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ROOTSTOCK INFLUENCE ON YIELD OF 'HASS' AVOCADO

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Abstract

The orchard yield of avocados in Australia has remained static for many years. With the lowering of returns, relative to the late 1970s, we, as an industry, need to address the reduced economic viability of production in Australia.

As a part of my management, I have individual yield records of all of my trees. The data clearly shows that some trees maintain very high levels of production, while others consistently yield small crops. All trees are grafted to seedling Guatemalan rootstock, are fertilised via fertigation, and have similar leaf nutrient levels. The highest and lowest producing trees have tested negative for sunblotch viroid and for the purposes of this comparison, data from trees significantly larger or smaller were discarded along with that from trees at the end of rows.

It is clear that the effects of rootstock are very large (416% between the highest and lowest-yielding trees). The long term economic benefit of selecting the best rootstock/scion combination for clonal propagation to improve our genetic base would far outweigh the initial costs in carrying out such a program. It is my belief that with such varied growing conditions (soil and climate) across our industry, it would be difficult to select a rootstock that would suit all circumstances. I would therefore strongly recommend that growers instigate a record-keeping programme to identify their best producing trees for rootstock recovery to clone for use in future orchards.

Introduction

From 1972/73 until 1995/96 the average yield for bearing avocado trees has been 36 kg/tree taken over the whole Australian industry. With a wide range of planting densities, it is estimated that this equates to about 7 t/ha. From energy balance studies, Wolstenholme (1986, 1987) has estimated the theoretical sustainable yield of avocado at 32 tonnes/ha. Whiley *et al.* (1996b) have reported single year production for 'Hass' on a block basis at 50 t/ha. However, sustainable yields from well managed 'Fuerte' and 'Hass' orchards in subtropical south-east Queensland are in the vicinity of 23-25 t/ha (Whiley *et al.* 1996a, b). It was concluded that such yields on a sustainable basis have reached the genetic limits of cultivars and rootstocks (seedling populations) currently used by the Australian industry in subtropical climates (Whiley, 1994). I would expect that many of the trees grown in Australasia, are not recipients of best management practices and therefore will never attain their production potential. However, for those trees which are well managed, it is likely that genetic factors will restrict their production potential thereby limiting their economic performance.

It is with this background that I present to you my observations that have lead me to the conclusion that the Australian avocado industry needs to examine the genetic composition of its trees if it is to remain competitive and viable in the future.

In this comparison I have addressed what I see as the factors causing variations in yield within a block of similar age trees. These are nutrition, irrigation, severity of root rot, virus/viroid infections, genetic variations in scion lines, tree size differences, end-of-row effects, and genetic variations in rootstocks. Management strategies have been developed to minimise the effect of these factors on production yet a significant variation in yield between trees is consistently recorded. Reasons for this result are discussed.

Materials and methods

Data presented in this paper has been collected from my orchard located 30 kilometres north of Toowoomba in SE Queensland, on the edge of the Great Dividing Range (Longitude 15 2°E; Latitude 27°S; Elevation 667 m asl). The orchard slopes gently to the north and the soil is a deep (30 m), light-texture krasnozem. Natural rainfall (average 950 mm pa, summer dominant) is supplemented with irrigation from 90 litre per hour, under-tree sprinklers (2 per tree) and scheduled by tensiometers. Irrigation water is drawn from bores and has a mean conductivity of 440 microsiemens/cm. Tree nutrition is serviced by decisions developed from regular soil and leaf tissue analyses with most fertiliser being applied by fertigation. Temperatures are mild with summer mean max./mins. of 27.6/16.6°C and winter mean max./mins. of 16.3/5.2°C (Australian Bureau of Meteorology). Temperature extremes are 39.2°C in summer and -4.4°C in winter.

