South African Avocado Growers' Association Yearbook 1995. 18:62-65

Effect of Mulching on Hass Avocado Fruit Growth and Yield in the Kwazulu/Natal Midlands

C. Moore-Gordon, B.N. Wolstenholme and J. Levin
Department of Horticultural Science, University of Natal, Private Bag X01, Scottsville, Pietermaritzburg, 3209, RSA

ABSTRACT

The Hass cultivar is important to the South African avocado industry as it is a late maturing cultivar and is preferred by overseas consumers. Unfortunately the cultivar is prone to bearing a large percentage of undersized fruit, which cannot be exported. Mulching as a possible method of increasing fruit size was investigated. In a field trial at Everdon Estate, Howick, root health has been improved by the application of coarse pine-bark mulch and calcium acetate crystals (500 g every month). All measured fruits, in both the length and diameter axes, fitted a Gompertz growth curve. Rate of fruit growth and total growth were significantly greater on the mulch treatment. At harvest, the mulch treatment resulted in a significant increase in mean fruit mass, mean fruit number per tree and total yield.

INTRODUCTION

Since the South African avocado industry is largely export orientated, cultivars such as Hass, which are preferred by overseas consumers, are important to the industry (Cutting, 1993). Furthermore, the cultivar is late maturing and is therefore useful for extending the harvesting season. The major draw-back of this cultivar, however, is that it bears a large percentage of undersized (< 200 g) fruit, and so there is some urgency within the industry to resolve the problem.

The small fruit problem, a physiological problem of the tree without pathogen involvement (Blanke and Bower, 1991), is more pronounced as the trees become older (Cutting, 1993) and in orchards situated in warmer and/or drier climates (Hilton-Barber, 1992). The major physiological reason for undersized fruit may be related to a lack of cell division in the mesocarp tissue (Schroeder, 1958) and early seed coat abortion (Wolstenholme *et al,* 1985; Cutting, 1993). A high level of promotive growth hormones (especially cytokinins) relative to inhibitive ones (abscisic acid) is believed to be important for maintaining seed coat health. The seed (Blumenfeld and Gazit, 1970; 1974) and more specifically the seed coat (Cutting, 1993) controls the influx of nutrients, assimilates and promotive hormones necessary for fruit growth; once the seed coat shrivels and dries, increase in fruit size slows markedly.

Relatively large amounts of cytokinins are synthesised by growing plant feeder roots (van Staden and Davey, 1979) and transferred via translocation pathways to the aerial portions, including fruits, so it seems that root health may be a critical factor influencing fruit size. Encouraging vigorous and active root growth through mulching could lead to an enhanced fruit cell division and fruit growth rate, with increased fruit size. A trial has been set up to determine the effect of mulching on various phenological, anatomical and physiological parameters. It is appreciated that fruit size is an integration of numerous, complex interacting factors, including vigour, leaf : fruit ratio, crop load and plant stress, but the hypothesis being tested is that improved root activity through mulching can reduce the proportion of small fruit on the tree.

MATERIALS AND METHODS

Treatment

This study was conducted using six year old Hass trees on clonal Duke 7 rootstock, on Everdon Estate, near Howick, in the KwaZulu/Natal midlands (30° 16'E and 29° 27'S). The orchard is situated in Bioclimatic region 3, which is characterised by cool mesic conditions, typical of a mist-belt climate. A total of 1.5 m^3 of coarse composted pine-bark was applied in February 1993 under the canopy of six trees to a depth of approximately 15 cm, and these were compared to a control (unmulched trees). 500 g calcium acetate crystals per tree were applied to the mulch on a monthly basis, in order to enhance root health and vigour. The trees are grown on a Hutton type soil which is characterised by an orthic A layer overlying a red apedal B horizon. Normal orchard practice was followed in terms of other cultural practices, including irrigation and fertilization.

