New Zealand and Australia Avocado Grower's Conference '05. 20-22 September 2005. Tauranga, New Zealand. Session 9. Fruit size and production. 7 pages.

AN INNOVATIVE SYSTEM TO ACHIEVE EARLY PRECOCITY IN AVOCADO UNDER THE MARGINAL GROWING ENVIRONMENT IN THE BAY OF PLENTY, NEW ZEALAND

David J Sher

P.O. Box 11096, Papamoa, New Zealand

Abstract

Modifications to established practices are required where soil and climate impediments influence tree productivity. Sub-optimal environmental conditions exacerbate physiological stress and subdue reproductive potential. Traditionally, performance has focussed on above-ground expression, while fruit yields from young trees have been disappointing and erratic. Recognition that a favourable root:shoot balance is a necessary pre-condition for early and sustained fruitfulness has inspired new guidelines for orchard establishment and management. Improvements include large, fertilised planting holes, revised nutrient, moisture, and mulch regimes, and a higher ratio of pollinator varieties. Field validation is measured against tree performance. Data collected across 4 young orchards (1-6yr) has delivered valuable information regarding growth patterns, root mass, and fruit yield. Examination of the cultural practices and their contribution to achieve early precocity is presented, as well as potential improvements to the programme.

Introduction

Avocado growing in the Bay of Plenty (latitude 37°S) is confined within a narrow, near frost-free, coastal strip stretching from Athenree in the west to Te Kaha in the East. The climate is described as cool to cold subtropical (Wolstenholme 2002) rather than warm temperate and characterised by cold wet winters and warm, dry summers (Dec-Feb rainfall approx. 20% (300mm) of annual precipitation). Average daily maximum temperatures (>20°C) generally occur from November to April, mean monthly temperatures below 12.5°C are experienced from May to September, with the mean annual temperature of 14.0°C at Tauranga being described as the coolest in the world for 'Hass' (Wolstenholme 2002)

Modified phenological behavior under a sub-optimal temperature regime is expressed by heavy determinate flowering, limited pollination events, floral abortion and seedless fruitlets (cukes), truncated summer flush, late maturity of fruit, and the photo-inhibition of over-wintered leaves. Accumulation of starch to a late winter peak to buffer against environmental stress is complicated when photosynthetic rates decline sharply below 15°C and net daily gains in carbon accumulation during the cooler months may not materialise. Maintenance of over-wintered leaf efficiency to adequately resource flowering and fruit set is a priority as regular bearing is unlikely without adequate starch reserves.

Previously, emphasis on first creating a structural framework in the early years produced many ‘late successional’ trees with a vegetative bias and variable and irregular fruiting habits. Production from established trees averaged around 5t/ha and would have been unsustainable in the long term. Further expansion into new plantings required a greater certainty of higher yields to offset rising land prices and growing costs. To achieve an annual surplus by year 5 and recovery of establishment costs by year 10, cultural practices to encourage early precocity are essential. Since tree thinning from 200 trees/ha to half that number commences after 6 seasons, a cumulative yield of 800-100 fruit per tree is required for profitable investment into higher planting densities. A new innovative approach understanding the interaction of tree and environmental physiology under local conditions to deliver superior tree health, improved root:shoot balance, maximum carbon accumulation, and regular bearing in new plantings was developed by Dr Jonathan Cutting in 1998. Climatic constraints are mitigated and outcomes of normal tree development and early precocity are achieved under this regime. In this paper, establishment and cultural practices together with performance data from a number of young orchards are presented.

Establishment

Two pairs of adjoining orchards situated in Oliver Road, Te Puna are described in this study, and referred to by the owner’s surname with year of establishment in parenthesis as follows; Cutting (1998), Maunder (1999), Hedge (2001), and Sands (2003). All the sites were contoured to varying degrees to improve the topography for planting, while exposure to cold winds from the southwest quarter required the planting of permanent perimeter shelter belts.

In addition to a broadcast fertiliser application based on soil test results, preplant preparation consisted of large (2m x 2m) excavated planting holes to a depth of 1 metre, followed by further digging *in situ* to a depth of 2m. Amounts of lime, superphosphate, and kieserite are added and mixed into the bottom metre of the hole. Further additions of lime, superphosphate, kieserite, plus gypsum and trace elements together with 0.5-0.75 m^3 of finely milled bark, are thoroughly mixed with the excavated soil before refilling the planting hole, which is then left undisturbed for at least a month prior to planting.

