

Field evaluation of superior avocado rootstocks with 'Hass' as scions¹

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ABSTRACT

The Australian avocado industry favours the seedling rootstock 'Velvick' which is well adapted to local conditions. New rootstocks have become available which warrant testing. This trial tests the productivity of 22 seedling and 11 clonal rootstocks with 'Hass' as scion.

The trial was established in central Queensland in 2004 in good soil under low *Phytophthora* pressure. Clonal and seedling 'Velvick' was used as the industry standard and clonal 'Duke 7' as the international standard rootstocks. Yield, vegetative vigour and tree health were monitored from 2006 to 2010 and fruit quality was assessed from 2008 to 2010.

Seedling rootstocks BW2 and 'Degania' had the highest cumulative yields for 2006 to 2010, 357kg/tree and 343kg/tree respectively compared to 'Velvick', 315kg/tree. 'Ashdot' rootstock produced noticeably smaller trees and had the highest yield efficiency (1.6kg/m³), followed by BW2 (1.3kg/m³) and 'Degania' (1.2kg/m³), compared to 'Velvick' (0.8kg/m³). However, given their small size and good yields, trees on 'Ashdot' showed tendencies for biennial bearing.

BC101 was the most precocious clonal rootstock and the highest producer for the first three years. BC62 had the highest cumulative yield, 350kg/tree, compared to clonal 'Velvick', 290kg/tree. 'Duke 7' and BC128 were amongst the poorest yielding rootstocks in the trial. BC62 gave rise to vigorous trees and thus did not have the highest yield in relation to the tree size. BC101 was the most productive tree in relative to its canopy size, 0.85kg/m³ compared to clonal 'Velvick', 0.75kg/m³.

Under these trial conditions, several rootstocks appear to be superior to the industry standard 'Velvick'.

La industria australiana de aguacate favorece el portainjerto de semilla 'Velvick' el cual se adapta muy bien a las condiciones locales. Nuevos portainjertos ahora están disponibles y necesitan ser probados. Este estudio examina la productividad de 22 portainjertos de semillas y 11 portainjertos clonales con 'Hass' como la púa.

La prueba se estableció en Central Queensland en el 2004 en buena tierra con poca presión de *Phytophthora cinnamomi*. Se usaron los portainjertos de semillas y clonales 'Velvick' como patrón estándar de la industria y 'Duke 7' como patrón estándar internacional. Se controlaron el rendimiento, el vigor vegetal y la sanidad de los árboles desde el 2006 hasta el 2010 y se valoró la calidad de las frutas desde el 2008 hasta el 2010.

Los portainjertos de semillas 'BW2' y 'Degania' tuvieron el rendimiento cumulativo más alto desde el 2006 hasta el 2010, 357 kg/árbol y 343 kg/árbol respectivamente comparado con 'Velvick', 315 kg/árbol. El portainjerto 'Ashdot' produjo árboles notablemente más pequeños y también tuvieron la más alta eficiencia de rendimiento (1.6 kg/m³), seguido por 'BW2' (1.3 kg/m³) y 'Degania' (1.2 kg/m³), comparado con 'Velvick' (0.8 kg/m³). Sin embargo, debido a los pequeños tamaños y los buenos rendimientos, los árboles de portainjertos 'Ashdot' mostraron las tendencias de añerismo.

'BC101' fue el más precoz de los portainjertos clonales y fue el más alto productor durante los primeros tres años. 'BC62' tuvo el rendimiento más alto cumulativo, 350 kg/árbol, comparado con el clon 'Velvick', 290 kg/árbol. 'Duke 7' y 'BC128' fueron entre los portainjertos con los rendimientos más bajos de la prueba. 'BC62' produjo árboles vigorosos y por eso no tuvo el rendimiento más alto en relación con el tamaño de los árboles. 'BC101'

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clonal fue el árbol más productivo en relación con su tamaño de canopia, 0.85 kg/m³ comparado con 'Velvick' clonal, 0.75 kg/m³.

Sobre las condiciones de esta prueba, unos portainjertos parecen ser superiores al estándar de la industria 'Velvick'.