Data collection

The data collection period for phenological events spanned from May 1993 through to December 1994. Root flushes were monitored by visually estimating the area covered by white healthy feeder roots under newspaper mulch (with an approximate area equal to 1250 cm^3). The newspaper mulch was placed 1m from the micro-jet nozzle on the southwest side of the tree, so as to avoid direct sunlight. Three readings per tree were taken at the end of each month. Visual estimates of root flushing were performed using a rating of 0-10. Kaiser and Wolstenholme's (1994), groupings of "poor", "medium" and "good" were chosen, viz. 0 to 2, 3 to 4, and ≥ 5 respectively.

For the purpose of measuring fruit growth, 40 fruits per tree were tagged on 26 October 1993, when all fruit were approximately 10mm in length. Subsequent length and diameter measurements, using digital calipers, were taken at regular intervals throughout the growing season. The number of fruit measured per tree gradually declined through the growing season because of fruit abscission, so at harvest an average of 15 fruits per tree were measured.

On 27 July 1994 the trial was harvested, and fruit size distributions were recorded for each tree. Fruit size was determined gravimetrically and classified according to the number of fruit per 4 kg export carton. Fruits were graded as follows:

Count 10	366-450 g
Count 12	306-365 g
Count 14	266-305 g
Count 16	236-265 g
Count 18	211-235 g
Count 20	191-210 g
Count 22	171-190 g
Count 24	156-170 g
Count 26	146-155 g
Factory grade	< 146 g

Total tree yields were calculated by adding the product of the number of fruit per count size and the class centre of all the count sizes.

RESULTS AND DISCUSSION

Root flushing

Root activity on the mulch treatment was more intense than in the control. In the mulch treatment root growth fell into the "medium" category for most of the season, whereas in the control mainly "poor" root growth was recorded. For a substantial part of the season (December 1993 through to April 1994) root activity was allocated a "good" rating for the mulch treatment (Figure 1). Root flushing periods occurred at roughly the same time, but in the mulch treatment appeared to occur slightly earlier and for a longer period (Figure 1).

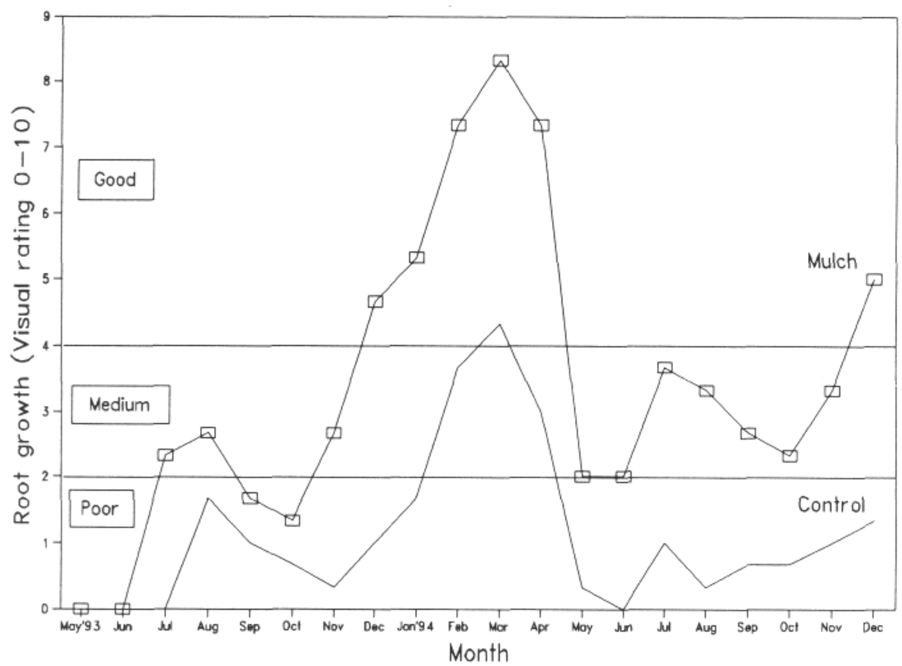

Figure 1
Root flushes as determined by a visual rating where there is no root growth for a rating of 0, and extensive root growth for a rating of 10.

