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The Hass Small-Fruit Problem: Role of Physiological Stress and its Amelioration by Mulching

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

ABSTRACT

The Hass cultivar is important to the South African avocado industry because it matures late and is preferred by overseas consumers. However, it produces a variable percentage of undersized fruit that cannot be exported. Mulching was investigated as a possible method of increasing fruit size through improved root activity and reduced tree stress. In a field trial at Everdon Estate, Howick, feeder root growth was greatly increased throughout two seasons by the application of coarse composted pine bark mulch beneath the tree canopy. Over two seasons, the mulch treatment resulted in a significant 11,8% increase in mean fruit mass, in spite of 16,7 % more fruits per tree. The combined effect was a 30,4 % greater yield, in spite of a high level of management and a relatively mesic environment. The probable explanation for this increase is that mulching ameliorates overall plant stress. Mulching reduced the incidence of premature seed coat abortion and pedicel ring-neck, both of which are associated with plant water stress. Furthermore, mulching reduced foliage temperatures during stress periods, indicating a reduction in plant water stress during these critical periods.

INTRODUCTION

Because the South African avocado industry is largely export oriented, cultivars such as Hass, which are preferred by overseas consumers, are important to the industry (Cutting, 1993). This cultivar is also late maturing and is therefore useful for extending the harvesting season. Unfortunately, Hass trees have a tendency to bear large numbers of undersize fruit, and fruit size is on average much smaller than in other major commercial varieties such as Fuerte, Pinkerton, Edranol and Ryan. Up to 50 % of the Hass crop may be undersize (less than 200 g or counts of more than 20 fruits per standard 4 kg export carton) in any particular season (Köhne, 1992), and in 1994 this problem was estimated to have cost the South African industry R30 million in lost revenue.

The phenomenon is not restricted to diseased and/or unhealthy trees. Even healthy Hass trees produce a significant proportion (5-25 %) of small fruit (Kremer-Köhne & Köhne, 1995) unsuitable for export. The small-fruit problem is physiological and occurs in trees without pathogen involvement (Blanke & Bower, 1991). It is exacerbated by the onset of symptoms of pedicel ring-neck and early seed coat senescence, and is aggravated by poor cultural practices. The problem becomes more pronounced with

tree age (Cutting, 1993) and is particularly noticeable in orchards situated in warmer and/or drier climates (Hilton-Barber, 1992; Whiley & Schaffer, 1994). Stress and ageing are therefore both major determinants of Hass avocado fruit size.

Fruit size is fundamentally determined by genome, so the long-term and ultimate approach is to discover or breed new large-fruited black-skinned cultivars. Unfortunately, breeding and testing new cultivars is time-consuming and does not resolve the problem immediately. There is therefore a requirement for an interim solution. We hypothesized that the application of a mulch could be a practical short-term solution to promote root growth and health, ameliorate stressful growing conditions and reduce the extent of the problem. This strategy is based on the avocado having evolved in a tropical to subtropical highland rainforest environment, and adaptation to soils with a litter layer and a high humic content. Reinforced mulching (in addition to natural litter fall) simulates rainforest floor conditions, thus providing roots with improved and more natural edaphic growing conditions. Improved root growth should impact positively on a cascade of physiological events promoting cell division in fruits, and prolonging seed coat viability. It is well known that premature seed coat abortion contributes to smaller fruit size (Blumenfeld & Gazit, 1974; Steyn *et al.,* 1993).

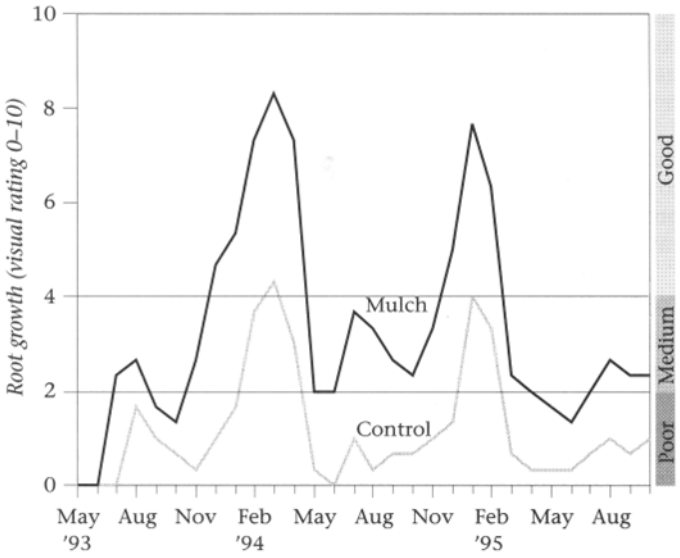

Figure 1
Root flushes as determined by a visual rating where:
0= no root growth; 10 = extensive root growth