INTRODUCTION

The Australian avocado industry comprises 1100 growers and produces 49,500 tonnes of avocados annually worth \$AUD180 million at farm gate and \$430 million at retail level (Allen 2011) (<http://industry.avocado.org.au/NewsItem.aspx?NewsId=69>). The cost of producing avocados in Australia is increasing steadily driven largely by high labour costs and increasing labour shortages (McKenzie 2010; O'Brien 2005). In order to remain competitive in both national and international markets production costs have to be kept in check. One of the most effective and sustainable ways of achieving this is by increasing productivity through rootstock and scion selection (Arpaia, Bender & Witney 1993).

Rootstocks have a significant influence on avocado yields, tree health, vigour and disease susceptibility (Ben-Ya'acov, A., Michelson & Sela 1995; Bijzet & Sippel 2001; Wolstenholme 2003). The Australian avocado industry has an existing rootstock breeding and evaluation program (McCarthy 2001) but since its establishment several new imported and locally selected rootstocks have become available and warrant testing. A rootstock evaluation trial was established in May 2004 by private investors to ascertain the efficiency of 33 new rootstocks that had not been included in the national rootstock program. While many avocado rootstock evaluation programs have focused on *Phytophthora* (root rot) tolerance the trial was established in a low *Phytophthora* pressure orchard and focussed predominately on yield productivity.

The Australian avocado industry is based largely on seedling 'Velvick' rootstock which was locally selected and is well adapted to the Australian growing conditions (Newett, Crane & Balerdi 2002). Several avocado growing countries have accepted the benefits of clonal rootstocks and are favouring clonals above seedling material (Mickelbart et al. 2007; Roe, Kremer-Kohne & Kohne 1995). The advantage of established clonal rootstocks has yet to be proven under Australian growing conditions and for this reason both clonal and seedling material was included in the trial.

METHOD

A rootstock trial was established in May 2004 in Childers, central Queensland (25°14'S 152°16'E, altitude 115m) on good, deep red soil with a soil pH of approximately 6.3 and low *Phytophthora* pressure. The trial consisted of 22 seedling and 11 clonal rootstocks with 'Hass' as scion (Table 1). Tree spacing was 11m X 5m and the orchard was under standard commercial managed according to the grower's orchard practices.

Table 1. Clonal and seedling rootstocks included in the trial with 'Hass' as the scions. The country of origin is given in parentheses

Seedling rootstocks	Clonal rootstocks
'Ashdot' ¹ (Israel)	BM1 (RSA)
'Degania' ¹ (Israel)	BM2 (RSA)
'Reed' (USA)	'Duke 7' ² (USA)
'Zutano' (USA)	BC101 (Aus)
BW127 (Aus)	BC128 (Aus)
BW128 (Aus)	BC16 (Aus)
BW140 (Aus)	BC19 (Aus)
BW16 (Aus)	BC197 (Aus)
BW181 (Aus)	BC62 (Aus)
BW19 (Aus)	BC7 (Aus)
BW197 (Aus)	'Velvick' ³ (Aus)
BW2 (Aus)	
BW5 (Aus)	
BW6 (Aus)	
BW62 (Aus)	
BW68 (Aus)	
BW7 (Aus)	
BW70 (Aus)	
BW78 (Aus)	
BW80 (Aus)	
BW93 (Aus)	
'Velvick' ³ (Aus)	

¹West Indian origin; ²Mexican origin; ³Guatemalan origin; all the others are believed to be West Indian x Guatemalan hybrids

The trial extended over four hectares. For each rootstock there were five randomized replicated plots, each plot consisting of three data trees with guard trees between the plots. Clonal and seedling 'Velvick' was used as the Australian industry standard and clonal 'Duke 7' as the international standard. The 'BW-' and 'BC-' rootstocks are Birdwood Nursery selections and believe to be of Guatemalan x West Indian origin.

Vegetative vigour, tree health and yield was monitored from 2006 to 2010. Yield was expressed in kg per tree and as yield efficiency i.e. kg of fruit produced per m³ of canopy volume, assuming an elongated spheroid shaped tree, $V = \frac{3}{4}\pi ab^2$, where V is canopy volume, a is the radius of the canopy height and b is the radius of the canopy width (Arpaia, Bender & Witney 1993; Mickelbart et al. 2007).

