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Field Evaluation of 64 Rootstocks for Growth and Yield of 'Kensington Pride' Mango

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***Abstract*. Despite an abundance of polyembryonic genotypes and the need for rootstocks that improve scion yield and productivity, simultaneous field testing of a wide range of mango (*Mangifera indica* L.) genotypes as rootstocks has not previously been reported. In this experiment, we examined the growth and yield of 'Kensington Pride' on 64 mango genotypes of diverse origin during the first four seasons of fruit production to identify those worth longer-term assessment. We also recorded morphological characteristics of seedlings of 46 of these genotypes in an attempt to relate these measures to subsequent field performance. Tree canopy development on the most vigorous rootstocks was almost double that on the least vigorous. Growth rates differed by more than 160%. Cumulative marketable yield ranged from 36 kg/tree for the lowest yielding rootstock to 181 kg/tree for the most productive. Yield efficiency also differed markedly among the 64 rootstocks with the best treatment being 3.5 times more efficient than the poorest treatment. No relationship was found between yield efficiency and tree size, suggesting it is possible to select highly efficient rootstocks of differing vigor. Two genotypes ('Brodie' and 'MYP') stood out as providing high yield efficiency with small tree size. A further two genotypes ('B' and 'Watertank') were identified as offering high yield efficiency and large tree size and should provide high early yields at traditional tree spacing. Efforts to relate the morphology of different genotype seedlings to subsequent performance as a rootstock showed that nursery performance of mango seedlings is no indication of their likely behavior as a rootstock. The economic cost of poor yields and low yield efficiencies during the early years of commercial orchard production provide a rationale for culling many of the rootstock treatments in this experiment and concentrating future assessment on the top ≈20% of the 64 treatments. Of these, 'MYP', 'B', 'Watertank', 'Manzano', and 'Pancho' currently show the most promise.**

Mango is grown in more than 80 countries throughout the tropics and subtropics with total annual production of ≈30 million tons (FAO, 2008). With few exceptions, commercial yields are low compared with other fruit crops, seldom exceeding 10 $t \cdot ha^{-1}$. Furthermore, the warm conditions necessary to sustain the species often mean vegetative growth is vigorous and significant management inputs are needed to maintain tree size. In tropical regions lacking a distinct "dormancy" period, managing tree vigor through pruning can severely reduce fruit production in subsequent seasons (Medina-Urrutia and Nuñez-Elisea, 1997). This combination of low yields, high vegetative vigor, and the complexity of managing vegetative vigor severely impact the profitability of mango production (Ngo and Owens, 2002).

Rootstocks offer the possibility of improving yields and managing tree size without increasing input costs. Over recent decades, a number of publications have clearly demonstrated the impact of rootstock on scion performance in mango, mirroring results commonly seen in other tree crops. As examples, Reddy et al. (2003) showed a yield difference of more than 100% among eight rootstocks under the variety 'Alphonso' and Smith et al. (2003) examined nine rootstocks under 'Kensington Pride' that differed in yield by 141%. Rootstock effects on tree size have been of similar magnitude.

Although there is clear evidence that rootstocks can improve yield and yield efficiency in mango, all experiments to date have one limitation in common: they examine only a small number of genotypes (10 or fewer) as potential rootstocks. This is despite the availability of a diverse range of polyembryonic cultivars that could be used as rootstocks. High costs and the length of time needed are significant obstacles to large-scale field evaluations and point to early screening techniques as a possible way of improving the efficiency of mango rootstock research. The lack of large-scale rootstock experiments may partly explain why the modern mango industry lags behind crops such as apple, in which selection of an appropriate rootstock is as important to the success of a new orchard as the choice of the scion variety (Russo et al., 2007).

The objective of this work was to simultaneously evaluate the growth and yield of 'Kensington Pride' scion grafted onto 64 different mango genotypes. Field performance in the first 4 years of cropping is described and compared with the morphological characteristics of the original rootstock seedlings in the nursery in an attempt to develop early screening techniques.