High quality (‘Hass’ grafted onto ‘Zutano’ seedling rootstock) nursery trees are planted at a spacing of 7m x 7m in early spring. Sprinkler irrigation, coarse mulch (e.g. pine peelings) and a tree shelter constructed from timber battens and shade cloth are provided at establishment. Pollinator trees (‘Bacon’, ‘Zutano’) are interspersed to provide a ratio of 1:8 after the first tree thinning (100/ha).

Tree management

Regular monthly (September to March) applications of fertiliser (Cuttings Avocado Young Tree Mix for the first two seasons followed by Cuttings Avocado Regular Tree Mix) plus potassium nitrate, potassium sulphate, and kieserite represent the typical per tree inputs as shown in Table 1. Supplementary broadcast dressings of superphosphate, calcium (agricultural lime, dolomite, and gypsum), and magnesium (kieserite) are recommended according to soil and leaf tests taken in autumn (late April/early May). Overwinter foliar applications of low-biuret urea and magnesium sulphate are necessary to maintain photosynthetic activity and leaf quality, while boron sprays at flowering are conditional upon the leaf tissue results. Trace element additions of soil-applied boron and zinc complete the annual fertiliser programme.

Table 1: Macro-nutrient inputs (g) per tree over 6 seasons at the Maunder orchard.

Season	N	P	K	S	Mg
1999/2000	105	28	89	28	12
2000/2001	334	81	338	84	35
2001/2002	381	96	702	190	48
2002/2003	381	96	765	477	243
2003/2004	447	122	867	552	314
2004/2005	460	122	905	502	276

Low trajectory under-tree sprinkler irrigation ensures good coverage of the expanding root system. To maintain a favourable soil moisture regime (2025 kPa in spring and summer, and 25-35 kPa in autumn) requires between 12 and 18 tensiometer monitored irrigation cycles per season. The trees are mulched periodically using a wood-based waste mulching material such as bark and peelings. Export fruit quality standards involve an integrated pest management programme and regular copper fungicide sprays. To date, *Phytophthora cinnamoni* control using phosphonic acid injection has only been exercised on the Hedge orchard (imperfect drainage). Honeybee introduction over flowering is practiced to promote cross-pollination and improve fruitlet retention. The first thinning of 7 yr trees (Cutting orchard) will be conducted after harvest this year.

Yield

Crop loads of greater than 40 fruit have been recorded on 2year-old trees (flowering). A harvest sample of 4 contiguous 3 year-old trees at the Hedge orchard (2nd flowering) produced 218 fruit with an average weight of 242g (13.2 kg/tree). Yield data from the same trees harvested on the 1st of October this year (3rd flowering) showed a four-fold increase to 866 fruit, equivalent to 53.5 kg per tree. Progressive increases in yield (Table 2) counteract any expression of alternate bearing. Fruit production by the 4th flowering (year 5) of 12.5 t/ha and 9.1 t/ha (frost affected) for the Cutting and Maunder orchards respectively, are significantly higher than the industry budgeted figure of 7 t/ha (Cutting and Dixon 2000). In all cases, harvest comprises a single strip pick either before or during flowering and yields (export + local market) for the 2 older orchards are reported in Table 2.

Table 2: Total yield (tonnes/ha) for the Cutting and Maunder orchards since 2001.

Harvest Date	Cutting orchard	Maunder orchard
September 2001	1.8	0.14
September 2002	4.0	1.76
October 2003	12.5	5.83
October 2004	15.9	9.16
October 2005	28.1	18.7

Discussion

To deliver superior tree performance under marginal growing conditions requires a clear understanding of two factors. Firstly, the impact of a suboptimal climate upon the physiological adaptation within the tree, and secondly, the degree to which modified cultural measures can ameliorate multiple constraints so maximum fruitfulness may be realised. An additional level of complexity is added in that the environmental and internal effects carryover from year to year in evergreen fruit crops (Lasko 1990). Moreover, while cropping inhibits growth of all vegetative organs, it is the growth of roots that are typically most affected. The avocado tree has a strong vegetative bias and cultural practices encouraging balance between root and shoot development need to commence at the establishment phase.