Fruit quality was assessed from 2008 to 2010 for all rootstocks. Fruit were assessed according to the Avocare Quality Assessment Manual (White *et al.* 2001) at eat ripe after being cold stored under domestic market commercial simulation conditions (Hofman *et al.* 2001). Fruit with internal defects extending over more than 10% of the flesh were deemed unmarketable.

The data from the clonal and seedling rootstocks was analysed separately. One way analysis of variance at 95% confidence level, linear regression analyses, and simple correlations were carried out using GenStat 11th Edition. Where necessary, data was log transformed in order to normalize it.

RESULTS AND DISCUSSION

Vegetative vigour and tree health

In general, the clonal rootstock trees took approximately 12-18 months longer to establish than the seedling trees. By the second harvest, 2007, the clonal trees had grown well and were only slightly smaller than their seedling counterparts. The tree canopy volume for the various rootstocks is shown in Figure 1. The 2010 canopy volume was not included in the

figure since the orchard was pruned at the end of the 2009 fruiting season. As could be expected, variation in canopy volume was more noticeable in the seedling rootstock trees than in the clonal trees (Fig. 1). Variability in physical and physiological characteristics of seedling rootstocks is well documented (Ben-Ya'acov, A 1976; Ben-Ya'acov, A., Michelson & Sela 1993, 1995; Whiley et al. 2007).

Seedling rootstock 'Ashdot' produced the smallest trees with 12 of the 15 'Hass' on 'Ashdot' trees appeared to be distinctly dwarfing. As a result of their very small size, these 12 trees seemed to be susceptible to environmental stresses and were the only trees in the trial that showed signs of stress after bearing a relatively heavy crop in 2008 and 2009. All the other trees remained healthy throughout the trial. None of the trees displayed any symptoms of root rot which was not surprising given the orchard's age, excellent management, reasonably dry seasons from 2004 to 2010 and the low *Phytophthora* pressure in the orchard.

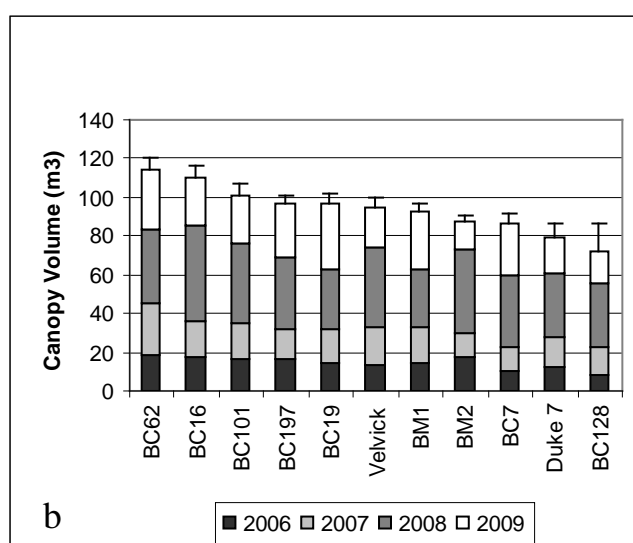
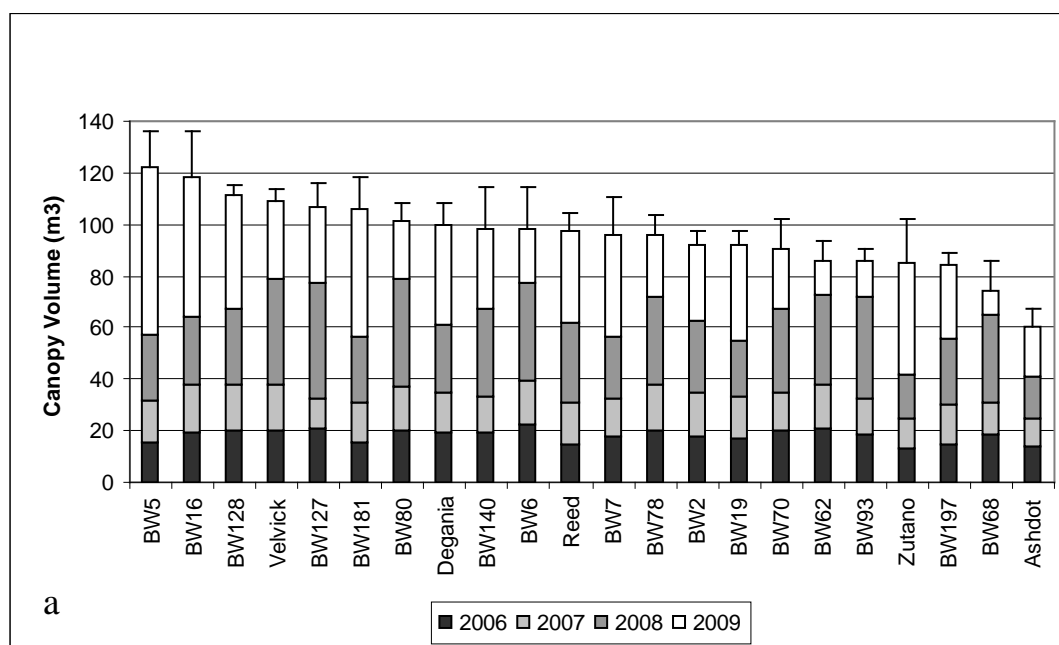