Materials and Methods

Mango accessions in the Northern Territory (N.T.) germplasm collections (Berrimah Research Farm, Coast Plains Research Station, Katherine Research Station), together with material from a private collection (Mr. Ken Rayner) and morphologically distinct individual trees in the Katherine township, were assessed in Nov. 1995 to determine whether the seed type was mono- or polyembryonic. Seed was collected from the 63 genotypes that proved to be polyembryonic together with seed from the monoembryonic cultivar Glenn. The scion cultivar used in the experiment, Kensington Pride, is polyembryonic and seed of it was included as a rootstock to serve as a control combination. All seed was sown in individual 5-L pots. In Jan. 1996, the resulting seedlings were side veneer-grafted (at 200 mm height) with 'Kensington Pride' budwood taken from a single tree that had shown consistently superior performance. In Feb. 1996, the rootstock seedlings were assessed for a range of morphological characters immediately before the rootstock was cut back to the graft stick. Characters assessed were seedling height, trunk diameter, stem and leaf dry weight, leaf area per plant, average leaf size and dry weight, internode length, bark thickness, bark percentage, and wood and bark density.

Grafted trees were field-planted in Apr. 1996 at a spacing of 8 m within the row and 10 m between rows in a commercial mango orchard near Katherine, N.T., Australia (lat. 14.483° S, long. 132.239° E). This region has a semiarid tropical climate with an intense

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wet season (average 972 mm per year) from December to February followed by a distinct dry period for most of the remaining months. The soil was a Ferric, Petroferric, Red Kandosol (loamy, Typic Alfisol) with free drainage throughout the profile. The soil had a pH of 8 and an electrical conductivity of less than 0.05 $dS \cdot m^{-1}$. Trees were managed according to standard commercial practices (Crane et al., 1997), including monthly foliar nutrient applications during the first 18 months of tree establishment. Structural pruning ensured all trees developed three layers of three to four scaffolding branches each 0.5 to 1 m in length. Once this tree structure was established, no further pruning took place other than skirting of canopies to prevent fruit touching the ground.

Treatments were arranged within the first five replicates of the balanced lattice design for 64 treatments, Plan 10.5 of Cochran and Cox (1957), to form a valid partially balanced lattice square. Partially balanced lattice designs are standard incomplete block designs, which ensure pairs of treatments occur together in blocks as equally as possible. The blocks of the lattice were arranged in 4 × 2 tree blocks across pairs of rows of the design. Treatments were randomized within blocks to improve neighbor balance properties. The experiment consisted of 320 trees (five single-tree replicates of 64 treatments) and was guarded on all sides. Data were analyzed using the REML directive in GenStat (Genstat 9; Lawes Agricultural Trust, Rothamsted, UK) fitting replicate and lattice block as random effects.

Trunk circumference was measured at 12 monthly intervals at both a distance of 100 mm above and 100 mm below the graft union and converted to trunk cross-sectional areas (TCA). A linear regression of TCA (below the graft union) against time from planting was fitted for each tree. The resulting slope of this regression line was then used as a measure of the growth rate of each tree (Littell, 1989). Tree canopy size was measured at the end of the fourth season's harvest when trees had been in the field for 5 years 8 months. Digital capture and analysis methods were used and a projected canopy silhouette area (CSA) value obtained for each tree (Smith et al., 2003). The start of fruit harvesting in each season was determined by testing flesh dry matter content and normally occurred in mid-October. There were two harvests in 2000, three in 1998 and 2001, and four in 1999 with harvest events being 8 to 12 d apart. Marketable fruit number and weight were recorded at each harvest. Yield efficiency was determined by using TCA ($kg \cdot cm^{-2}$ TCA) as well as CSA ($kg \cdot m^{-2}$ CSA). Efficiency values based on TCA were calculated in each season using the corresponding trunk measurements for that season as well as for cumulative 4-year yield. An overall yield efficiency value was also calculated by dividing the cumulative 4-year yield by the CSA value determined after the final harvest. A gross income (GI) was calculated for each tree to take account of the interaction between yield, fruit size and earliness, and the economic advantage of high yields of large fruit produced early in the season. To calculate GI, each tree's yield at each harvest date was multiplied by the market price for that size fruit and the results summed. A 7-d period was allowed between the harvest date and the market price (Wholesale Markets Sydney, Sydney, Australia) used in this calculation to allow for time from harvesting to selling. Results were summed for the four seasons to produce a gross dollar value for each tree.