The soil type across all the orchards is classified as Katikati sandy loam (rolling phase). Although characterised by good drainage properties and high plant available water holding capacity, these soils can become heavily compacted when subjected to contouring, heavy machinery use, and long-term cattle grazing. Analysis of sub-surface soil horizons indicates very low fertility levels (D.H. Lushington pers.comm.) Pre-plant incorporation of lime and gypsum addresses the issue of soil acidity. Also, available calcium is known to act as a weak fungicide against *phytophthora* root rot, and a desirable pH (6.0-6.5) throughout the rooting depth is a necessary disease preventative step. Soil samples taken at 150mm horizons to a depth of 1m from the planting holes at the Cutting orchard in April 2003 produced a pH range of 5.9-6.3 and base saturation percentages for calcium of between 35.7 and 54.7 (unpublished data). Successive surface applications of calcium are unlikely to influence soil levels below a depth of 30cm.

Phosphorus is credited as preferentially promoting root growth and the development of reproductive structures. High levels of phosphorus have been shown to advance flower initiation in newly planted apple trees, which supports a suggested correlation between P supply, root growth and increased cytokinin levels (Neilsen *et al* 1990). A soil study on Katikati sandy loam shows high P retention (74% w/w in the topsoil 0-15 cm) and little downward movement below 30cm even after 21 consecutive annual phosphate dressings (Sher 2004). Addition of P into the planting hole is therefore essential for accelerated root activity and early expression of floral initiation and fruit set.

Magnesium deficiency strongly favours the distribution of carbohydrate supply towards shoot growth over root growth, which in turn, can lead to the breakdown of the feeder root system and impaired nutrient uptake. The root system is an important storage site for carbon reserves in young trees, and root carbohydrate acts as an energy source for ion uptake during respiration. Photo-inhibition (an excess of light that cannot be utilized under cold conditions) causes chlorophyll breakdown, a situation moderated by good magnesium availability. High inputs of magnesium (kieserite) are required (Table 1) to maintain cation balance with calcium and potassium, and achieve satisfactory leaf test levels (0.4-0.7% DM).

As well as fertiliser, an input of organic matter in the form of 0.5-0.75 m^3 fine milled bark is added to each planting hole to improve soil porosity for oxygen diffusion into the soil pores. Respiration and the normal functioning of avocado roots are very dependent on an adequate oxygen supply. The milled bark showed little evidence of breakdown when examined after 5 years. Enhanced porosity allows critical soil oxygen concentrations to be sustained, especially during the root flush period over the wet winter months.

The advantages of these modifications on avocado root development was assessed by comparing root measurements to a depth of 1m taken from large (2m x 2m x 2m), fertilised planting holes (Cutting orchard) against smaller (1.5m x 1m x 600mm) unfertilised planting holes. Soil type, tree size, and age (4½ yr) were the same at both Te Puna sites (Sher and Dixon 2003). The collected data showed increases of 39% and 73% for total root dry weight and estimated root mass, as well as a more even root distribution down the soil profile for the fertilised treatment. Conclusions drawn from the study included findings that incorporation of fertiliser is an essential pre-condition if root potential is to be realised, and that the above-ground proportion of trees does not reflect the size of the root system below ground. Another observational study on avocado tree root systems in the Bay of Plenty further reinforced the latter finding (Dixon and Sher 2003).

Lack of effective shelter (windbreaks), either perimeter or internal, across all the orchards provides little opportunity for temperature change. Schaffer and Whiley (2002) reported that the maximum photosynthetic rate of ‘Hass’ leaves declined from 19.0 µmol CO_2 m^{-2} s^{-1} during autumn (min. daily temp. >14°C) to 10.9 µmol CO_2 m^{-2} s^{-1} during winter (min. daily temp. <10°C). Since the root:shoot balance is a necessary pre-condition for early precocity, and yield is a function of total carbon accumulation and the apportionment of that carbon among the competing sinks (priority order: seeds>fruits> shoots and leaves>cambium>roots> storage), then an understanding of the vegetative and reproductive adaptations must be integrated into ongoing tree management decisions under marginal climate conditions.

