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RESULTS WITH SPACING, TREE TRAINING AND ORCHARD MAINTENANCE IN YOUNG AVOCADO ORCHARDS

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SUMMARY

Avocado orchards have in the past been planted in a square configuration and allowed to develop naturally. This, sooner or later, led to crowding when the trees started to grow into each other. Under vigorous growing conditions and with closer planting distances, light could become a limiting factor at a stage when the orchard has hardly started bearing. It is suggested that planting avocado trees in a rectangular configuration and training the trees to a pyramidal shape could ensure photosynthetic activity through continued, effective light interception and penetration. In this article it will be shown that avocado trees can be trained to a central leader by applying simple pruning techniques. Cultivars such as 'Hass', 'Pinkerton' and 'Edranol' can be easily maintained in higher density orchards. 'Hass' has after 43 months at a density of 1667 trees per ha given a 45% higher yield than the 606 trees per ha by already producing 13.6 $t \cdot ha^{-1}$ during that year while the 'Edranol' higher density planting had a yield of 22.4 $t \cdot ha^{-1}$ 43 months after planting. Although the experimental planting of trees at 4 x 1.5 m spacing has done well, a 5.5 x 3 m spacing should at this stage be the generally accepted commercial guideline for most cultivars. Allowance must be made for vigorous growth, and soils with high nitrogen retention must be avoided. Pruning is not a one-off operation and follow-up summer pruning will be required. Research is currently being conducted to accelerate the pruning process by using mechanical pruners but no conclusive results are available at this stage for making firm recommendations. Cincturing, bio-regulators and especially nitrogen management must all be seen as "tools" to be used in conjunction with pruning.

KEY WORDS: Central leader, plant density, cincturing, bio-regulators, mechanical pruning

INTRODUCTION

Avocado trees have a tendency to grow very vigorously and develop into very large trees. In certain climatic regions and with fertile soil conditions this situation is exacerbated. Such large trees no longer comply with the economic and commercial

realities of the day. The need today is for more intensive orchards that produce viable yields at an early age with smaller tree dimensions that facilitate orchard labour and mechanical activities.

Köhne & Kremer-Köhne (1991) indicated that 800 trees per hectare should produce higher yields in the initial years and Razeto *et al.* (1998) confirmed these findings with production figures. Stassen *et al*. (1995) discuss the principles involved in achieving this ideal while Stassen and Davie (1996b) describe techniques for shaping trees into a central leader. Stassen *et al*. (1997a) provide guidelines for planning such an intensive orchard and for maintaining it so that problems currently being experienced with higher density orchards do not occur in the future.

To maintain such orchards and initiate reproductivity, use could be made of growth inhibitors (Köhne and Kremer-Köhne, 1987; Wolstenholme *et al*., 1990) and cincturing (Snijder and Stassen, 1998) as well as suitable planting systems and tree shapes (Stassen *et al*., 1997a). It is also important to realize that injudicious application of nitrogen can lead to unwanted vegetative growth (Stassen *et al*., 1997b).

It is clear that there can be little chance of success unless a planned tree manipulation program (Stassen and Davie, 1996a; Stassen and Snijder, 1996a), as well as the correct planting and tree training system (Stassen and Davie, 1996b), is followed. Tree pruning can be done mechanically, selectively or as a combination of the two, while bending, cincturing, chemical inhibition, nutrient supply, irrigation and especially fruit load, are all contributing “tools” to complement tree manipulation (Stassen and Davie, 1996a).

Stassen and Davie (1996b) recommend a hedgerow with north/south row orientation as the most suitable planting system. The avocado tree lends itself to being trained as a central leader (Stassen *et al*., 1995; Stassen *et al*., 1997a and Stassen *et al*., 1998) but this does not imply that a multiple leader system cannot be used, especially where the tree spacing within the rows is 3.5 m or more (Snijder and Stassen, 1999).

This paper will concentrate on the more important steps to be followed in order to prevent new avocado plantings developing into the congested orchards previously experienced, by using the correct spacing, tree training procedures and other available “tools” to curb excessive growth.

MATERIALS AND METHODS

1. Development of a central leader tree

The first trial was established on a private farm in the Kiepersol area to implement the concepts of Stassen *et al*. (1995) and Stassen and Snijder (1996a) for developing and maintaining a ‘Hass’ tree as a central leader. The original planting of ‘Hass’ on ‘Edranol’ seedling rootstock was done in March 1993 and these trees were immediately trained to a central leader. Initially the orchard was planted at 5 x 5 m but a year later was adapted to 5 x 2.5 m with rows in a north/south direction. This orchard was specifically

selected as the soil was gravelly (25% clay), thus making it easier to manipulate growth with nutrients and water.

Trees were pruned according to the principles described by Stassen *et al*. (1998) but continuously subjected to corrective pruning. For the purpose of selective hand-pruning, 20 of the trees planted in 1993 in this orchard were randomly chosen to be monitored even though the whole orchard was pruned.