Figure 1. Progressive growth in canopy volume from 2006 to 2009 for 'Hass' on (a) seedling and (b) clonal rootstocks. Bars above the columns represent the standard error of the mean for the 2009 data.

Crop yield

The first crop was harvested in 2006 with seedling rootstocks producing significantly larger crop loads (group average: 13.7kg / tree) than the clonal trees (group average: 3.7kg / tree, Tables 2 and 3). BW2, believed to be a seedling of 'Velvick' was found to be a precocious rootstock and produced the highest cumulative yield for 2006 to 2010. BW2 produced 13% more fruit over the five year observation period than the industry standard rootstock 'Velvick'. The Israeli seedling rootstock 'Degania' was also found to be a good precocious bearer with a cumulative yield almost 10% higher than seedling 'Velvick'. 'Ashdot' despite being almost half the size of the trees on 'Velvick' produced a cumulative yield only 6% less than that of 'Velvick'. 'Hass' on 'Reed' and 'Zutano' rootstocks had the lowest yields throughout the monitoring period despite producing reasonably sized trees.

Table 2. Average yield (kg) per tree for seedling rootstocks with 'Hass' as scion

Average yield per tree (kg)						
Rootstock	2006	2007	2008	2009	2010	Cumulative
BW2	20.6	48.7	104.0	57.9	125.8	357.0
'Degania'	18.8	45.3	91.7	64.2	123.4	343.3
BW70	17.5	36.0	87.6	66.8	117.5	325.4
BW80	10.0	28.8	105.0	56.4	124.5	324.7
BW19	17.4	38.5	85.1	58.4	124.8	324.3
BW78	12.0	34.9	93.3	74.7	100.9	315.8
'Velvick'	13.6	32.6	86.0	53.7	129.3	315.1
BW181	13.7	39.5	78.5	66.6	116.0	314.3
BW140	11.1	29.4	87.2	65.8	114.1	307.6
BW7	17.6	39.7	80.0	64.8	104.7	306.8
BW197	14.4	33.2	84.7	61.6	112.5	306.4
BW93	10.7	35.5	86.1	47.4	124.0	303.8
BW16	15.9	36.9	76.6	51.4	121.0	301.7
BW127	12.7	41.4	90.2	43.1	111.9	299.3
'Ashdot'	18.9	39.5	81.5	77.1	78.6	295.5
BW6	9.8	34.5	90.3	56.2	104.2	294.9
BW62	9.2	36.4	94.2	42.3	112.6	294.7
BW5	15.8	38.9	77.0	38.6	120.7	291.0
BW128	13.3	26.7	79.8	46.5	113.9	280.2
BW68	7.8	21.9	72.8	73.5	97.9	273.9
'Zutano'	15.3	21.3	60.8	58.2	102.5	258.2
'Reed'	6.1	18.6	65.9	50.5	103.8	244.9
Group Avg	13.7	34.5	84.5	58.0	112.9	303.6
P	<0.001	<0.001	<0.001	0.116	0.112	0.001
d.f.	21	21	21	21	21	21
v.r.	4.24	4.47	3.01	1.43	1.41	2.32