Any layer of plant material that occurs naturally or is applied to the soil can be considered a mulch (Turney & Menge, 1994). The benefits derived from mulching include increased water and nutrient availability (Gregoriou & Rajkumar, 1984), improved soil structure and porosity (Gallardo-Laro & Nogales, 1987) and a narrowing in the diurnal soil temperature range (Gregoriou & Rajkumar, 1984). In addition, mulching creates a suppressive environment for *Phytophthora cinnamomi,* thus reducing the impact of this phytopathogen (Turney & Menge, 1994). All of the above

benefits of mulching serve to reduce the impact of environmental stress on the tree.

The objective of this study was to investigate whether mulching could be a practical cultural method of increasing mean Hass fruit size through improved root activity and reduced tree stress.

MATERIALS AND METHODS

Treatment

This study was conducted on six-year-old (in 1993) Hass trees on clonal Duke 7 rootstock at Everdon Estate, near Howick, in the Kwazulu-Natal midlands (30° 16' E and 29° 27' S). The orchard is situated in Phillips' Bioclimatic region 3, which is characterized by cool mesic conditions, typical of a 'mist-belt' climate. Mean maximum and minimum temperatures range from 26,1 and 15,0 °C in January to 19,4 and 6,7 °C in July. Mean annual rainfall is 1 052 mm and altitude is ca. l 080 m. Orchards receive standard cultural treatment, including microjet irrigation based on tensiometers, and management efficiency is excellent. The soil is an oxisol of the Hutton form, dystrophic, with a high clay content of ca. 50 %. A total of 1,5 m^3 of coarse composted pine bark (Gromed® coarse potting mix) was applied in February 1993 under the canopy of six trees to a depth of approximately 15 cm, and these trees were compared with six adjacent unmulched trees.

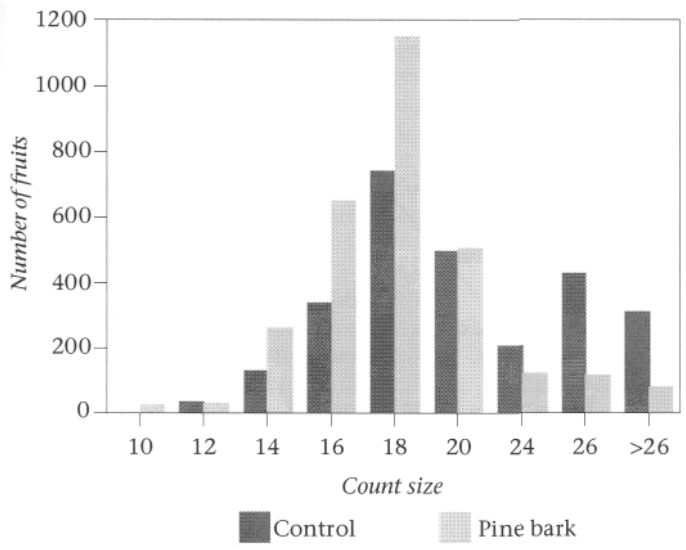

Figure 2
Overall Hass fruit size distribution at harvest for the 1993/1994 season

Data collection

The data collection period for phenological events spanned from May 1993 through to October 1995. Root flushes were monitored by visually estimating the area covered by white healthy feeder roots under a newspaper mulch (Whiley *et al.,* 1988) with an

approximate area of 1 250 cm^2. The newspaper mulch was placed 1 m from the microjet nozzle on the south-west side of the tree, so as to avoid direct sunlight. Three readings per treatment were taken at the end of each month. Visual estimates of root flushing were performed using a rating of 0-10. Kaiser & Wolstenholme's (1994), groupings of 'poor', 'medium' and 'good' were chosen, viz. 0-2, 3-4, and 5 respectively.

At the end of each season the trials were harvested, and fruit size distributions were recorded for each tree. Fruit size was determined gravimetrically and classified according to the number of fruit per standard 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.