Results

Tree growth. Measures of tree size and growth rate revealed large differences between the rootstock treatments (Table 1). 'Kurukan' produced the largest tree canopy (CSA = 7.52 m^{-2}), whereas 'Vellaikulamban' was the smallest (CSA = 4.16 m^{-2}). The small tree size of 'Vellaikulamban' was also reflected in its low growth rate (4.91 cm^{-2} TCA/month) in contrast with 'Orange', which produced the highest growth rate of 10.33 cm^{-2} TCA/month. Trees with large CSA tended to have high TCA, although the correlations were always less than 0.7, suggesting the need for caution in estimating tree size based solely on trunk measurements. Similarly, tree growth rates based on changes in TCA showed some discrepancies with CSA. For example, although 'Neil' and 'Rosa' had a similar CSA, the latter had a growth rate 66% higher than the former. Most rootstock genotypes produced graft unions in which the scion TCA was smaller than the rootstock TCA with only 10 treatments developing scion overgrowth, the most notable being 'Neil' (ratio of scion TCA:rootstock TCA = 1.12). This effect was reversed, resulting in a distinct "benching" effect with rootstocks such as 'Kensington Pride' (0.69), 'Phoenix' (0.69), and 'Vellaikulamban' (0.73). However, these rootstock differences in graft union morphology were not related to any tree growth or yield differences and should not be used as a criterion for rootstock selection.

Fruit production. Rootstock had a significant effect on marketable yields in each of the four individual seasons (data not presented) as well as cumulatively (Table 2). On a cumulative basis, marketable fruit yield was highest on 'B' (181 kg/tree) and lowest on 'Chandrakaran' (36 kg/tree). In the third season, rootstocks differed more than eightfold between the highest and lowest yielding treatments, whereas in the fourth season, they differed more than fivefold. High-yielding rootstock treatments tended to perform consistently across the four seasons, although it is too early to be certain that these stocks have reduced biennial bearing. Yield efficiencies varied widely between different rootstocks (Table 2). Rootstocks that produced high yield efficiency on a CSA basis for cumulative yield tended to perform well when yield efficiency was expressed on a TCA basis in individual seasons. Similarly, rootstock treatments with low efficiency based on CSA for cumulative yield tended to perform poorly based on TCA in individual seasons. Rootstocks with high yield efficiency included 'MYP', 'B', 'Manzano', 'Brodie', 'Pancho', 'Starch', and 'Watertank'. These rootstocks are some of the most promising and warrant further assessment. Among the least yield efficient rootstocks were 'Pico', 'Tong Dum', and 'Muvandan'.

Significant rootstock effects on average fruit size were detected in the second and third seasons of cropping but not in the first or fourth. When average fruit size was calculated for cumulative production, rootstock effects were not significant (data not presented). Gross income per tree was highest for 'B' ($569/tree) and lowest for 'Chandrakaran' ($104/tree) (Table 2).

There was no relationship between tree size (CSA) and yield efficiency for the 64 rootstocks ($r^2 = 0.008$) (Fig. 1). However, the scatterplot clearly demonstrates the opportunity to select highly efficient rootstocks of differing vigor. For example, 'B', 'MYP', and 'Brodie' had similarly high yield efficiencies but differed markedly in canopy size.

Nursery versus field performance. Our attempts to correlate the 12 morphological characteristics of nursery seedlings and subsequent field performance characteristics (tree size, yield, yield efficiency, and average fruit size) revealed no significant relationships between nursery and field variables. The strongest correlation (–0.32) was between bark percentage and cumulative yield, suggesting that genotypes where the bark occupies a larger percentage of the trunk diameter tended to produce low yields when used as rootstocks. However, the relationship is too weak to be of value in screening germplasm.

Discussion

This experiment has identified a subset of genotypes with high yield and productivity worthy of longer-term evaluation. The magnitude of differences between the best and worst treatments is substantially higher than in previous rootstock research and points to the importance of screening a large number of genotypes of diverse origin in the search for superior rootstocks for mango. Furthermore, the poor performance of most genotypes in this experiment, compared with rootstocks currently in local commercial use (mainly 'Kensington Pride'), illustrates the financial dangers of using rootstock genotypes that have not been adequately evaluated.

Results from previous mango rootstock experiments suggest that the highest yields (on a per-tree basis) are associated with the most vigorous rootstocks. However, in this experiment with a far larger range of genotypes, it becomes clear that rootstock vigor is not necessarily related to fruit production. For example, the rootstock 'Orange' produced very large trees with the highest growth rate and yet yielded nearly 50% less

Table 1. Canopy silhouette area (CSA), trunk growth rate, and scion:rootstock girth ratio of 'Kensington Pride' mango field-grown for 5 years 8 months on 64 rootstocks of diverse origin.