Avocado trees, with their rainforest origin, are adapted to growing in soils with a thick humic layer and a high organic content, and avocado roots; being "litter feeders" with a high oxygen requirement (Moore-Gordon *et al.,* 1994), thrive under such edaphic soil conditions. By applying the pine bark mulch, rain-forest floor conditions have essentially been simulated, resulting in the more intense and prolonged feeder root activity.

Fruit growth

All fruits measured at the trial site fitted a Gompertz curve which has the following mathematical equation:

y = C exp [-exp (-B (x M))] + A

where:

A = starting value

B = growth rate

C = total growth

M = point of inflection

Each fruit measured had a regression coefficient (R^2) value greater than 0.99 indicating an extremely good fit. This was the case for both the length-ways and diameter measurements. The mathematical equations for each growth curve are summarized as follows:

- Length Axis:

Mulch: $y = 110.10 \exp[-\exp(-0.02297(x - 51.61))] - 8.16$

Control: $y = 95.84 \exp[-\exp(-0.02252(x - 53.86))] - 5.20$

- Diameter axis:

Mulch: $y = 77.08 \exp[-\exp(-0.02222(x - 48.29))] - 7.07$

Control: $y = 67.53 \exp[-\exp(-0.02336(x - 54.13))] - 2.66$

An analysis of variance was performed on each parameter of the Gompertz curve equation and results are summarized in Table 1. Figures 2 and 3 illustrate a graphical presentation of the resultant growth curves.

Table 1

Summary of mean values and standard errors for each growth parameter of the Gompertz curve for length-ways and diameter measurements on Hass fruit. Values are means of 82 fruits in the mulch treatment and 92 fruits in the control. (Using an F-test, NS denotes parameters are not significantly different; * denotes parameters are significantly different at the 95 % confidence level; and ** denotes parameters are significantly different at the 99 % confidence level).

	Parameter	*$x \pm SE(x)$*		
		Mulch	*Control*	*Significance*
Length	*A*	-8.16 ± 0.99	-7.07 ± 0.93	NS
	B	0.02297 ± 0.00084	0.02252 ± 0.00079	NS
	C	110.10 ± 1.70	95.84 ± 1.61	**
	M	51.61 ± 1.08	48.29 ± 1.02	NS
Diameter	A	-7.07 ± 1.24	-2.66 ± 1.17	*
	B	0.02222 ± 0.00105	0.02336 ± 0.00099	NS
	C	77.08 ± 2.38	67.53 ± 2.25	**
	M	48.29 ± 1.29	54.13 ± 1.22	*

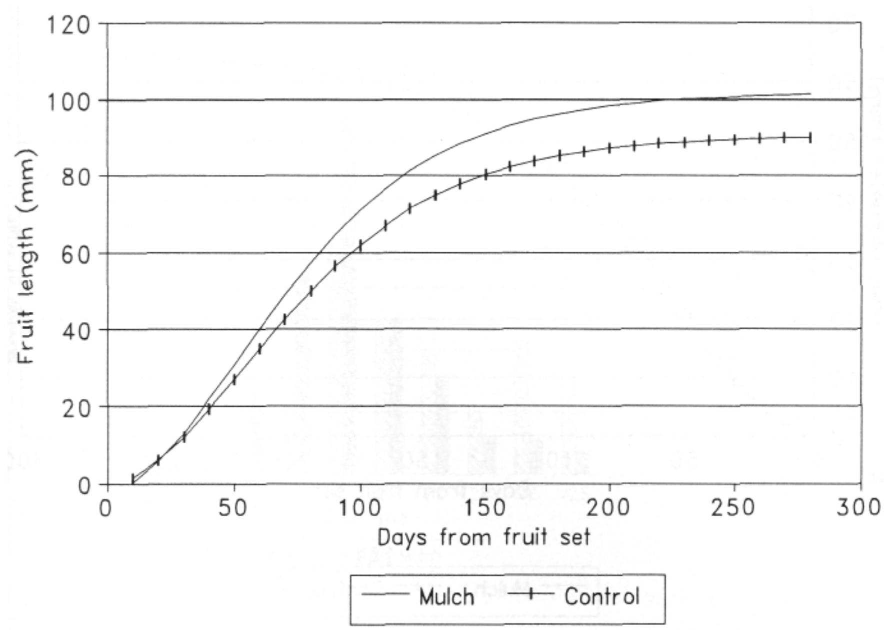

Figure 2
Hass fruit growth curves in the length-ways axis for mulch and control treatments.

