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Growth, yield and scion–rootstock interaction effects of the custard apple in south-east Queensland

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Summary

The growth and yield of African Pride and Pink's Mammoth custard apple cultivars were evaluated for two rootstocks under the subtropical environment of south-east Queensland. The African Pride cultivar was a much more precocious bearer than Pink's Mammoth. In the sixth year after planting, the mean marketable yields for African Pride were 18.7 t/ha on cherimoyer rootstock and 9.2 t/ha on sugar apple. In comparison, the Pink's Mammoth cultivar produced 7.2 t/ha on cherimoyer rootstock and 6.2 t/ha on sugar apple. The experiment demonstrated that satisfactory yields can be obtained with the African Pride cultivar without the need for hand pollination. Although the sugar apple rootstock exhibited dwarfing characteristics this species cannot be recommended due to the higher susceptibility to bacterial wilt, *Pseudomonas solanacearum*. The tendency to biennial bearing with some high yielding trees indicates that management factors such as thinning and fertilising need to be more fully evaluated. The wide variability in yield and growth on seedling rootstocks indicates the necessity to produce cultivars on their own roots (propagated by cuttings) or to clonally propagate rootstocks.

INTRODUCTION

The custard apple or atemoya, *Annona squamosa*×*A. cherimola* has the potential to become a major horticultural crop, however, the fruit is little known outside Queensland. A small commercial industry based on this species has developed in coastal, subtropical areas of Oueensland and northern NSW. Other countries, including California, Chile and Spain have developed commercial industries on a closely related species, the cherimoyer, *A.cherimola*, however, this species suffers from poor pollination and fruit set problems (Schroeder 1970). With the cherimoyer, hand pollination is currently the only effective method of ensuring good fruit set.

The atemoya is a hybrid between the cherimoyer and the sugar apple *Annona squamosa* (Wester 1915; Gandhi and Gopalkrishna 1957). The cherimoyer is indigenous to the subtropical highlands of Peru and Ecuador while the sugar apple is found widely throughout the tropical lowlands of northern South America and the West Indies (Popenoe 1974). Climatic requirements for growth and fruit maturation in atemoya are intermediate to the parent species.

A scarcity of information exists on environmental and management factors affecting productivity and fruit quality of atemoya in the subtropical environment of south-east Queensland. This experiment was initiated to evaluate the yield and growth performance of the two main cultivars currently grown in Queensland and to determine if these cultivars would set commercial crops without the need for hand pollination. Due to the influence of rootstock on scion performance, the two main rootstock species used in this region, cherimoyer and sugar apple, were also evaluated.

MATERIALS AND METHODS

Site

The experiment was initiated in October 1977 at the Maroochy Horticultural Research Station at Nambour, Queensland (26°37′S, elevation 80 m). The experiment was located on a yellow podzolic soil type, with a sandy loam surface layer overlying a sandy clay subsoil at a depth of 500 mm. Rows were mounded to give a soil depth of 1000 mm along the rows to a width of 2 m.

Climatic data

The region has a mean annual temperature of 19.5°C and a mean annual rainfall of 1797 mm with 60% of this falling from December to March. Mean monthly temperatures and rainfall for the flowering and fruit maturation periods for the four cropping seasons are presented in Table 1.

Table 1. Mean monthly temperature and rainfall recorded during the four cropping seasons

Period	Mean min. temperature (°C)	Mean max. temperature (°C)	Rainfall (mm)
Flowering			
October	13.2	25.9	78
November	16.4	27.9	111
December	19.0	29.9	144
January	19.8	29.4	288
Fruit maturation			
February	19.6	29.2	150
March	18.0	28.5	122
April	15.1	26.6	145
May	13.3	23.6	273
June	8.3	21.0	156

Experimental design

The experiment was a 2×2 factorial in a randomised block design with ten single tree replications. The treatments were scion–rootstock combinations of the two cultivars, Pink's Mammoth and African Pride and two rootstock species, cherimoyer (*A. cherimola*) and sugar apple (*A. squamosa*). The trees were guarded externally. The experiment was terminated before interplant competition became apparent.