Accession number[z]	Rootstock	Origin[y]	CSA (m^2)	Growth rate (cm^2 TCA[x]/mo.)	Scion:rootstock (ratio)
NT51	Vellaikulamban	Sri Lanka	4.16	4.91	0.73
NT9	Brodie	Northern Territory, Australia	4.18	3.89	0.91
NT55	Chandrakaran	Cochin, India	4.54	4.76	0.95
NT31	Saigon	Unknown	4.62	5.42	0.91
NT44	CPRS Seedling	Unknown	4.94	4.31	1.06
NT47	Blue	Queensland, Australia	5.06	5.18	1.06
NT36	Nam Doc Mai	Thailand	5.11	6.15	0.82
NT50	MYP	Unknown	5.14	5.03	0.84
NT8	Rayner 4X	Northern Territory, Australia	5.19	5.71	0.87
NT57	Teluk Anson	Malaysia	5.40	6.00	0.77
NT49	Police Common	Northern Territory, Australia	5.44	4.98	0.81
NT40	Pico	Philippines	5.52	5.34	1.01
NT30	Ok Rong	Thailand	5.62	5.98	0.79
NT64	Golden Tropic	Queensland, Australia	5.62	5.86	0.83
NT12	Glenn[w]	Florida, US	5.63	7.14	0.78
NT27	Starch	Trinidad and Tobago	5.65	5.98	0.94
NT54	False Chausa	India	5.66	5.75	0.78
NT48	Kopu Reva	Cook Islands	5.67	5.83	0.94
NT4	Top End Rural	Northern Territory, Australia	5.71	6.45	0.74
NT62	Olour	India	5.72	6.58	1.01
NT17	Batavi	Indonesia	5.80	7.38	0.79
NT2	Giles Road	Northern Territory, Australia	5.90	5.36	1.09
NT58	R11T1	Northern Territory, Australia	5.94	5.83	0.85
NT28	R2E2	Queensland, Australia	5.97	6.73	0.78
NT46	Eddie Special	Unknown	5.97	5.53	1.04
NT43	Suvernakuekha	Alamanda, India	6.01	5.70	0.93
NT11	Stuttered	Northern Territory, Australia	6.04	6.09	0.97
NT6	Giles Fence	Northern Territory, Australia	6.06	5.89	0.97
NT16	Kensington Pride	Queensland, Australia	6.10	6.49	0.69
NT39	Manzano	Puerto Rico	6.11	7.02	0.70
NT41	Pineapple	Queensland, Australia	6.11	5.74	0.86
NT5	Kalano	Northern Territory, Australia	6.12	6.16	1.05
NT35	Banana Callo	Queensland, Australia	6.16	7.21	0.76
NT53	DHC Small	Northern Territory, Australia	6.16	5.74	0.85
NT18	Sg. Siput	Malaysia	6.18	6.04	1.06
NT32	Cathania	India	6.19	6.62	0.81
NT56	Lemon D2	Northern Territory, Australia	6.19	5.57	0.83
NT59	Tong Dum	Thailand	6.21	6.65	0.88
NT26	Bappakai	India	6.23	7.98	0.86
NT42	A	Indonesia	6.24	7.08	0.79
NT38	Black Jamaica	Unknown	6.26	5.54	1.00
NT10	Pancho	Indonesia	6.29	5.31	1.10
NT29	Florigon	Florida, US	6.33	7.17	0.84
NT45	Elephant Tusk	Thailand	6.38	6.70	0.78
NT3	Comsip	Northern Territory, Australia	6.52	5.99	0.92
NT20	Carabao	Philippines	6.54	6.45	1.00
NT52	13-1	Egypt/Israel	6.60	6.88	1.00
NT24	Rapa	Cook Islands	6.61	7.33	0.88
NT37	Ah Toy Long	Northern Territory, Australia	6.61	7.69	0.92
NT19	Phoenix	Northern Territory, Australia	6.67	7.51	0.69
NT7	Adelaide River	Northern Territory, Australia	6.74	6.66	0.79
NT22	Early Gold	Florida, US	6.75	6.79	0.89
NT13	Grain	Northern Territory, Australia	6.76	5.73	0.96
NT23	Sabre	South Africa	6.76	7.23	0.74
NT15	Neil	Northern Territory, Australia	6.83	5.63	1.12
NT34	False Julie	South Africa	6.86	6.74	0.85
NT60	Rosa	Brazil	6.89	9.37	0.83
NT61	Muvandan	India	7.05	8.80	0.81
NT1	Rayner 2X	Northern Territory, Australia	7.11	6.06	0.96
NT63	B	Indonesia/Malaysia	7.12	7.53	0.90
NT25	exCairns	Queensland, Australia	7.16	7.21	0.85
NT33	Orange	Indonesia/Malaysia	7.17	10.33	0.90
NT14	Watertank	Northern Territory, Australia	7.24	7.50	0.92
NT21	Kurukan	India/Sri Lanka	7.52	7.42	0.97
P value			<0.001	<0.001	<0.001
$LSD_{0.05}$			1.19	1.51	0.14