Of greatest importance to ensure regular fruitfulness is the production of ideal flowering wood and the condition and function of over-wintered leaves. Cutting (2003) has shown that spring flush wood with plenty of sylleptic growth than hardens off in January has significantly higher flowering intensity. Controlling further vegetative expression through crop load and judicious nitrogen application allows for greater carbon allocation to the root flush in February and March. If starch accumulation during winter cannot be relied upon due to temperature, then maximum carbohydrate production during autumn is the desired goal. In young trees, starch reserves found mostly in the roots and wood, help to buffer the tree against environmental stress.

Healthy, over-wintered leaves, well supplied with nitrogen, chlorophyll, and starch, are retained longer into the new season, and provide stored and current photosynthates for flowering, fruitset, and spring vegetative growth. During the period between full flowering to early fruitlet abscission, proximal leaves account for nearly 60% of recently fixed assimilates and recovery was generally proportional to the dry weight of each organ (Finazzo, Davenport, and Schaffer 1994). The cultural practice of autumn and late winter fertilisation, combined with foliar sprays of low-biuret urea and magnesium sulphate during the cold, wet winter months preserves leaf function and delays senescence. Although past their physiological optimum by flowering, retention of proximal leaves for up to 16 months on fruitful shoots, both determinate and indeterminate, are regularly observed in the orchards. In this way, any shortfall in reserve carbon accumulation is counterbalanced by current assimilate supply from photosynthetically active over-wintered leaves.

The orchard performances have shown that early precocity is achievable when the right combination of physiological adaptation and modified cultural practices are applied. Competition between roots and shoots for carbohydrates and nutrients is coupled to the environmental factors that ultimately determine the tree response. Removing the negative effects of soil compaction and raising soil fertility pre-plant is a logical first step towards a root system in balance with the above-ground portion. Other noted benefits from this approach are increased leaf and trunk size, tree anchorage, and early canopy complexity. Suggested refinements to the concept are for further expansion of the planting hole over time by either deep ripping or trenching around the root periphery as the initial hole has a finite capacity for root expansion and occupation. Another is for increased amounts of lime and gypsum, as well as superphosphate to be incorporated into the planting hole at the excavation stage. Collectively, the greatest advantage from all the manipulatory strategies is the enhanced buffering against constant environmental stress, and the delivery of increased productivity on a sustainable basis in young avocado trees.

Acknowledgements

Thanks are due to J.C.M. Cutting for providing helpful advice and support and for the co-operation from orchardists A. Hedge, C. Maunder, and R. Sands. The author also thanks Ravensdown Fertiliser Co-operative Limited for their funding towards this project.

References

Cutting, J.G.M. (2003) Research note: Impact of spring and summer flush type on flowering intensity in ‘Hass’ avocado. New Zealand Avocado Growers Association Annual Research Report 3:42-47.

Cutting, J.G.M. and Dixon, J. (eds) (2000) New Zealand Avocado Growers Manual. New Zealand Avocado Growers Association, Tauranga, New Zealand.

Dixon, J. and Sher, D.J. (2003) Observations on avocado tree root systems in the western Bay of Plenty. New Zealand Avocado Growers Association Annual Research Report 3:32-41.

Finazzo, S.F., Davenport, T.L., and Schaffer, B. (1994) Partitioning of photoassimilates in avocado (*Persea americana* Mill.) during flowering and fruit set. Tree Physiology 14:153-164.

Lasko, A.N. (1990) Interactions of physiology with multiple environmental stresses in horticultural crops. HortScience 25(11):1365-1369.

Neilsen, G.H., Hogue, E.J., and Parchomchuk, P. (1990) Flowering of apple trees in the second year is increased by first-year P fertilization. HortScience 25(10):1247-1250.

Schaffer, B. and Whiley, A.W. (2002) Chapter 6 Environmental physiology. In *The Avocado: Botany, Production and Uses* (eds A.W. Whiley, B. Schaffer and B.N. Wolstenholme) CAB International ISBN 0-85199-357-5.

Sher, D.J. and Dixon, J. (2003) Establishing avocado trees for maximum root production. Avoscene Sept: 24-5.

Sher, D.J. (2004) Kiwifruit fertility study: Surprising secrets beneath the orchard floor. The Orchardist 77(7): 52-55.

Wolstenholme, B.N. (2002) Chapter 4 Ecology: Climate and the edaphic environment. In *The Avocado: Botany, Production and Uses* (eds. A.W. Whiley, B. Schaffer and B.N. Wolstenholme). CAB International ISBN 0-85199-357-5.