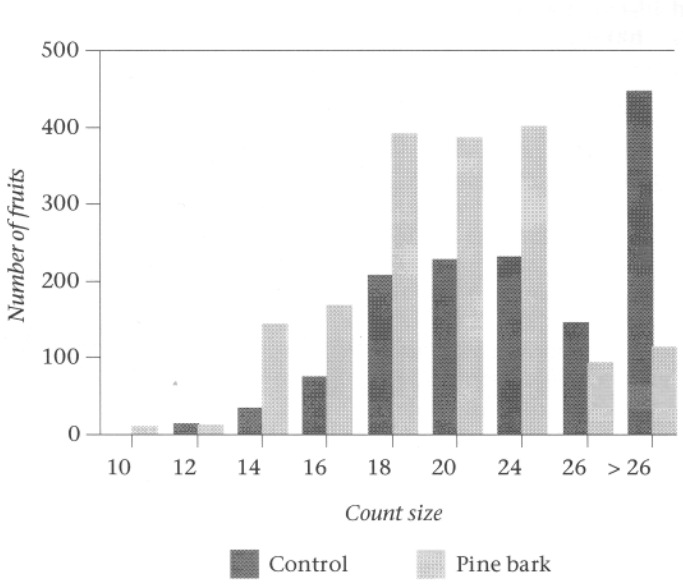

Figure 3
Overall Hass fruit size distribution at harvest for the 1994/1995 season

Monitoring of tree stress

Seed coat viability

To determine the relationship between seed coat viability and fruit size, all fruit from a single eight-year-old Hass tree on Everdon Estate was harvested on 21 July 1995, at the time of initial fruit harvest. These fruits were weighed and allocated a seed coat viability rating. Broad groupings of 'healthy', 'degenerate' and 'intermediate' were selected (healthy seed coats were still white and fleshy, degenerate seed coats, brown and thin, and the intermediate category falling between these two extremes).

Incidence of pedicel ring-neck

To determine the effect of mulching on the incidence of pedicel ring-neck, 100 fruits per tree were randomly harvested, with care being taken to ensure that the fruit were still attached to their pedicels. Before fruits were passed through the packhouse, the presence or absence of the ring-neck syndrome was recorded for each fruit.

Foliage temperature

Using weather-proof infra-red thermometers (IRTs), surface canopy temperatures of two trees per treatment were recorded continuously from November 1994. Insulation and reflective foil were applied to the IRTs to reduce temperature effects. The IRTs were mounted 2,5 m from the trees, facing south, on tripod stands at a height of 4,5 m above the ground. IRTs were connected to a Campbell Scientific CRIO® data-logger beneath the trees. Simultaneous air temperature measurements were recorded by two thermocouples, and these data were also fed into the datalogger.

RESULTS AND DISCUSSION

Root flushing

Root activity in the mulch treatment was always 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, and December 1994 through to March 1995) root activity was allocated a 'good' rating in the mulched treatment (figure 1). Root flushing periods followed a similar pattern, but in the mulch treatment they occurred two to four weeks earlier and continued longer (figure 1).

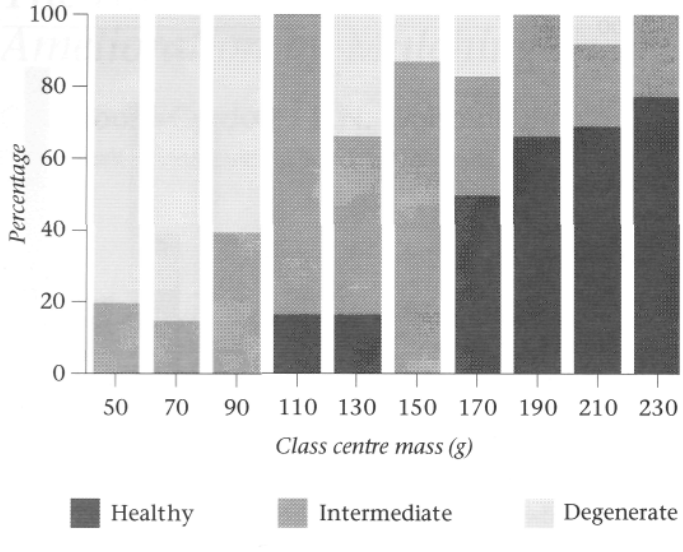

Figure 4
Allocation on a percentage basis of seed coat viability into categories of 'healthy', 'intermediate' and 'degenerate'

Avocado trees are adapted to growing in soils with a thick litter layer and a high organic content, and avocado roots, being 'litter feeders' with a high oxygen requirement (Moore-Gordon *et al.,* 1995), thrive under such edaphic conditions. Although healthy trees shed large numbers of leaves (which are relatively short-lived for an evergreen tree), application of the composted pine bark mulch reinforced rain-forest floor conditions, resulting in the more intense and prolonged surface feeder root activity. The rhizotron studies of Whiley (1994) are more representative of root activity at depth, and have indicated the potential for new root growth through winter in deep, cool, high organic matter krasnozem soils in the high rainfall areas of S.E. Queensland. It is not known whether such root activity, at depths of up to 1 m, occurs under the climate and edaphic environment of Everdon, but the soils are substantially similar.