[z]Unique code given to each individual accession in Northern Territory mango arboreta.
[y]Indicative only as a result of the complexity of tracing the true origin of mango germplasm.
[x]TCA = trunk cross-sectional area.
[w]The only monoembryonic rootstock in the experiment.
LSD = least significant difference.

Table 2. Cumulative yield, yield efficiency [based on both canopy silhouette area (CSA) and trunk cross-sectional areas (TCA)] and gross income of 'Kensington Pride' mango on 64 rootstocks in the first 4 years of cropping.

Rootstock	Cumulative yield (kg/tree)	Yield efficiency ($kg \cdot m^{-2}$ CSA)	Yield efficiency ($kg \cdot cm^{-2}$ TCA)	Gross income ($/tree)
B	181	26.1	0.485	569
Watertank	165	23.0	0.385	510
Manzano	159	26.0	0.397	490
Pancho	155	25.5	0.500	476
MYP	138	27.8	0.476	413
Phoenix	137	21.1	0.315	411
Starch	131	23.0	0.380	403
Stuttered	130	22.0	0.436	397
Grain	129	17.9	0.386	398
Kensington Pride	128	21.5	0.376	385
Carabao	124	19.3	0.364	375
13-1	122	18.8	0.364	370
Top End Rural	120	20.6	0.325	367
Bappakai	118	19.2	0.291	361
Sg. Siput	116	19.5	0.349	354
Glenn	115	20.6	0.337	363
Comsip	113	17.2	0.360	338
False Julie	113	16.1	0.301	344
Early Gold	110	17.2	0.289	339
Brodie	108	25.9	0.503	336
Kurukan	106	14.1	0.280	314
Kopu Reva	100	17.6	0.375	291
R2E2	99	16.3	0.273	301
Kalano	98	16.4	0.307	294
Giles Road	98	16.9	0.360	288
Rayner 2X	98	14.1	0.296	285
Adelaide River	97	14.6	0.266	306
exCairns	96	13.2	0.267	292
Sabre	96	13.3	0.209	286
Pineapple	96	15.9	0.317	281
False Chausa	95	17.2	0.346	282
Giles Fence	95	16.0	0.308	278
Police Common	93	17.4	0.400	280
Rapa	90	13.0	0.223	276
Eddie Special	90	15.3	0.339	265
Golden Tropic	90	15.8	0.329	280
Neil	88	13.4	0.290	259
Ah Toy Long	87	13.5	0.221	272
Suvernakuekha	87	13.4	0.312	263
Florigon	86	13.3	0.243	267
Orange	86	11.9	0.185	258
Ok Rong	85	15.3	0.261	264
Lemon D2	85	15.1	0.330	248
A	83	13.7	0.230	262
Vellaikulamban	80	19.3	0.312	247
Batavi	78	13.3	0.195	244
Rayner 4X	78	15.9	0.272	227
DHC Small	76	12.7	0.288	232
Saigon	75	17.3	0.259	236
Black Jamaica	75	12.0	0.305	227
Banana Callo	75	12.1	0.214	231
Olour	72	12.4	0.195	220
Cathania	71	11.1	0.232	209
Rosa	71	11.0	0.166	215
Teluk Anson	69	13.1	0.243	205
R11T1	68	12.1	0.253	204
Muvandan	66	9.2	0.149	203
Nam Doc Mai	64	12.2	0.235	197
Elephant Tusk	64	10.0	0.194	189
CPRS Seedling	64	15.2	0.309	191
Tong Dum	52	8.9	0.173	153
Blue	51	10.1	0.227	157
Pico	39	7.9	0.193	119
Chandrakaran	36	9.4	0.174	104
P value	<0.001	<0.001	<0.001	<0.001
$LSD_{0.05}$	43	7.3	0.122	135

