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PERFORMANCE OF COMMERCIALLY GROWN 'HASS' AVOCADO ON CLONAL ROOTSTOCKS AT WESTFALIA ESTATE, SOUTH AFRICA

D. J. Roe; T. M. Morudu; J. S. Köhne
Merensky Technological Services, P O Box 14, Duivelskloof 0835, South Africa. E-mail: westfalia.nursery@pixie.co.za

SUMMARY

The Californian clonal rootstocks Thomas, Barr Duke, D9, and Duke 7 have been tested on commercial scale, for the Hass cultivar, at three sites, since 1989. Individual tree yields and tree dimensions have been measured annually. Yield efficiency of Hass on D9 and Barr Duke was superior to Hass/Duke 7. Two local rootstock selections, Merensky 1 and Merensky 2, have also been tested commercially for Hass since 1994 and both have produced greater Hass yields than on Duke 7 rootstock, although in terms of yield efficiency, only Merensky II was superior to Duke 7. Phytophthora tolerance of these two local selections is also superior to Duke 7. Although it is still early in the commercial evaluation of these rootstocks, promising Phytophthora tolerance results have led to an early release of Merensky to local and overseas institutions for testing purposes.

INTRODUCTION

Merensky Technological Services is the research and development company of Hans Merensky Holdings (Pty) Ltd, which also owns Westfalia Estate in South Africa. Westfalia Estate comprises about 1000 ha of avocados, and is situated in the subtropical areas in the north east of South Africa, where most of the country's avocados are grown. In these areas, avocado production is limited mainly to those areas which are frost-free, and soils are deep, well-drained, red or brown apedal oxisols and inceptisols. These soils have a lower *P. cinnamomi* threat than more anaerobic soil types. The average rainfall is about 1300 mm, but in some years, this may exceed 1800 mm, which falls mainly during the warm summer months. These warm, wet conditions with good soils contribute to a most favourable environment for *Phytophthora cinnamomi*, as well as vegetative growth, generally at the expense of production.

California has had a most productive rootstock selection programme producing a number of avocado rootstocks with good tolerance to *Phytophthora cinnamomi* including Duke 7, G755 series, Thomas, D9, Barr Duke and Torro Canyon. Rootstocks tolerant to Phytophthora are not necessarily productive in terms of fruit yield, and for this reason it was decided to test some of the Californian rootstocks under Westfalia conditions.

During the early 1980's selections were made at Westfalia (Roe *et al*., 1995) of a number of rootstocks, the most promising in terms of *Phytophthora* tolerance being Merensky I (renamed from Latas) and Merensky II (renamed from Dusa). The first commercial planting of Hass on these rootstocks was in 1993, and these have been monitored since.

The choice of rootstock in South Africa has been mainly for Phytophthora tolerance, although, since the discovery of phosphorous acid trunk injections (Darvas *et al.*, 1978; 1983) this is no longer a major problem. The Californian clonal rootstock, Duke 7, is presently the standard rootstock for all cultivars in South Africa. The predominance of one rootstock is not healthy for the industry and new alternatives are continually being sought.

This paper reports on the performance of Hass on clonal Californian rootstocks, at three sites, as well as on locally selected clonal rootstocks, at Westfalia Estate.

MATERIALS AND METHODS

Hass avocado trees, on the Californian clonal rootstocks Thomas, D9, Barr Duke and Duke 7, produced by Westfalia Nursery by means of a modified Freulich method, were planted in commercial orchards, at 5 x 5 m spacing, in 1989 at one site (Zendelingshoek Farm (100 trees/rootstock). In 1991, the same rootstocks were established at two other sites (Evenrond Farm (100 trees/rootstock) and Westfalia Farm (20 trees/rootstock)). Thirty-five of each of the Westfalia-selected clonal rootstocks Merensky 1 and Merensky 2 (formerly Latas and Dusa respectively), with Hass as the scion, were established in 1993, with Hass on Duke 7 clonal rootstock as comparison.

All blocks were irrigated using micro-sprinklers, although both the Evenrond and Zendelingshoek sites were affected by drought during the period from 1992 to 1995. The Zendelingshoek site was detrimentally affected by excessive levels of lime. At Evenrond Farm, Hass on Duke 7 in a block neighbouring the trial site was used for comparative purposes.