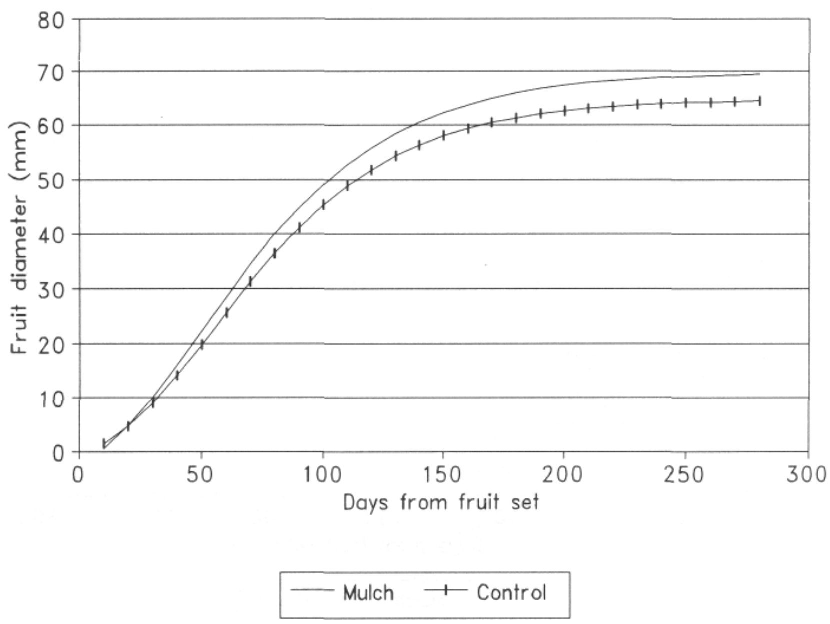

Figure 3
Hass fruit growth curves in the diameter axis for mulch and control treatments.

It is possible that those fruit which are set early may set up a monopoly for available resources at the expense of smaller fruits. Hence for a valid comparison of fruit growth dynamics on different treatments it is important that all fruits are initially the same size.

The starting values *(A)* (Table 1) were not significantly different between treatments in the length axis, indicating that all fruit were tagged at approximately the same length. In the diameter axis, the starting value *(A)* was significantly greater for control fruit at the 95% confidence level, so if anything, control fruit may initially have been stronger sinks. When fruit were first measured, 20 days after fruit set, all fruit were approximately the same size (average length measurements of 5.8 and 6.0mm, and average diameter measurements of 4.8 and 4.7mm for mulch and control treatments respectively). This shows that differences in fruit growth rates between the mulch treatment and the control could be attributed to factors during the fruit growth period, after the fruitlets had been tagged.

Total growth (*C*) was significantly different between treatments at the 99% level of confidence (Table 1). At the time of harvest, approximately 284 days after fruit set, fruit on the mulch treatment had grown an average of (14.26 ± 2.34) mm more along the length axis than fruit on the control. Similarly, fruit expansion in the diameter axis was (9.55 ± 3.27) mm more on the mulch treatment during the same period. At harvest, average fruit length on the mulch treatment was 101.4mm compared to 90.1mm on the control. Average fruit diameter at harvest was 69.6mm on the mulch treatment compared to 64.6mm on the control. These results show that mulching has led to an overall increase in fruit growth and ultimately has increased average final fruit size. Furthermore, the results suggest that increased average fruit mass at harvest on the mulch treatment is not solely attributed to increased growth in one direction, but rather increased growth in both axes. The results support work done by Zilkah and Klein (1987) who showed that avocado fruits grow proportionately in all directions.