LSD = least significant difference.

than some treatments. Conversely, 'MYP' produced some of the highest yields on some of the smallest trees. This diversity has important implications for different production systems in which it might be anticipated that low vigor stocks are needed in higher-density plantings (Reddy et al., 2003) and more vigorous stocks for traditional spacing. Wheaton et al. (1995) found that the economic viability of high-density plantings in citrus was dependent on the availability of lower vigor rootstocks. This might also be true for a terminal bearing tree crop like mango. In our experiment, the GI value of each rootstock was calculated from market price, fruit size, seasonal maturity time, and yields in each of the four seasons and showed a strong relationship with cumulative yield. However, this calculated income per tree does not account for crop management and harvest costs that may differ between rootstocks. For example, 'MYP' and 'Phoenix' gave a similar GI value, but the former was almost 30% smaller in tree size and therefore would be cheaper to manage and harvest. Thus, a number of genotypes offer similar economic returns in terms of high yields of good-sized fruit at the right time of the season, but a subset of them may also lower orchard costs through reduced vegetative vigor.

The prospect of highly efficient rootstocks of differing vigor has particular implications for hot tropical environments such as the area used in this experiment, where managing vegetative vigor can be a major problem. Tree pruning in such environments has only a short-term effect in reducing tree size, stimulates excessive vegetative growth, and can reduce fruit production in subsequent seasons (Medina-Urrutia and Nuñez-Elisea, 1997). Highly efficient rootstocks of moderate vigor may reduce the frequency and intensity of pruning in hot tropical regions. Furthermore, the wide range of observed responses in terms of tree size, growth rates, and fruit production may offer future research opportunities to better understand the physiology of this low-yielding species. Rootstocks like 'Orange', 'Chandrakaran', 'B', and 'MYP' clearly differ in how they influence scion biomass accumulation as well as carbon allocation between vegetative and reproductive processes. Studying these stocks under a range of management practices, including pruning, may improve our understanding of carbon allocation between vegetative and reproductive growth and lead to better management practices.

Results from this experiment are somewhat different from those obtained previously with 'Kensington Pride' in this region (Smith et al., 2003). Principal among these differences has been the improved performance of 'Sabre' and 'Kensington Pride' and the mediocre performance of 'Sg Siput'. This may be the result of differences in soil type between the two experiments with the original experiment planted on a sandy soil and this most recent work planted on a clay loam. Evidence from other tree crops suggests that it is unlikely a single rootstock will perform well on all soil types, and although there is no known evidence of mango rootstocks differing in performance as a result of soil type (other than where salinity is an issue), our results illustrate the need to examine a range of improved rootstock genotypes

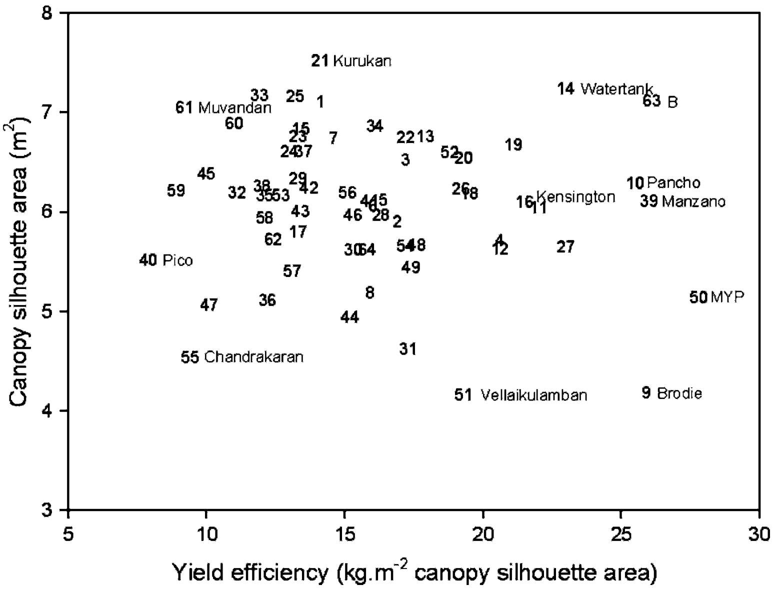

Fig. 1. Relationship between tree size (canopy silhouette area) and yield efficiency of 'Kensington Pride' mango on 64 rootstocks. Rootstock names of most interest are indicated following the plotted accession numbers (as per Table 1).

under various conditions to identify superior genotypes for commercial orchards.