Trunk diameter, tree height and canopy diameter, as well as fruit yields, were measured annually. Yield efficiency (YE) per rootstock/scion combination was determined both as kg fruit/cm^2 trunk cross sectional area, and as kg fruit/m^3 canopy volume. The following formulae were used:

$$\text{Trunk cross sectional area} = \frac{(\text{Circumference})^2}{4\pi}$$

The shape of an unpruned Hass tree closest resembles a hemisphere, therefore:

$$\text{Volume of a hemisphere} = \frac{\pi\ (\text{average of canopy height and diameter})^3}{12}.$$

RESULTS AND DISCUSSION

The progress of these evaluations has been reported annually (Roe *et al.*, 1995; 1996; 1997; 1998).

Tree vigour

The vigour of Hass on the Californian clonal rootstocks Duke 7, D9, Barr Duke and Thomas, varied according to the conditions at each location (Table 1). At Zendelingshoek Farm, where soil chemical problems of high lime were experienced, both Duke 7 and

Thomas imparted higher vigour to Hass than did D9 and Barr Duke during the early years of growth. Later this difference became non-significant, which is in agreement with observations in California (Arpaia *et al.*, 1993). Under conditions of drought at Evenrond Farm (Table 1) there were no differences in Hass vigour attributable to these rootstocks. At Westfalia Farm, where there were no major stress factors, and which was most likely the most ideal site, D9 resulted in Hass with significantly smaller ($P \leq 0.01$) trunk circumference than the other three rootstocks. There was no significant difference in stem circumference between Hass trees on Merensky 1, Merensky 2 and Duke 7.

Yields

Californian Rootstocks

Yields were extremely variable over the three evaluation sites (Table 1). Where there were soil chemical problems (Zendelingshoek), only two crops worth mentioning were produced over the evaluation period. At this site, the tendency was for greater production of Hass on D9 and Barr Duke, although this was not a significant difference.

At Evenrond Farm, severely affected by drought from 1992 to 1995, The cumulative Hass yield on D9 rootstock (45.7 $t \cdot ha^{-1}$) was significantly ($P \leq 0.01$) superior to Hass on Barr Duke (36.4 $t \cdot ha^{-1}$) and Thomas (12.1 $t \cdot ha^{-1}$) rootstocks (Table 1). Hass on Duke 7 in a neighbouring block produced similar crops to D9, but statistical comparison was impossible due to differences in locality, tree number and slope aspect.

In contrast, however, at Westfalia Farm, where conditions were most ideal, both Duke 7 and Thomas produced significantly larger cumulative yields than did D9. This suggests that under conditions of stress, D9 may be a superior rootstock, but when conditions are more optimal, Thomas may be a suitable alternative to Duke 7 for the Hass cultivar. Thomas has also been reported to be sensitive to salinity in California.

Westfalia rootstock selections

Both Merensky 1 and 2 have produced greater cumulative Hass yields than did Duke 7, Merensky 2 significantly so ($P \leq 0.05$) (Table 2). These rootstocks have also performed well in terms of root rot tolerance in California (Menge, 1998) and in South Africa (Duvenhage; Kremer-Köhne, unpubl. data, 1999). However, it is still early in the evaluation of these rootstocks, and no definite recommendations can be made yet.

Yield Efficiency

It is sometimes misleading to present data on vigour and yield data alone, because a rootstock scion combination may be producing a large crop on an excessively large tree, which is undesirable horticulturally. In the expression of YE, the units kg fruit/cm^2 trunk cross sectional area, and kg fruit/m^3 canopy volume were used. Yield efficiency of Hass on the Californian rootstocks during years 6-8 (Figure 1) and of the Westfalia selections during year 4-5 (Figure 2) showed interesting differences in expression of yield efficiency. When expressed as yield per cross trunk sectional area, values ranged from 0.22 to 0.42 $kg \cdot cm^{-2}$, the order of efficiency of Californian rootstocks (Figure1) was: Duke 7 > D9 = Barr Duke > Thomas.

Table 1. Tree size data and yields ($t \cdot ha^{-1}$) from commercial plantings of Hass avocado on different rootstocks at three localities at Westfalia Estate, South Africa.