2. Pruned versus unpruned

This experiment was established on a private farm in the Kiepersol area to compare 'Hass' on clonal 'Duke 7' trees planted at a density of 800 per ha (5 x 2.5 m) in a north/south row-orientation and trained from inception to a central leader, with a standard planting of 400 trees per ha (5 x 5 m) that has not been pruned. These trees were planted on high potential Hutton soil (53% clay) that was previously under bananas resulting in a high soil nitrogen content and extremely vigorous growth. Four tree plots replicated 10 times were used per treatment for this experiment.

3. Planting densities

This experiment was established at the Burgershall experimental station in the Kiepersol area to compare a relatively standard planting of 5.5 x 3 m (606 trees per ha) of the five more important commercial cultivars with a higher density planting of 4 x 1.5 m (1667 trees per ha).

This orchard was planted on medium to high potential Hutton soil (32% clay) not previously planted to bananas. 'Fuerte', 'Hass', 'Pinkerton', 'Edranol' and 'Ryan' all on clonal 'Duke 7' rootstocks were planted in October 1995.

All the trees were already shaped as central leaders in the nursery. For the purpose of selective hand-pruning four-tree plots were replicated five times for each of the two densities. Statistical analysis was performed to detect differences between the tree spacing and not between cultivars. The tree rows were north/south orientated.

To prevent trees bearing more fruit than their estimated potential, small, poorly growing and misshapen fruits were removed in November as recommended by Stassen and Snijder (1996b). This resulted in as much as 30% fruit removal in certain cases. Where there were fewer fruit than the estimated bearing potential no thinning was carried out. 'Fuerte' trees in both spacings were treated with a soil application of Cultar ®(0.8 ml 250 $mL^{-1}.m^{-2}$ drip area) 16 months after planting.

4. Cincturing

This work was carried out in the same orchard described for experiment 2. Cincturing was done with a sharp knife making a spiral incision around the stem. Twenty randomly chosen trees were used per treatment. Trees were cinctured in 1997 on 29th February, 20th March, 2nd and 16th April, 4th and 16th May.

5. Bio-regulators

Six treatments were compared with a control in the pruned 5 x 2.5 m orchard discussed in experiment 2. The treatments were as follows:

- Sunny®(50g.L^{-1} uniconazole) sprayed once at full flower using 0.7% plus UP 50 (Erasmus & Brooks, 1998 discuss the compound and the application method fully).
- Two Sunny® sprays. One at full flower as described above and a second spray of 0.3% plus UP 50 on the summer flush when it is about 150 to 200 mm in length.
- Cultar® (250 g.L^{-1} paclobutrazol) sprayed once at 0.4% plus 15 mL.100L^{-1} Nu-Film® sticker/spreader at full flower.
- Two Cultar® sprays with the same concentration as above. The first is applied at full flower and the second when the summer flush is about 150 to 200 mm in length.
- Cycocel® (750 g.L^{-1} chlormequat chloride) at 0.4% was applied once at full flower.
- Cycocel® was applied at full flower, as at the same concentration on the summer flush when it was 150 to 200 mm in length.
- Control (no chemical sprays)
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The statistical lay-out consisted of five-tree plots with four repetitions per treatment.

6. Mechanical pruning

These trials were conducted in the same orchard described for experiment 3. The trials consisted of: a) selective hand-pruning (SEL) where shoots were selectively removed or cut back, and b) mechanical pruning (MEC) with a portable rotating blade cutter driven by a light-weight petrol engine. Unwanted shoots were cut back by cutting the whole tree row at a set angle.

Time of pruning: a) In the post-harvest period (PH) attention is given to tree shape, tree height and the removal or cutting back of shoots that cause canopy congestion.
b) During the summer period (SP) in about October, water-shoots were removed or cut back and bearer shoots manipulated while in December/January (depending on the cultivar and the area) water-shoots were cut and bearer shoots lightly tipped.
Four-tree plots were replicated five times for each pruning treatment. Statistical significance was determined per plant spacing and between pruning treatments.

All data collected were statistically analysed at $P< 0.05$. Results are presented in such a way that data means with the same letter do not differ significantly.

RESULTS AND DISCUSSION

1. Development of a central leader tree.

This work was done for the sole purpose of establishing the feasibility of training an avocado tree to a central leader and to develop techniques for achieving this aim. No study has been done comparing these trees with unpruned trees. Yield data (Table 1) are presented for relative comparisons with any standard planting.

The data implies that reasonably good yields are obtained from trees that were shaped and maintained by selective pruning. Razeto *et al*. (1998) show that a 5.5 x 3 m 'Bacon' planting will produce 20 to 30 t.ha^{-1} in the sixth and seventh year if it is not pruned.

It was, however, established that 'Hass' avocado trees can be successfully trained to a central leader based on the principles set out by Stassen and Snijder (1996a) and Stassen *et al*. (1998) with some corrections. These principles can be briefly summarised as follows:

1. Remove vigorously growing side shoots that are more than 1/3 of the thickness of the leader.
2. Remove all side shoots with acute angles to the vertical.
3. Tip all side shoots each time they have grown 200 mm in length to force lateral growth.
4. Ensure that horizontal shoots are evenly dispersed in a spiral formation. No shoot should be directly above another shoot.
5. Continue to remove water-shoots during the second growth season, maintaining the branch hierarchy and developing tree complexity while ensuring good light penetration.
6. During the post-harvest period shape the trees and control tree height. Selectively remove branches to open up trees for light penetration.
7. Carry out summer pruning to remove water-shoots and other upright-growing shoots.