Source arboretum trees of some of the 64 genotypes included in the experiment appeared morphologically indistinguishable but were included as separate treatments because of different origins and/or naming. Four such trees were 'Sg Siput', 'B', 'Eddie Special', and 'Pancho'. Results presented in this article show the performance of these four rootstocks to be quite disparate, contrary to what would be expected if they were an identical genotype. A similar situation exists with two of the most important rootstocks used for citrus. Troyer and Carrizo citrange are morphologically identical, some even arguing that they are the same genotype (Savage and Gardner, 1965), and yet they sometimes show important differences (e.g., nematode resistance, juice Brix) when used as rootstocks. In the case of mango rootstocks, our results suggest the need for caution in assuming that morphologically identical polyembryonic cultivars will behave similarly when used as rootstocks.

One of the longest running and most widely published mango rootstock experiments is in Bangalore, India [most recently described in Reddy et al. (2003)] in which eight rootstocks are being examined for their influence on 'Alphonso' performance. An early report on this experiment (Kohli and Reddy, 1989) stimulated efforts to introduce these genotypes into the N.T. germplasm collection. Seeds from these genotypes were thus available for our experiment with 'Kensington Pride'. As a consequence, we can now examine the comparative performance of a range of mango rootstocks with different scion varieties on two different continents. Reddy et al. (2003) found major rootstock effects on tree growth and vigor with 'Vellaikulamban' identified as imparting dwarfing. It was also found to give high yield efficiency. We also found that 'Vellaikulamban' reduced vigor with this cultivar giving the smallest canopy size and lowest growth rate of any of the 64 rootstocks. However, 'Kensington Pride' has yielded poorly on this rootstock, resulting in low yields per tree and low yield efficiency. Our results for other stocks examined in Bangalore are also generally consistent in terms of canopy size and development, but not in terms of fruit production. For example, Bangalore's highest yielding rootstock, 'Muvandan', is in our lowest 15% of treatments in terms of cumulative yield. Another Bangalore-recommended rootstock, 'Olour', also failed to show outstanding performance in our experiment. These discrepancies may be explained by different climatic/edaphic conditions and the intrinsic differences between the scion varieties 'Alphonso' and 'Kensington Pride'. For example, the highest yielding rootstock in our experiment produced 181 kg/tree within 6 years of planting, whereas in the experiment with 'Alphonso', this yield level was not reached on the best rootstock until the 14th year.

Galán Saúco et al. (2001) have demonstrated the occurrence of spontaneous chromosome doubling in apomictic mango cultivars, which results in tetraploid progeny morphologically distinct from their diploid progenitors. An identical phenomenon occurs within the Citrus genus and has long been recognized as a potential source of dwarfing rootstocks for this crop (Lee, 1988), although it has yet to achieve any commercial significance. The occurrence of these morphologically distinct mango plants in seed batches from polyembryonic cultivars was noted by an astute nurseryman at Katherine, N.T., in 1989. He grew some of these seedlings through to maturity and observed that the progeny of these trees also showed the same distinct morphology. Consequently, we were able to include this material ('Rayner 4X') along with the original diploid progenitor ('Rayner 2X') as two treatments in our rootstock experiment. Our preliminary results with mango indicate a reduction in canopy size associated with the tetraploid, although yield efficiency has not changed. Thus, there may be some value in developing and screening autotetraploids of superior mango rootstock genotypes in the hope of reducing vigor while retaining other superior characteristics.

The time and cost involved in long-term field experiments makes the prospect of predicting field performance from nursery seedling morphology a very attractive one. However, our results suggest that the morphology of seedlings bears little relationship to their subsequent performance as rootstocks. At this stage, there seems to be no alternative to field evaluation to identify the most promising rootstock genotypes.

The geographical origin of genotypes examined in this experiment seemed to play no clear role in their performance as rootstocks with the more promising genotypes coming from a range of countries, including Australia, India, Malaysia, Puerto Rico, and the United States. The early and widespread distribution of mango cultivars around the world makes the determination of the true botanical origin of this germplasm very difficult to establish, although it seems clear that in future screening work, it would be wise to examine polyembryonic genotypes from all continents where mangoes are grown.

This preliminary field screening of a diverse range of germplasm has demonstrated large differences in rootstock performance and the potential to select highly efficient genotypes with differing vigor. A subset of this material warrants longer-term assessment before commercialization.

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