Crop establishment

Plant sites were prepared by the addition of superphosphate at 0.45 kg/m^2. Dolomite was broadcast over the whole area at 7.5 t/ha. Trees were spaced 5.5 m apart in the row with 6.0 m between rows, giving a density of 300 trees/ha. Rootstocks were grafted in the field in September 1977.

Cultural practices

Irrigation. During the first three years of the experiment all trees were irrigated using a microjet irrigation system supplying 18 L/hour to each tree from two microjets. In September 1980, this system was converted to an under tree sprinkler irrigation system supplying 53 L/hour from one sprinkler outlet per tree. Water was applied twice weekly with the quantity equal to 80% of evaporation from a class A pan over the foliage plan area of the canopy. Rainfall was taken into account but falls of 5 mm or less were ignored.

Nutrition. All trees received four equal applications of fertiliser per year, in September prior to bud-break, in December and January during the peak growth period and in March, prior to harvest. Total rates of major elements applied per tree per annum increased gradually from 100 g N, 30 g P, 80 g K in 1977–78 to 550 g N, 180 g P, 750 g K in 1982–83. The major elements were applied as ammonium nitrate, potassium sulphate and single superphosphate.

Defoliation and pruning. During the pre-cropping phase all trees were lightly pruned in September, at the commencement of leaf abscission and again in mid November and

January, during the growing period. Once trees began cropping (1980) summer pruning was discontinued. All trees were defoliated in early September using 0.5 mL/L ethephon plus wetter, to encourage the development of small fruit-bearing laterals.

Weed control. In September of each year, trees were mulched along the row with the sugar mill by-product, bagasse, applied in a one metre wide strip 80 mm deep. Weeds along the edge of the mulched strip were controlled with paraquat spot sprays and the inter-row area was mown six times a year.

Pest and disease control. During the 1981, 1982, 1983 harvest seasons, one methidathion spray at 0.5 mL/L was applied for the control of soft brown scale (*Coccus hesperidum*). During the 1983 harvest period, one mancozeb spray at 4 g/L was applied for the control of phomopsis (*Phomopsis anonacearum*).

Measurements and biometrical analyses

Trunk girth measurements. Trunk girth 30 cm above ground was measured prior to bud-break each year. Butt cross-sectional areas were determined from this measurement.

Crown radius. Crown radius (r): the mean of radial measurements taken in east-west, north-south directions.

Tree canopy volume. Tree canopy volume was calculated from the formulae for determining the volume of a half sphere which is the approximate shape of custard apple trees.

$$\text{Volume of half sphere} = \tfrac{1}{2} \times 4/3\ r^3 \quad (r = \text{crown radius}).$$

A similar method to determine tree volume in citrus and peaches is described by Culver and Till (1967).

Number of weak laterals. The number of weak laterals (<0.5 m length and having a base circumference of between 20 and 40 mm) was counted in the south-west quadrant of the trees. A close correlation (r= 0.95) exists between the number of laterals counted in this quadrant and the total number of laterals per tree. The estimated total number of weak laterals per tree was determined from this measurement.

Number of strong leaders. The number of strong leaders (>1 m in length and having a base circumference >60 mm) was counted in the south-west quadrant of the tree. A close correlation (r=0.93) exists between the strong leaders counted in this quadrant and the total number of strong leaders per tree. The estimated total number ofstrong leaders per tree was determined from this measurement.

Yields. Trees were harvested either weekly or fortnightly, depending on fruit maturity, with treatments requiring up to 10 picks. Fruit were judged as unmarketable according to one of the following criteria:

a) fruit weight <300 g;
b) overripe and soft;
c) 10% superficial skin damage on fruit surface;
d) splitting or growth cracks present on fruit.