The block chosen for comparative analysis was planted in October 1985 and consisted of 86 'Hass' trees grafted to Guatemalan seedling rootstocks planted 9 x 9 m apart. Three high-yielding and three low-yielding trees were selected from this block for the study. Replacement trees were excluded from selection, as were all trees on the ends of rows to remove the effects of light on crop performance. Trees significantly larger or smaller than the average were also not used in the comparative analysis. In May 1997, leaf nutrient concentrations of trees selected for comparative yield analysis, were determined following the collection of 10 leaves per tree which were pooled for each category, oven dried and then analysed by standard techniques. Tree health was maintained by one injection per year of Fosject® using low pressure syringes to control Phytophthora root rot. Trees showing any visible signs of reduced vigour, received a second injection treatment. The orchard is in an area of low disease pressure. Yield reduction in avocado due to sunblotch viroid has been reported from South Africa (Smith and Köhne, 1992). To reduce the likelihood of sunblotch effecting tree yields in this study, high and low-bearing trees were tested for sunblotch viroid using the recently developed and highly sensitive PCR technique (R.M. Harding, Brisbane, unpublished, 1996).

Harvesting in the orchard is assisted by the use of a cherry picker and individual tree yields have been recorded since 1991. This is done by picking into crates which hold 20 kg of fruit when full. Data are then recorded on a site plan and subsequently transposed to computer records.

Results

All trees tested for sunblotch viroid produced a negative result (R.M. Harding, unpublished data, 1996). With the level of detection now possible using the newly developed PCR technique (1000 times more sensitive than previous methods), it is reasonable to assume that sunblotch is not present in the trees used for this study.

There was no real difference in leaf nutrient levels between high and low-yielding trees (Table 1). Most nutrient concentrations fell within the recommended critical concentrations though N and Ca were a little lower than target levels for 'Hass'.

Table 1 Leaf analysis results comparing high to low-yielding trees taken in April 1997

N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	B (mg/kg)
						High producing trees				
2.21	0.18	1.1	0.6	0.58	0.01	44	77	596	77	102
						Low producing trees				
2.25	0.17	1.0	0.6	0.63	0.01	47	76	416	60	93

Annual production from high and low-yielding trees from 1991-1996 inclusive are presented in Table 2. Based on data for the high-yielding group, production peaked when trees reached 8-years-old. The decline thereafter may be due to shading as trees grew taller and closer together. From 1991 the low-yielding group showed a pronounced biennial bearing pattern (based on mean values) however, this was not seen in either the high-yielding trees or the overall block yields. From block yields for the six year period of the study, production from the high-yielding group was 38% higher than the block average and 416% higher than the low-yielding group.

Discussion

The data I have collected demonstrates a significant variation in yield characteristics of 'Hass' trees growing within a block in a well-managed commercial orchard planted on a uniform soil type. There is cause for concern that production differs by 416% between the highest and lowest yielding groups of trees, but it also illustrates the potential for significant improvements in avocado yields. The results suggest that the greatest source of variation in yield can be attributed to the use of seedling rootstock. In similar long-term studies with seedling rootstocks, Ben Ya'acov *et al.* (1992) found that outstanding individual trees of 'Hass' produced 100% more than the average trees of the block where they were growing. They also demonstrated that the recovery and cloning of high-producing trees has the capacity to significantly improve orchard yield. The effect of elite, cloned rootstocks on 'Hass' yield has also previously been reported (Whiley *et al.,* 1990; Arpaia *et al,* 1991). Clear differences in yield based on canopy efficiency, when trees were grown in the absence of Phytophthora root rot, have been demonstrated between a range of clonal rootstocks when grafted to 'Hass'.