Yield and fruit size distribution

The control trees showed a typical fruit size distribution for the Hass cultivar with many fruit in the count size range of 22-26 (small fruits), and a high proportion of factory-grade avocados (figures 2 and 3). Mulching with pine bark had the effect of shifting the overall count size distribution towards large fruits, i.e. the mulch treatment yielded fewer small fruits and more large fruits (figures 2 and 3).

Average fruit mass was significantly ($P < 0,01$) increased in response to pine bark mulching. Fruits from the mulch treatment were on average 23,3 g + 1,2 g heavier than control fruit after one year of the treatment, representing an 11,8 % increase in mass, in spite of more fruits per tree (table 1). Harvest results for the 1994/1995 season confirm that the pine bark treatment resulted in a significant ($P < 0,01$) increase in fruit size, with fruit from this treatment being on average 21,0 g ± 1,4 g heavier (11,8 %) than control

fruit (table 1).

Seasonal effects on mean fruit size are also evident, with fruits being 10 % smaller in the control and 10 % smaller in mulched trees in the second season. This might be attributed to the shorter fruit growth period during the second season (255 days in 1994/1995 compared to 284 days in 1993/1994). Since avocado fruit expansion proceeds throughout fruit development (Schroeder, 1953), albeit at a slower rate during the later stages, a prolonged period of fruit growth would be expected to result in larger fruit size.

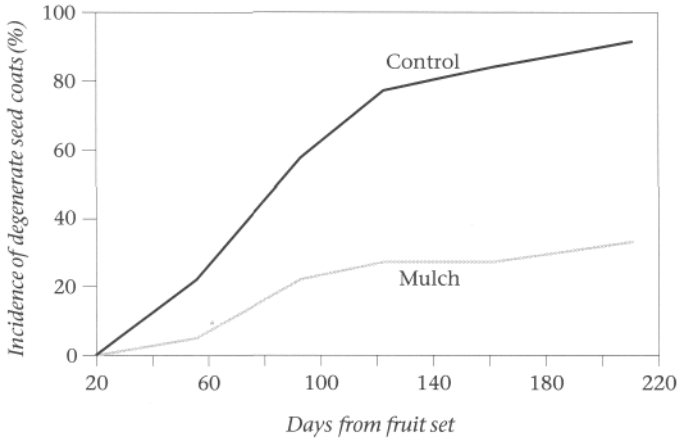

Figure 5
Incidence of fruits having degenerate seed coats from the mulch and control treatments on a percentage basis (values were calculated from 18 fruits per treatment at each time interval)

Assimilate supply to a fruit will depend on the extent of competition from other established fruit sinks (Monselise fit Goldschmidt, 1982), and so fewer sinks should yield larger fruit. Table 1 shows that increase in fruit size was achieved in spite of a 6,1 % and 27,2 % increase in number of fruits per tree in the mulch treatment in the first and second seasons respectively. This supports the hypothesis that mulching has altered endogenous physiological conditions in favour of increased fruit growth. The increased fruit size coupled with increase in number of fruits per tree resulted in an overall 18,5 % increase in yield at the end of the first year, and a 42,2 % increase in yield for the second season (table 1), i.e. an average increase in yield of 30,4 % over the two seasons.

Table 1
Summary of the effects of pine bark mulching on average fruit mass, number of fruits per tree and total yield. Figures are means of six trees. *Denotes a significant (P ≤ 0,01) increase by mulching.

		Control	*Mulch*	*% increase*
1993/1994	Mean fruit mass (g)	198,0	221,3	11,8*
	Fruit number/tree	509	540	6,1
	Yield (t/ha)	20,16	23,88	18,5*
1994/1995	Mean fruit mass (g)	178,2	199,2	11,8*
	Fruit number/tree	262	333	27,2*
	Yield (t/ha)	9,32	13,26	42,2*

Seed coat viability

Results show that there is a good correlation between Hass fruit size and the extent of seed coat degeneration. Smaller fruits had a higher proportion of degenerate seed coats; while larger fruits had a higher percentage of healthy ones (figure 4). The practice of mulching reduced the incidence of fruit with degenerate seed coats (figure 5). Assuming that seed coat degeneration is a consequence of plant stress, this implies that mulching reduces plant stress, probably through improved water uptake as a result of increased water availability and increased root absorbing surface. Maintenance of seed coat health means that the seed still has the capacity to import minerals and assimilate, and other factors necessary for fruit growth: this partly explains why fruit growth was enhanced by mulching.

