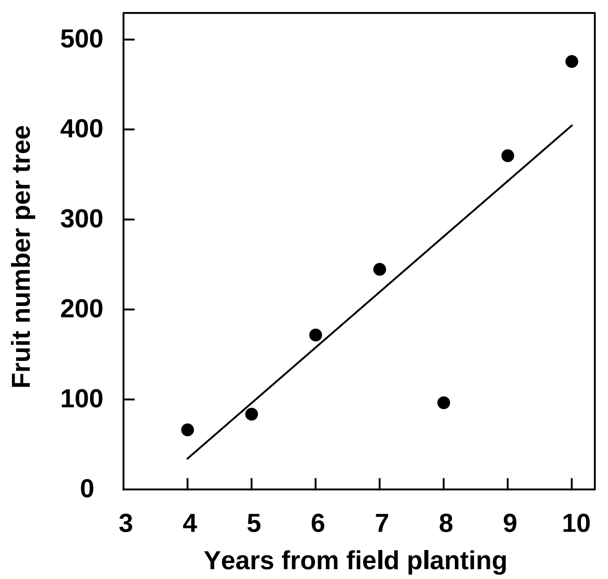

Figure 2. Fruit number per tree. The data points are the fitted mean fruit number per tree from 3 replicates of 16 high yielding selections of Kensington Pride mango. The line represents the modelled linear increase in fruit number per tree per year (y = –212.53 + 61.69 × year, $P = 0.001$).

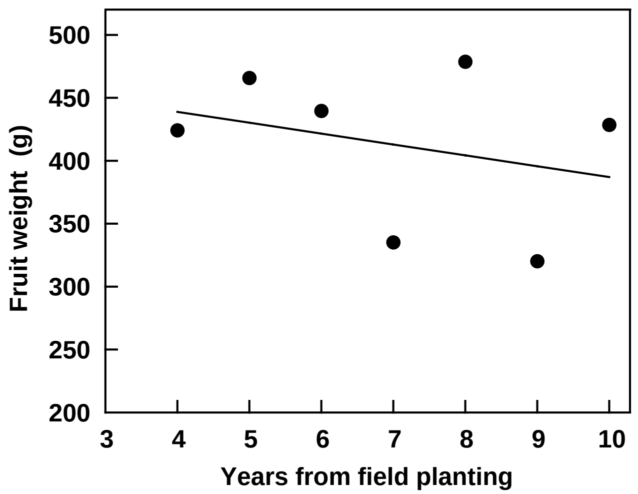

Figure 3. Average fruit weight; the data points are the fitted mean fruit weight from 3 replicates of 16 Kensington Pride mango selections. The line represents the modelled linear increase in average fruit weight per year ($y = 0.47 - 0.008 \times$ year, n.s., $P = 0.48$).

relationship was linear ($P = 0.002$) with a slope of –0.14. This was equivalent to a reduction in average weight of 14 g for every extra 10 fruit per tree.

The yields presented here are higher than many commercial orchards in Queensland and, although this group of trees were selected as the better trees in the industry, their yields indicate the potential for improvement in young developing Kensington Pride orchards. Meurant *et al*. (1999) suggested that commercial yields in mangoes of 8–12 years old are between 20 and 200 kg/tree with a typical orchard producing about 84 kg of fruit/tree from year 8 onwards. The yields of the top group of Kensington selections in this experiment are at the top end of this range, with predicted yields of 109.4, 132.4 and 155.7 kg/tree in years 8, 9 and 10, and actual yields of 41.0, 120.8 and 206.2 kg/tree in years 8, 9 and 10 (Fig. 1).

When these cropping patterns were converted to a per hectare basis (100 trees/ha) the following yields were achieved: In year 3, some trees started to crop with an average yield of 423 kg/ha. Expected yields in year 4 were 1551 kg/ha (15.51 kg/tree) with an annual increase of 2334 kg/ha.year until year 10 when yields were 15531 kg/ha. Ten-year-old trees had an average height of 5 m with a 6.2 m canopy diameter. Random fluctuations in yield, from 105% above to 45% below expected yield, can occur from year to year.

Conclusion

The yield differences among the Kensington Pride selections were not sufficient to select 1 or 2 accessions as superior, however a group of the best 16 selections has been identified. The low variability among the selections suggests that selection within existing Kensington Pride populations is unlikely to be a tool to improve the cultivar, and crossbreeding with other cultivars is more likely to generate improvements. However, clonal selection may be useful to evaluate some of the poor yielding types.

The cropping patterns of the top group of Kensington selections demonstrated the annual growth in yield of a young developing orchard. Large variations in cropping between years can be expected.

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