The number of unmarketable fruit was recorded for each season. Mean marketable fruit weights and mean harvest times were determined for the four cropping seasons. Other derived data included yield per cross-sectional area of butt and percentage marketable fruit weight.

RESULTS

Tree growth and morphological characteristics

The dwarfing characteristics of the sugar apple rootstock for both custard apple cultivars is demonstrated in Tables 2, 3 and 4. The annual tree growth increment for both cultivars is markedly less for the sugar apple stock than for the cherimoyer (Table 2). A larger number of fruiting laterals were produced by the African Pride cultivar, particularly on the cherimoyer rootstock, over all cropping seasons (Table 3).

Table 2. Tree canopy volumes

Cultivars	Rootstock	Tree Canopy Volumes (m^3)			
		1980	1981	1982	1983
Pink's Mammoth	cherimoyer	10.50	25.97	44.90	54.23
	sugar apple	7.75	18.52	26.76	31.15
African Pride	cherimoyer	7.00	21.06	34.06	48.54
	sugar apple	10.73	12.01	13.61	19.05
	rootstock × years				
l.s.d. (P=0.05)	6.37				
(P=0.01)	8.42				

Table 3. Estimated number of weak fruiting laterals per tree (extrapolated values taken from data of the SW quadrant)

Cultivars	Rootstock	No. of weak laterals per tree		
		1981	1982	1983
Pink's Mammoth	cherimoyer	128	301	360
	sugar apple	161	272	269
African Pride	cherimoyer	371	486	565
	sugar apple	230	373	285
	rootstock × years	cultivar × rootstock		
l.s.d. (P=0.05)	72	59		
(P=0.01)	95	78		

The number of strong leaders was recorded as a measure of tree vigour and juvenility (Table 4). A significantly higher number of strong leaders was produced by the Pink's Mammoth cultivar in the 1981 and 1982 years, particularly on the cherimoyer rootstock (P=0.01).

Table 4. Estimated number of strong leaders per tree (extrapolated values taken from data of the SW quadrant)

Cultivars	Rootstock	No. of strong leaders		
		1981	1982	1983
Pink's Mammoth	cherimoyer	72	78	16
	sugar apple	27	22	6
African Pride	cherimoyer	27	42	10
	sugar apple	1	2	1
	cultivars × years	rootstock × years		
l.s.d. (P=0.05)	17	17		
(P=0.01)	22	22		

Yield performance

The African Pride cultivar was a more precocious bearer than Pink's Mammoth, and produced significantly higher accumulated yields over the first four cropping years (Tables 5 and 6, *P*=0.01). Although both cultivars were initially more precocious on the sugar apple rootstock, in later years the cherimoyer rootstock produced superior yields especially with the African Pride cultivar (*P*=0.01). The yield differences within cultivars on different rootstocks were less pronounced when compared on a butt cross-sectional area basis (Table 7). No significant differences were recorded between rootstocks for this parameter in the 1982 and 1983 cropping years (*P*=0.05). The yield per butt cross-section area of the African Pride cultivar declined in the 1983 cropping year.

Table 5. Fruit numbers per tree

Cultivar	Rootstock	Mean fruit number per tree				
		1980	1981	1982	1983	Accumulated
Pink's Mammoth	cherimoyer	1.2	8.0	31.6	69.5	110.3
	sugar apple	2.5	37.6	25.6	60.5	126.2
African Pride	cherimoyer	42.2	228.4	301.1	356.9	928.6
	sugar apple	63.0	242.9	200.0	206.1	712.0

	cultivar × rootstock	cultivar × years	rootstock × years	cultivar
l.s.d. (*P*=0.05)	30.46	43.08	43.08	659.33
(*P*=0.01)	40.24	56.91	56.91	1193.28