The cause of differences in the growth curves of the two fruit populations is not growth rate *(B)* related as there are no significant differences between treatments for this parameter. Instead, the differences in average fruit size at harvest may be sought in the parameter representing the point of inflection (M), which shows a significant difference between treatments for the diameter axis at the 95% confidence level.

Yield and fruit size distribution

Average fruit mass was increased in response to mulching with the two fruit populations being significantly different at the 99% level of confidence. Fruit on the mulch treatment were on average (23.32 ± 1.20)g heavier than control fruit, and this represented an 11.8% increase in mass over control fruit (Table 2).

Assimilate supply to a fruit will depend on the extent of competition from other established fruit sinks (Monselise and Goldschmidt, 1982), and so fewer sinks should yield larger fruit. The results summarized in Table 2 show that the increase in fruit size was not the result of fewer sinks per tree, as there was an average of 6.1% more fruits per tree on the mulch treatment. This supports the theory that mulching has in some way altered endogenous physiological conditions within the plant in favour of increased fruit growth. The increased fruit size coupled with increased fruit numbers has resulted in an overall 18.5% increase in yield (Table 2).

Table 2
Summary of the effects of mulching on average fruit mass, number of fruit per tree and total yield. Figures are means of six trees. **denotes that mean fruit mass is significantly different between treatments at the 99 % confidence level.

	Control	*Mulch*	*% Increase by mulch*
Mean fruit mass (g)	198.0	221.3	11.8**
Fruit number $tree^{-1}$	509	540	6.1
Yield (kg $tree^{-1}$)	100.8	119.4	18.5

The control trees show a typical fruit size distribution of the Hass cultivar with many fruit in the count size range of 22 to 26, and a high proportion of factory grade avocados (Figures 4 & 5). 43.5% of fruit on the control occurred in the count size range of 22 and lower, compared to only 19.3% of the fruit on the mulch treatment (Table 3). Mulching had the effect of shifting the overall count size distribution in favour of large fruit, i.e. the mulch treatment yielded fewer small fruit and more large fruit (Table 3, Figures 4 & 5).

Table 3
Summary of fruit size distribution at harvest in terms of fruit number and fruit mass per count.

Count size	*Mulch*				*Control*			
	Fruit number	*Fruit mass (kg)*	*Percentage of total*		*Fruit number*	*Fruit mass (kg)*	*Percentage of total*	
			#	mass			#	mass
10–14	308	91.9	9.5	12.8	156	46.0	5.1	7.6
16–20	2306	520.8	71.2	72.7	1568	347.8	51.4	57.5
22–26	547	93.0	16.9	13.0	1019	167.1	33.4	27.6
>>26	76	10.7	2.4	1.5	310	43.6	10.1	7.3
TOTAL	3237	716.4	100	100	3053	604.5	100	100

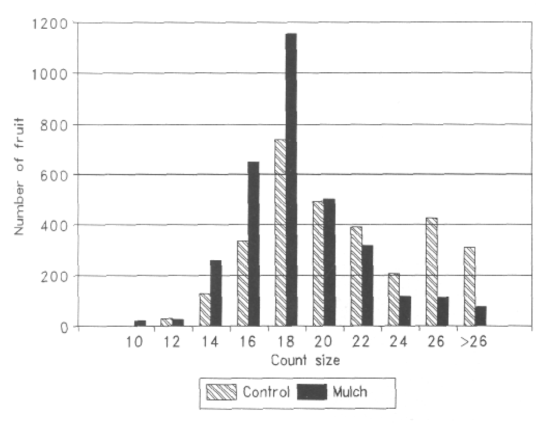

Figure 4
Hass fruit size distribution at harvest in terms of fruit number per count.