Incidence of pedicel ring-neck

The practice of mulching reduced the incidence of fruit with pedicel ring-neck by 57,1 % and 45,9 % for the first and second seasons respectively (table 2). Since pedicel ring-neck is associated with plant water stress (Whiley *et al.,* 1986), one could surmise that mulching reduced the impact of adverse environmental pressure. It is worth noting here that the degree of this disorder is less advanced in the mesic KwaZulu-Natal midlands climate than in the more stressful environment of the Northern Province and Mpumalanga.

Table 2
Summary of the effect of mulching on the incidence of pedicel ring-neck. Values were calculated from a total of 100 fruits per tree

Year	*Incidence of pedicel ring-neck (%)*	
	Control	*Mulch*
1993/1994	17,5 ± 2,2	7,5 ± 2,4
1994/1995	13,3 ± 2,7	7,2 ± 1,9

Foliage temperature

The surface temperature of a leaf is the tangible manifestation of its energy balance and therefore is affected by abiotic and biotic factors. The most prominent of the latter are the stomates which, in closing, limit the amount of energy that can be dissipated by transpiration, and consequently cause the leaf temperature to increase (Raschke, 1960). These facts led Tanner (1963) to postulate that the surface temperature of the leaf may be used to assess the water status of the canopy, i.e. the degree of water stress. Since leaf canopy temperatures of control trees are generally higher than that on the mulch treatment ($T_{control}$ T_{mulch} is approximately 0,5 °C on average) (figure 6), this implies that mulching has reduced overall plant water stress.

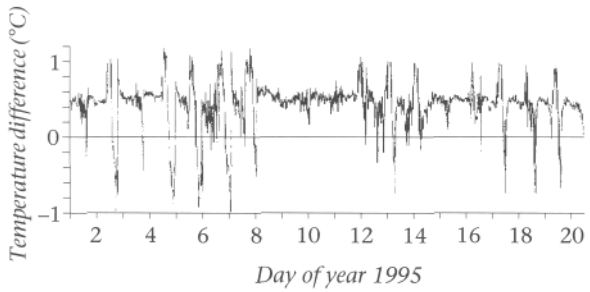

Figure 6
Foliage canopy temperature differences between the control and mulch treatments ($T_{control} - T_{mulch}$)

CONCLUSIONS

Thick, composted pine bark mulch applied in February 1993, supplemented by the natural avocado leaf mulch, was compared to no mulch (regular removal of fallen leaves). Mulched trees showed more prolonged and more extensive root growth, especially in the summer/autumn root flush but also throughout the year, including the critical fruit set period. Fruit growth on the mulch treatment was significantly increased, in spite of increased numbers of fruit per tree. Resultant fruit mass at harvest was 11,8 % greater in both years, and total yield per tree 18,5 % and 42,2 % greater, in the first and second seasons respectively. These results lend support to the hypothesis that a healthy and vigorous root environment, ameliorated by reinforced mulching, can lead to larger average fruit size and mass.

A probable explanation why mulching has a positive effect on fruit size is that this practice might reduce overall plant stress, thus creating favourable physiological conditions for fruit growth. Mulching considerably reduced the incidence of premature seed coat degeneration and pedicel ring-neck, both of which are associated with tree water stress. Mulching also reduced leaf canopy temperatures by approximately 0,5 °C during the ecological dry period, providing further evidence that mulching reduced overall plant stress. In addition, the role of improved mineral uptake must be mentioned.

In leached acid soils in Queensland, Australia, Smith *et al.,* (1995) found that soil boron applications improved Hass fruit size by 11-15 % Improved boron nutrition may be another beneficial effect of mulching.

Properly regulated mulches thus provide a practical solution to the grower to increase average fruit size, presumably by ameliorating plant stress at critical periods. The Everdon climate can be classified as only moderately stressful, being cool and mesic with high rainfall and humidity, and with good orchard management. Benefits of mulching are therefore likely to be greater in more stressful environments, provided that crop load is not excessive. Canopy management to ensure sufficient leaf area per fruit is therefore vital, particularly for Hass in warmer areas where initial fruit set can be excessive.

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