Table 6. Fruit weights per tree

Cultivar	Rootstock	Mean annual yield per tree (kg)				
		1980	1981	1982	1983	Accumulated
Pink's Mammoth	cherimoyer	0.48	3.85	18.87	29.44	52.64
	sugar apple	0.98	16.59	15.85	25.24	58.66
African Pride	cherimoyer	13.66	58.57	91.63	93.13	256.99
	sugar apple	21.50	50.85	55.36	55.36	179.17

	cultivar × years	rootstock × years	cultivars × rootstocks	cultivar × rootstocks
l.s.d. (*P*=0.05)	11.59	11.59	8.19	110.23
(*P*=0.01)	15.32	15.32	10.83	n.s.

n.s. not significant

Marketable fruit weights per tree are presented in Table 8. Accumulated marketable yields were highest for the African Pride cultivar on cherimoyer rootstock (*P*=0.01). Over all cropping years the percentage of marketable fruit weights was significantly higher for the Pink's Mammoth compared with African Pride cultivar, that is 80 compared with 63% (*P*=0.01). Although no significant differences were recorded in percentage of marketable fruit weights for the Pink's Mammoth cultivar on different rootstock lines, the African Pride cultivar had a higher percentage of marketable fruit weights on cherimoyer than on sugar apple rootstocks that is 65% compared with 60% (*P*=0.01).

Table 7. Yield per butt cross-sectional area

Cultivars	Rootstock	Yield per butt cross-sectional area g/cm²			
		1980	1981	1982	1983
Pink's Mammoth	cherimoyer	8.08	48.2	169.98	171.74
	sugar apple	20.84	202.32	148.79	184.59
African Pride	cherimoyer	210.50	601.23	703.45	547.50
	sugar apple	390.59	682.71	646.64	485.65

	cultivar × year	rootstock × year
l.s.d. (P=0.05)	80.16	80.16
(P=0.01)	105.89	105.89

Table 8. Marketable fruit weights per tree

Cultivar	Rootstock	Marketable fruit weight per tree (kg)				
		1980	1981	1982	1983	Accumulated
Pink's Mammoth	cherimoyer	0.48	3.47	13.93	23.76	41.64
	sugar apple	0.96	14.16	11.95	20.42	47.49
African Pride	cherimoyer	11.63	34.28	60.03	61.79	167.73
	sugar apple	18.69	21.23	37.35	30.50	107.77

	cultivar × rootstock	cultivar × years	rootstock × years	cultivar × rootstock
l.s.d. (P=0.05)	5.50	7.78	7.78	31.01
(P=0.01)	7.27	10.28	10.28	56.11

Tree growth and yield relationships

For the African Pride cultivar, a linear relationship between fruit set and both tree volume and small fruiting lateral numbers was evident (Figures 1 and 2). For Pink's Mammoth, the relationship between fruit set and these parameters was non-significant.

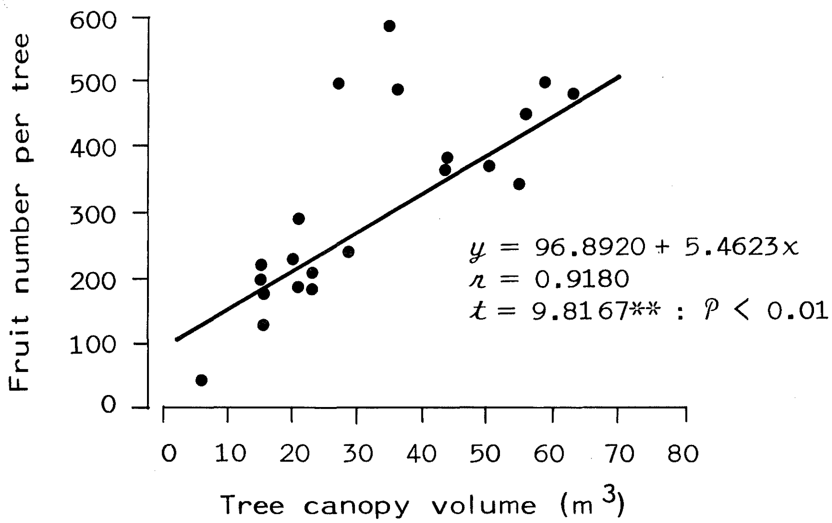

Figure 1. The relationship between fruit numbers and canopy volumes for the African Pride cultivar.