	Rootstock				LSD	Level of Significance
	Duke 7	D9	Barr Duke	Thomas		
Stem Circumference (cm)						
Zendelingshoek Farm (planted 1989, affected by soil problems)						
1992	32.9 a[1]	27.9 b	28.8 b	31.8 a	1.21	0.01
1994	43.3 a 50.4 a	39.6 b	39.9 b	42.8 a	1.49	0.01
1995	54.9 a	45.4 c	45.4 c	48.7 b	1.66	0.01
1996	82.3	50.1 b	49.4 b	53.5 a	2.84	0.01
1998		71.9	71.7	74.6	NS	
Evenrond Farm (planted 1991; severely affected by drought 1992-95)						
1993		20.8	21.3	21.4	NS[2]	
1994		30.4	31.6	32.2	NS	
1995		39.9	39.1	39.9	NS	
1996		45.3	44.7	45.6	NS	
1998	(52.2)	63.0	64.4	56.3	NS	
Westfalia Farm (planted 1991; not severely affected by drought)						
1995	30.5 a	24.3 b	28.5 a	30.0 a	3.29	0.01
1996	40.9 a	32.0 c	36.8 b	39.3 ab	4.04	0.01
1998	70.7 a	55.7 b	66.8 a	68.3 a	6.89	0.01
1999	81.8 a	62.1 b	74.4 a	77.0 a	8.06	0.01
Yield (t/ha)						
Zendelingshoek Farm (planted 1989, affected by soil problems)						
1992	0.3	0.03	0.01	0.37	NS	
1996	2.9 bc	10.0 a	5.0 b	1.1 c	3.2	0.01
1997	0	0	0	0	NS	
1998	24.3	24.9	28.4	27.6	NS	
Cumulative	27.5	35.0	33.4	29.1	NS	0.01
Evenrond Farm (planted 1991; severely affected by drought 1992-95)						
1994	(1.0)	2.8 a	2.4 b	2.7 ab	0.32	0.05
1995	(6.8)	5.2 a	2.5 b	0.14 c	1.10	0.01
1996	(1.7)	4.5 a	2.0 b	0.6 c	1.19	0.01
1997	(7.4)	8.6 a	8.6 a	2.7 b	2.54	0.01
1998	(27.9)	24.6 a	20.9 a	6.0 b	5.01	0.01
Cumulative	(44.8)	45.7 a	36.4 b	12.1 c	9.87	0.01
Westfalia Farm (planted 1991; not severely affected by drought)						

Yield (t ha^{-1})						
1995	6.9 a	2.9 c	3.4 c	4.9 b	1.53	0.05
1996	4.5 a	4.4 a	4.4 a	5.1 a	1.62	0.05
1997	9.3 a	5.4 b	6.4 ab	7.1ab	2.82	0.05
1998	26.1	24.2	24.6	28.1	NS	
1999	23.1 a	11.7 c	14.6 bc	18.8 ab	5.34	0.05
Cumulative	69.9 a	48.6 c	53.4 bc	64.0 ab	11.31	0.05

[1] Means in each row (year) followed by the same letter are not significantly different according to F test.
[2] NS = Non-significant
Data in parenthesis are from 60 Hass/Duke 7 trees planted at the same time as, in similar soils as, and within 300 m of the rootstock trial at Evenrond Farm; no statistical comparison with Duke 7 was done at this site.

Table 2. Yield of 'Hass' avocado on three rootstocks**.**

Rootstock	**Yield (t·ha^{-1})**				
	1996	**1997**	**1998**	**1999**	**Cum.[z]**
Duke 7	1.5 b	3.0	14.8 b	9.1	28.3
Merensky I	2.6 ab	3.8	14.0 b	10.3	30.6
Merensky II	3.8 a	3.4	20.8 a	7.5	35.5
Level of significance	0.05	NS	0.05	NS	NS

[2] Cumulative

However when expressed as yield per canopy volume, data ranged from1.76 to 3.51 kg·m^{-3}, and the order of efficiency was: D9 > Barr Duke > Duke 7 > Thomas, which compared favourably with YE reported by Arpaia *et al.* (1993). These data also indicated that stem circumference was not necessarily a good reflection of the overall tree vigour, but that canopy dimensions should also be determined.

There was a greater correlation between the two expressions of YE in the Westfalia-selected rootstocks (Figure 2), where the order of YE was: Merensky 2 > Duke 7 > Merensky 1, using either expression of YE.

Since canopy dimensions are of greater relevance than stem circumference when determining plant densities, the YE expressed as kg/m^3 canopy volume is assumed to be of greater value to producers of avocado.

CONCLUSIONS

Although Duke 7 is still the recommended rootstock for South African Hass orchards, the clonal rootstocks D9, Merensky 2, and Barr Duke to lesser degree, appear to be more efficient at producing Hass fruit than Duke 7 is.