Table 3. Average yield (kg) per tree for clonal rootstocks with 'Hass' as scion

Average yield per tree (kg)						
Rootstock	2006	2007	2008	2009	2010	Cumulative
BC62	4.0	33.6	110.6	63.1	139.0	350.3
BC101	8.1	34.0	88.9	50.5	122.5	304.1
BC19	4.0	25.9	85.7	40.0	147.9	303.5
'Velvick'	4.3	27.2	77.1	47.6	133.7	289.7
BM2	4.1	26.0	80.5	56.2	120.5	287.2
BC197	4.5	28.0	85.6	46.2	119.6	283.9
BC16	3.0	30.6	82.5	41.2	124.0	281.3
BM1	1.3	16.0	68.8	55.6	119.2	260.9
'Duke7'	4.0	21.2	59.7	52.1	102.5	239.6
BC7	1.9	21.5	66.9	54.9	92.7	237.9
BC128	1.0	14.9	51.9	23.3	98.2	189.4
Group Avg	3.7	25.4	78.0	48.3	120.0	275.3
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
d.f.	10	10	10	10	10	10
v.r.	7.18	4.58	9.61	5.22	4.08	8.68

Initially the clonal rootstocks produced lower 'Hass' yields than the seedling rootstocks but by 2010, BC62 had exceeded the production achieved by the seedling rootstocks. Clonal rootstock BC62 produced the highest cumulative yield (350kg / tree) of all clonal rootstocks tested, equating to 20% higher than clonal 'Velvick' (290kg / tree) and 45% higher than the international standard clonal 'Duke 7' (240kg / tree). In general, the clonal rootstocks produced lower yields than the seedling trees but this could be related to their smaller canopy volumes. As a direct comparison, over the five year observation period seedling 'Velvick' produced 10% more fruit than its clonal counterpart.

Yield efficiency

Often large vigorous trees produce a good crop load but they may not be the most cost effective producers, since they are often more expensive to manage. Therefore, yield was expressed in terms of canopy volume, 'yield efficiency'. Seedling rootstock BW2 produced strong 'Hass' trees which were less vigorous than trees on the seedling 'Velvick' rootstock (Figure 1). In the 2010 harvest BW2 produced 1.3kg of fruit per m³ of canopy volume which was 53% more productive than the industry standard 'Velvick' (0.8kg/m³). The Israeli seedling rootstock 'Ashdot' had the highest yield efficiency throughout the five year monitoring period (Figure 2). 'Hass' on 'Ashdot' rootstock produced a moderate crop load but because of its small tree size, had the highest yield efficiency. 'Ashdot' may be well suited for high density planting but given its small tree size, may be susceptible to environmental and physiological stresses.

Although BC62 was the highest bearing clonal rootstock, because of its large tree size it did not have the highest yield efficiency (Figure 3). BC101 had the highest yield efficiency followed by BC19. BC128 performed poorly throughout the trial.