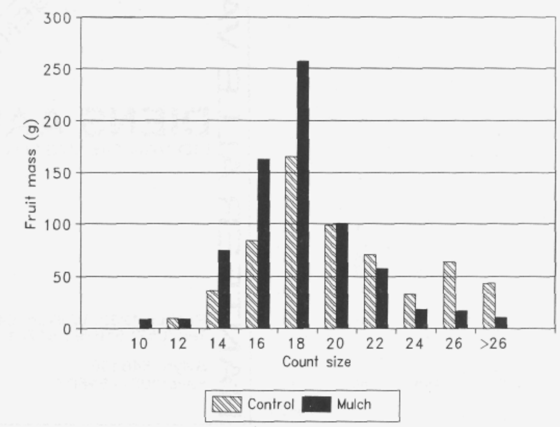

Figure 5
Hass fruit size distribution at harvest in terms of fruit mass per count.

CONCLUSIONS

A thick, composted pine-bark mulch applied in February 1993, supplemented by natural leaf mulch, was compared to trees receiving no mulch (regular removal offallen leaves). The 1993/1994 season's crop was compared. Mulched trees showed more prolonged and more extensive root growth, especially in the summer/autumn root flush but also throughout the year. Fruit growth, in spite of a 6% increase in number of fruit per mulched tree, was significantly increased in both length and width. Resultant fruit mass at harvest was 11.8% greater and total yield per tree 18.5% greater, in mulched trees.

These results lend support to the hypothesis that a healthy and vigorous root environment, ameliorated by mulching, can lead to larger average fruit size and mass, and a shift in fruit counts to the larger sizes, with larger fruit and fewer small fruit. Some aspects of the hypothesis still have to be tested, especially plant growth substance trends in xylem sap and in fruits. Results not reported here indicate more cells in the larger fruits from mulch treatments, and delayed seed coat degeneration. The trial is being continued to further investigate these aspects. It is also important to establish whether these effects can be carried over into a second (and subsequent) season.

REFERENCES

BLANKE, M.M. & BOWER, J.P. 1991. Small fruit problem in citrus trees. *Trees* 5: 239 - 243

BLUMENFELD, M.M. & GAZIT, S. 1970. Cytokinin activity in avocado seeds during fruit development. *Plant Physiology* 46: 331 - 333

BLUMENFELD, M.M. & GAZIT, S. 1974. Development of seeded and seedless avocado fruits. *Journal of the American Society of Horticultural Science* 199: 442 - 448

CUTTING, J.G.M. 1993. The cytokinin complex as related to small fruit in Hass avocados. *Acta Horticulturae* 329: 147 - 149.

HILTON-BARBER, D. 1992. Hass crisis turned to PR success. *AVOKAD: Journal of the South African Avocado Growers' Association* 12: 1.

KAISER, C. & WOLSTENHOLME, B.N. 1994. Aspects of delayed harvest of Hass avocado *(Persea Americana* Mill.) fruit in a cool subtropical climate. II. Fruit size, yield, phenology and whole tree starch cycling. *Journal of Horticultural Science* 69: 447 - 457.

MONSELISE, S.P. & GOLDSCHMIDT, E.G. 1982. Alternate bearing in fruit trees: A review. *Horticultural Reviews* 4: 128 - 173.

MOORE-GORDON, C., CUTTING, J.G.M. & WOLSTENHOLME, B.N. 1994. A preliminary report on the effect of mulching on Hass avocado fruit growth. *South African Avocado Growers' Association Yearbook* 17: 83 - 87.

SCHROEDER, C.A. 1958. Growth and development of the avocado fruit. *Yearbook of the California Avocado Society* 42: 114 - 118.

VAN STADEN, J. & DAVEY, J.E. 1979. The synthesis, transport and metabolism of endogenous cytokinins. *Plant, Cell and Environment* 2: 93 - 106.

WOLSTENHOLME, B.N., HOFMAN, P.J., CUTTING, J.G. & LISHMAN, A.W 1985. Theoretical and practical implications of plant growth substance trends in developing Fuerte avocado fruits. *South African Avocado Growers' Association Yearbook* 8: 92 - 96.

ZILKAH, S. & KLEIN, I. 1987. Growth kinetics and determination of shape and size of small and large avocado fruits cultivar Hass on the tree. *Scientia Horticulturae* 32: 195 - 202.