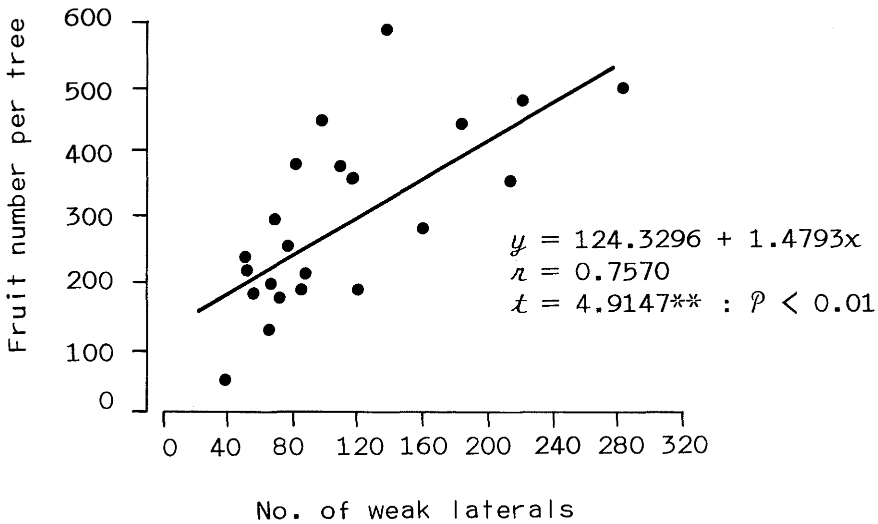

Figure 2. The relationship between fruit numbers and number of weak laterals for the African Pride cultivar.

The cropping characteristics of selected African Pride trees are presented in Figure 3. The graphs illustrate the high variability in individual tree performance and the tendency towards biennial bearing in high yielding trees.

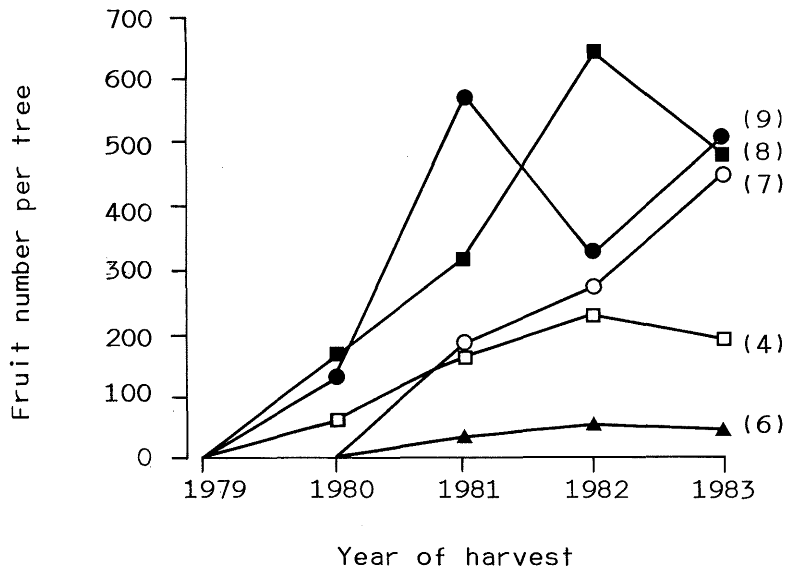

Figure 3.The relationship between fruit number per tree and year of harvest for selected African Pride trees.