Table 2 Yield comparisons between consistently high and low-yielding trees from 1991 to 1996

Year	Tree description								Block
	High-yielding (kg/tree)				Low-yielding (kg/tree)				Mean
	R21T8	R22T7	R19T5	**Mean**	R23T3	R20T8	R14T5	**Mean**	
1991	190	140	138	**156**	5	1	44	**17**	**99**
1992	183	107	219	**170**	82	21	95	**66**	**124**
1993	328	325	328	**327**	57	0	2	**20**	**176**
1994	195	263	228	**229**	106	61	80	**82**	**170**
1995	256	240	145	**214**	50	23	8	**27**	**84**
1996	160	302	225	**229**	145	110	70	**108**	**172**
Total	**1312**	**1377**	**1283**	**1324**	**445**	**216**	**299**	**320**	**825**
Mean	**219**	**230**	**214**	**221**	**74**	**36**	**50**	**53**	**138**

The pronounced biennial bearing pattern recorded for the low-yielding trees is of interest and suggests an imbalance in tree physiology. Whiley *et al.,* (1996a, b) were able to induce biennial bearing and lower cumulative yields in 'Fuerte' and 'Hass' trees by hanging fruit late. Whiley (1994) has also reported differences in tree physiology between high and low-yielding trees and suggested that the rootstock/scion interface is likely responsible for differences in tree performance.

Advances in the understanding of nutrition, irrigation, disease management and general crop physiology over the last 10 years, should have resulted in a measurable improvement in production however, this has not occurred (Table 3). It could be said that industry is responsible for the lack of progress in yield improvement through directing funding to where results can be achieved in the short-term, thus avoiding the harder long-term commitment to genetic improvement through encouraging the development of improved rootstock/scion combinations. Whiley (1991, 1994) has previously said that rootstock improvement offers the greatest opportunity for advancing the performance of avocado in Australia. Indeed, if we examine what has been achieved in other agricultural industries from this approach we can be encouraged that this is a step in the right direction. For example, I would like to compare the performance of the avocado and SE Queensland dairy industry over the last 10 year.

The dairy industry in this region was inefficient when compared to other production areas in Australia and it was a case of improving efficiency or leaving the industry. The impressive gains in production by this industry have been largely attributed to the improvement of the genetic base through herd recording and selecting for performance, both from the male and female stock. This has resulted in an 80% improvement in the production from dairy cows during the last 9 years whereas avocado production has remained relatively static 1986/87 avocado production is atypical of long term records (Table 3).

Table 3 **Summary of production for the S.E. Queensland dairy industry and the Australian avocado industry for the years 1986/87 to 1995/96. Data for avocado are only calculated from bearing trees**

Industry	86/87	90/91	91/92	92/93	93/94	94/95	95/96
[z]S.E. Qld. Dairy cow prodn. (l/cow)	2856	4218	4411	4847	5228	5232	5108
Australian avocado prodn. (kg/tree)	49.74	38.85	36.52	38.81	41.79	40.41	37.75

[z]Source: QDAS summary of results for SEQ dairy farms

On examining trends for avocado production over longer periods, it is clear to see that yields have not changed in the last 23 years (Table 4). However, it is interesting to note the marked reduction in yield from 1976/77 to 1982/83. This most likely due to the "big wet" which effected many mature trees in northern NSW and SE Queensland.

Table 4 **Summary of the Australian avocado industry statistics for the period of 1972-73 to 1995-96 (Source: Australian Bureau of Statistics)**

Year	Trees	Bearing trees	Production	Yield/bearing tree
	('000)	('000)	(Tonnes)	(kg)
72-73	65	21	953	45.4
73-74	71	21	701	33.4
74-75	74	20	677	33.9
75-76	92	23	710	30.9
76-77	105	25	570	22.8
77-78	118	33	662	20.1
78-79	164	47	980	20.9
82-83	356	163	3355	20.6
83-84	425	202	5429	26.9
84-85	459	157	6200	39.5
85-86	492	173	7467	43.2
86-87	455	195	9700	49.7
87-88	450	217	9797	45.2
88-89	462	267	11081	41.5
89-90	472	304	11413	37.5
90-91	445	309	12005	38.9
91-92	450	316	11541	36.5
92-93	483	333	12925	38.8
93-94	600	402	16801	41.8
94-95	607	387	15640	40.4
95-96	712	448	16914	37.8

Economic Benefits

It is quite obvious that there are considerable economic benefits to be gained from planting an orchard from high producing trees. To put this into perspective I have developed a simple exercise using an average wholesale price of $2.00 per kg. I have assumed that the trees are planted at a density of 123 per hectare. From these parameters the mean of the high and low-yielding trees can then be compared to the block average (Table 5).