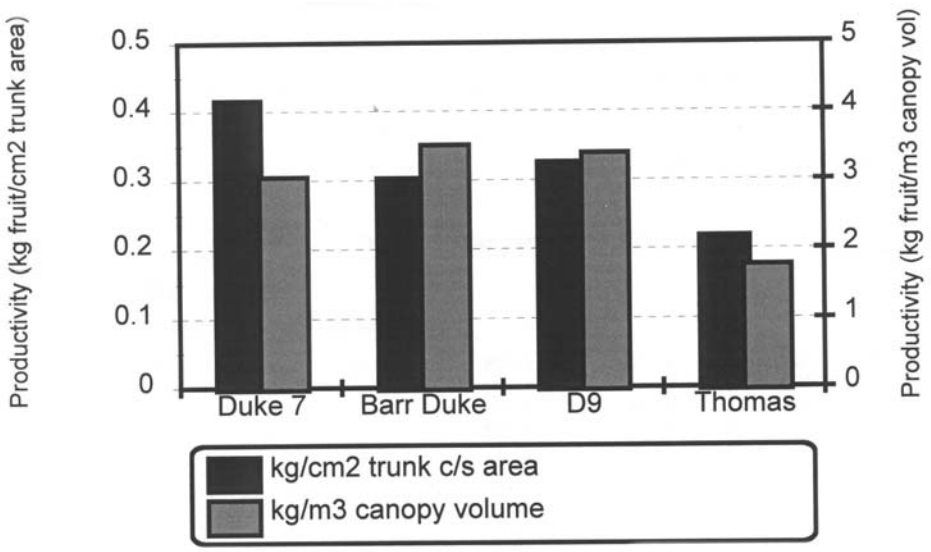

Figure 1. Yield efficnecy of 'Hass' avocado on differente Californian clonal rootstocks in years 6-8m averaged river three sites (150 trees per rootstock) at Westfalia Estate, South Africa. Yield efficiency was expressed as kg fruit/cm^2 trunk cross sectional area, and as fruit kg·m^{-3}of canopy volume.

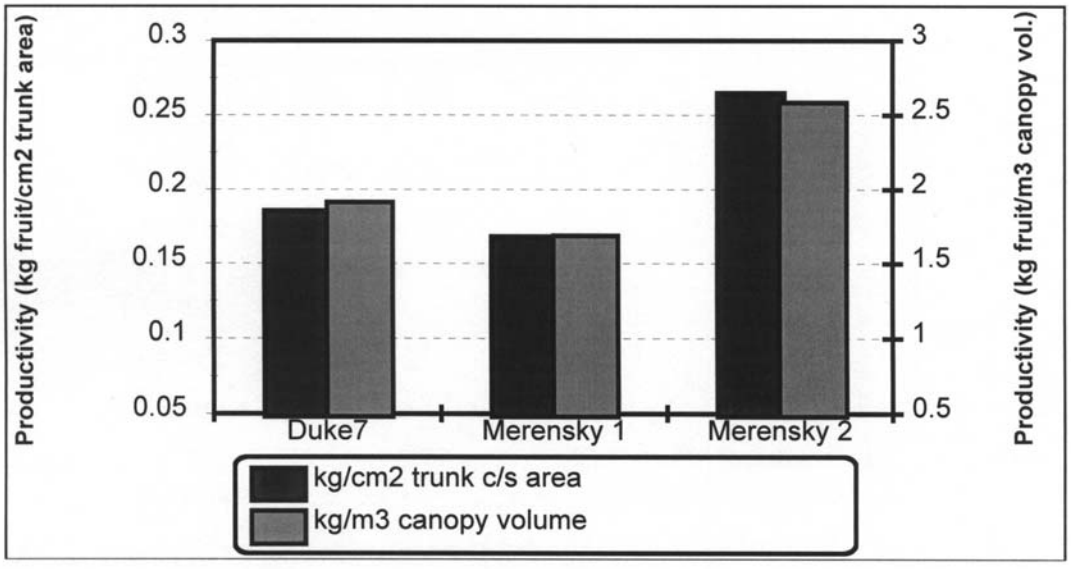

Figure 2. Yield efficiency of 'Hass' avocado on clonal root-stocks selected at Westfalia Estate, South Africa, in year 4-5 at Westfalia Estate, South Agrica. Yield efficiency was expressed as kg fruit/cm^2 trunk cross sectional area, and as fruit kg·m^{-3} of canopy volume.

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