DISCUSSION

The experiment demonstrated the precocity of bearing of the African Pride cultivar, particularly on the cherimoyer rootstock. The mean marketable yields in 1983 for the African Pride cultivar were 18.7 t/ha on cherimoyer rootstock and 9.2 t/ha on sugar apple.

The Pink's Mammoth cultivar was less precocious bearing, and in 1983 produced 7.2 t/ ha on cherimoyer rootstock and 6.2 t/ha on sugar apple. Higher yields in the 1983 season could probably have been achieved, because dry conditions during the peak flowering months of November and December reduced fruit set. In many studies, low humidities and high atmospheric stress have been shown to be causes of poor set unless flowers are hand pollinated (Schroeder 1970).

Although both cultivars were initially more precocious bearing on the sugar apple rootstock, by the 1982 and 1983 cropping seasons significantly higher yields per tree (P=0.01) were being obtained on cherimoyer rootstocks. However, when yields were compared on a butt cross-secional area basis, a measure of yield efficiency or fruitfulness (Westwood and Roberts 1970), no significant differences were recorded between rootstocks in the 1982 and 1983 seasons, although the trend was towards higher yield efficiency on the cherimoyer rootstock.

The dwarfing characteristics of the sugar apple rootstock are probably due to the poor adaptability of this tropical species to the cool subtropical environment of south-east Queensland, rather than due to any incompatability problems. It is suspected that under subtropical conditions the sugar apple rootstock has a shorter growing season. With increasing crop load in successive cropping years, the trees on this rootstock became progressively weaker. Although no tree mortalities were recorded during the experiment, 30% of the trees on the sugar apple rootstock died within twelve months of the completion of the experiment. Bacterial wilt caused by *Pseudomonas solanacearum* has been identified as the cause of tree death (Mayers, pers. comm. 1983).

The African Pride and Pink's Mammoth cultivars exhibit marked differences in growth habits, flowering and pollination mechanisms. Most custard apple cultivars bear fruit mainly on the basal sections of newly emerging vegetative laterals with most fruit set occurring on laterals with a base circumference of 20 to 40 mm. Excessively vigorous or weak laterals fail to set fruit. In the African Pride cultivar a strong linear relationship exists between the number of weak laterals and fruit set (Figure 2). The number of weak laterals increases as the trees grow in size. This accounts for the close relationship which also exists between tree volume and fruit set (Figure 1).

By comparison, the Pink's Mammoth cultivar exhibits a long period of juvenility (6 to 8 years from planting). This cultivar produces strong apically dominant leaders (Table 4) and fewer weak laterals (Table 3). The poor relationship which was found between the number of weak laterals and fruit set in this cultivar may be due to a higher level of small fruitlet abscission caused by strong competition from vigorously growing terminals. Besides differences in growth habits, the effective pollination percentages for Pink's Mammoth are much lower than they are for African Pride, that is 1% compared to 3%.

The tendency to biennial bearing with some high yielding African Pride trees is also evident (Figure 3). This problem may have been reduced to some extent through fruit thinning and increased rates of fertiliser applied to the higher yielding trees. It is also apparent that considerable variations in growth (cv. 50%) and yield (cv. 65%) exist within cultivars on seedling rootstocks, due to differences in the seedling rootstocks. Such variability was unexpected and suggests that the rootstock has a major influence on scion behaviour.

CONCLUSIONS

The experiment demonstrated that satisfactory commercial yields can be obtained with the African Pride cultivar without the need for hand pollination. The sugar apple rootstock could have proved valuable as a dwarfing rootstock except that this species was more susceptible to bacterial wilt. At present, the cherimoyer is the only rootstock species recommended for use in commercial planting in south-east Queensland. The tendency to biennial bearing with high yielding trees indicates that management factors such as thinning and fertilising need to be more fully evaluated. The variability in yield and growth performance on seedling rootstocks also indicates the necessity to produce cultivars on their own roots (propagated by cuttings) or to clonally propagate rootstocks.

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