Table 5 Projected cash returns from high and low-yielding 'Hass' trees assuming all fruit were marketed

Year	High-yielding trees		Low-yielding trees		Block	
Year	Mean yield (t/ha)	Return ($/ha)	Mean yield (t/ha)	Return ($/ha)	Mean yield (t/ha)	Return ($/ha)
1991	19.2	38,376	2.0	3,936	12.2	24,354
1992	20.9	41,820	8.1	16,236	15.3	30,504
1993	40.2	80,442	2.5	4,920	21.7	43,296
1994	28.2	56,334	10.1	10,086	20.9	41,820
1995	26.3	52,644	9.0	6,642	10.3	20,664
1996	28.2	56,334	13.3	26,568	21.2	42,312
Mean	27.2	54,325	7.5	11,398	16.9	33,825

From Table 5 it is seen that the return per hectare for low-yielding trees is substantially less than for high-yielding trees. The other comparison to be made is the effect of the low-producing trees on the block average when compared to the high-producing trees (the block average is what was picked off all trees in the block).

When comparing yields in Table 5, reference should be made to the estimated Australian average production of 7 t/ha. Compared with the block average production in my orchard, there is an opportunity to substantially improve production firstly through the implementation of better management practices, and secondly by improvement of the genetic base of our orchards.

As a grower, what can you do to address this situation?

If you are new to the industry plant a wide variety rootstocks including those that have some track history, eg 'Velvick' and 'Duke 7'. Make sure that the rootstocks have been identified and recorded according to their maternal source, by the nursery. Ensure, from local knowledge, that they include the best rootstocks for your area. As these trees develop, record their yields, and any other pertinent factors such as grade percentages, growth characteristics etc. As your trees reach full production, remove low producing trees and replace them with clones of your high producing trees. If you are continuing to expand, select your highest producing trees to clone for your new blocks.

For established growers, the first step is to record yield. This can be done in a number of ways. The most simple technique is to rate each tree prior to picking. The trees are then marked according to whether they are poor, average or excellent producers. This can be achieved by means of colour-coded trunk marks. The assessment should be carried out by the same person. This system can work for all sized orchards. For smaller family run orchards, the system can be developed to record an approximate weight of fruit from each tree. Yield data need to be collected for at least three seasons to make an accurate assessment.

Once the high producing trees have been established, you have two methods available to clone the rootstock. These are:

- Cut down those trees below the graft. The rootstock will then sucker profusely. It is from this new growth, that you can clone your new rootstock. Prior to cutting your best tree, budwood can be taken and re-established, so as to reproduce the exact genetic replicate
- By exposing some of the larger roots of the selected tree to light and cincturing them, the root will then produce suckers. It is these suckers that you can then clone for your new trees. The scion can then be simply matched from the existing tree

Conclusions

During the last 25 years, our understanding of all factors relating to growing avocados should have substantially increased. But it is certain that we have not paid any attention to improving the rootstocks that we use. The industry in both Australia and New Zealand at times have looked at clonal rootstocks. They are more expensive to produce and in many areas, the resultant yield was comparable, or in some instances, inferior to a nearby tree on a seedling rootstock. There were no perceived benefits to growing avocados on clonal rootstocks.

What clonal rootstock did you use? Was it performance tested in your region? Has it been proven to be the best rootstock for your management style? These are the questions that need to be answered if you are serious about improving your productivity. They are questions that are answered from keeping records, and acting on the results.

Our research scientists are working towards the goal of finding the best general rootstock for a number of areas suited to 'Hass'. Trials will further quantify the benefits of improved rootstocks and will identify those that are best suited to various conditions. This will benefit the industry, but it will be activities of you, the growers, that can turn this problem of low production around. You need to keep yield records for a period of three seasons, and select that best combination of root and scion to be the basis of your new orchards.

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