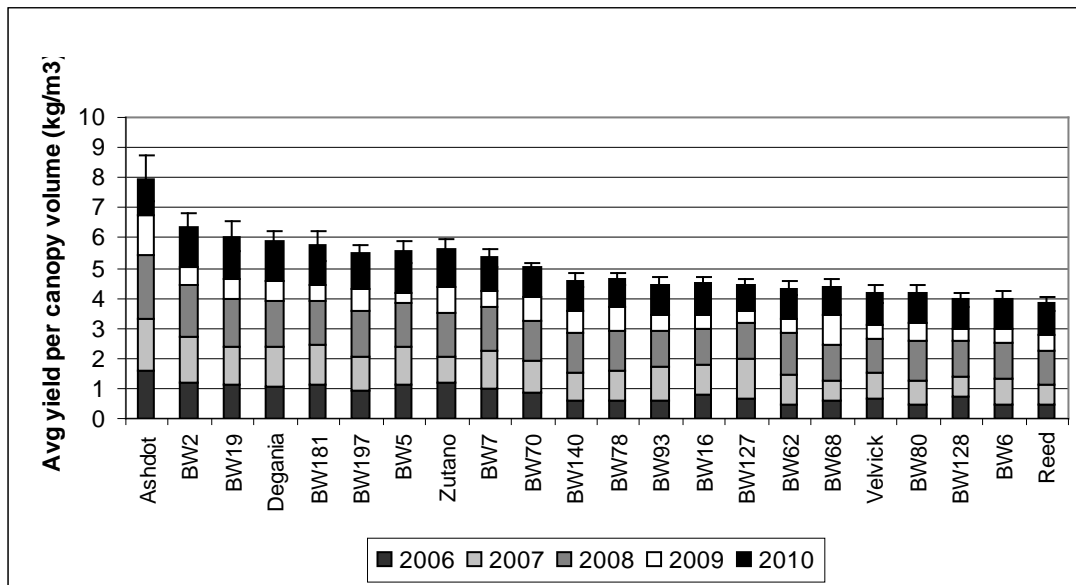


Figure 2. Average yield (kg) per canopy volume (m^3) of 'Hass' on seedling rootstocks. Bars above the column indicate the standard error of the mean for the cumulative yield (2006 to 2010).

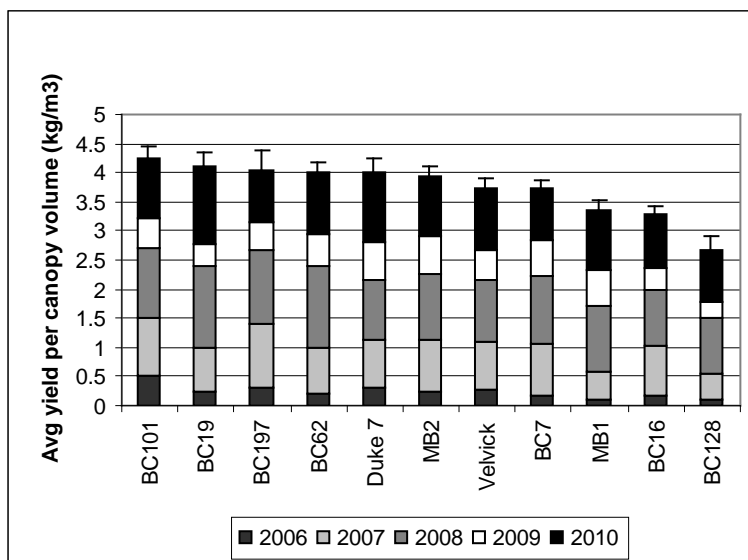


Figure 3. Average yield (kg) per canopy volume (m^3) of 'Hass' on clonal rootstocks. Bars above the column indicate the standard error of the mean for the cumulative yield (2006 to 2010).

Fruit quality

Rootstocks can have a direct influence on fruit quality (Burdon et al. 2007; Dixon et al. 2007; Marques, Hofman & Wearing 2003; Smith & Kohne 1992). However, in the present trial fruit quality appeared to be more closely related to crop load than to specific rootstocks. In general, trees that produced large crop loads tended to produce good quality fruit. However, this could not be statistically proven. The fruit quality increased noticeably as the trees aged. In 2008 approximately 70% of the 'Hass' fruit sampled from seedling rootstocks were of marketable quality, 82% in 2009 and 97% in 2010.

CONCLUSION

Under the current trial conditions, BW2 appears to be potentially superior to the existing Australian industry standard rootstock, seedling 'Velvick'. BW2 is precocious but less vigorous than 'Velvick' and produces a higher 'Hass' yield than 'Velvick'. Although BW2 has not been included in rootstock trials in other avocado growing regions, it has been commercially grown in many regions and is proving highly successful. Seedling rootstock 'Degania' also has good potential as do clonal rootstocks BC62 and BC101. Seedling rootstock 'Ashdot' appears to have dwarfing qualities and may be well suited for higher density plantings on fertile soils. However, given its potential susceptible to environmental and physiological stresses 'Ashdot' may require careful management.

The results presented here are from young trees that have not yet reached their production potential. Some rootstocks may take longer than other to reach optimum production and it is recommended that the monitoring of the trial continues until the trees reach maturity.

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