The same techniques can also be used to develop a multiple leader tree with two or three upright leaders for orchards with less than 600 trees/ha (Snijder & Stassen, 1999).

Table 1. Yields ($t \cdot ha^{-1}$) of 'Hass' avocado trees in the Kiepersol area trained to a central leader.

	Yield ($t \cdot ha^{-1}$)			
Production year	1996	1997	1998	1999
Months after planting (planted March 1993)	38	50	62	74
Spacing 5 x 2.5 m	9	15.4	28.1	18.3

2. Pruned versus unpruned 'Hass' trees

This trial is part of a commercial planting with the main purpose of comparing a 5 x 2.5 m central leader planting with a standard commercial 5 x 5 m planting. Results achieved to date are summarised in Table 2.

Contrary to what was expected the higher density planting did not give significantly higher yields. The unpruned 5 x 5 m planting performed significantly better than the pruned 5 x 2.5 m planting in 1998. A possible reason for this can be found in the tremendous growth achieved in the high potential (53% clay) soils which were previously planted to bananas.

Drastic pruning that is counter-productive to yield had to be applied in these circumstances. Conditions of high nitrogen reserves in the soil were further aggravated by the use of a leguminous cover crop (velvet beans) in the initial years. No nitrogen

management could be effectively applied because of the high nitrogen content already in the soil.

Table 2. Comparative yields achieved with 'Hass' avocado trees planted at 5 x 2.5 m and trained as central leaders as opposed to a standard 5 x 5 m planting that was not pruned.

Treatment	Planting date and spacing Nov 1994	Yield ($t \cdot ha^{-1}$) (months from planting in brackets) 1997 (30)	1998 (42)	1999 (54)
Pruned	5 x 2.5 m	2.45 a	8.9 a	7.1 a
Unpruned	5 x 5 m	2.03 a	10.7 b	7.1 a

Both groups performed relatively well in 1998 when the trees were only 42 months old although the yield declined in 1999. The fact that the owner let the fruit hang on the trees longer than normal in 1998 to try and get better prices may have had an effect.
Under the circumstances the 5 x 5 m planting is already starting to develop serious crowding problems while the 5 x 2.5 m pruned orchard is not experiencing any light problems and this may affect future production.

It is, however, clear that pruning of trees on such fertile soils complicates matters as the associated nitrogen management required can have no effect under these circumstances. Stassen *et al*. (1997b) recommend that such soils be avoided until the retained nitrogen has been reduced and effective nitrogen management can be applied. Other measures are needed to support the pruning actions but excessive nitrogen will to a large extent negate all efforts.

3. Planting densities

This trial was planted in order to determine how the different cultivars will perform at different plant densities and whether higher density orchards can be justified and maintained. Results are presented for trees that have, throughout this trial, been selectively pruned and with excessive growth controlled with nutrient and water management except for one Cultar drench of 'Fuerte' (Table 3).

Results indicate that no advantage is gained by planting 'Fuerte' at 4 x 1.5 m. The natural growth vigour of the cultivar demands wider spacing. In the case of 'Hass' good yields were already achieved 31 months after planting and at 43 months yields of 9.34 and 13.60 $t \cdot ha^{-1}$ respectively were achieved at the 5.5 x 3 m and the 4 x 1.5 m planting distances. The higher density planting was still significantly better.

As was expected 'Pinkerton' performs well with higher density planting. In 1999, 43 months after planting the yield was, however, lower than expected. The reason could possibly be the result of a too severe fruit thinning programme as well as inadequate nitrogen application.

'Edranol' is highly suited to higher density orchards and as a central leader tree. This is evident as shown by the 1999 harvest figures where 43 months after planting 17.2 $t \cdot ha^{-1}$ and 22.4 $t.ha^{-1}$ respectively were produced in the 5.5 x 3 m and 4 x 1.5 m spacings. 'Ryan' can be accommodated in higher density orchards with yields of 11.9 $t \cdot ha^{-1}$ for 5.5 x 3 m spacing and 13.8 $t.ha^{-1}$ for 4 x 1.5 m spacing.

A few more years data are required but there can already be said that with the exception of 'Fuerte', all other cultivars in the trial can be readily shaped and maintained in an orchard of 606 trees/ha or more.

Table 3. Yield of five avocado cultivars at two plant spacings and trees shaped to a central leader.

		Yield ($t \cdot ha^{-1}$) (months from planting in brackets)			
Cultivar	Spacing (m)	1996 (7)	1997 (19)	1998 (31)	1999 (43)
Fuerte	5.5 x 3	0	0	3.11 a	6.25 a
	4 x 1.5	0	0	3.39 a	5.33 b
Hass	5.5 x 3	0	0.50	4.87 a	9.34 a
	4 x 1.5	0	1.20	8.77 b	13.60 b
Pinkerton	5.5 x 3	0	0.67	7.03 a	8.07 a
	4 x 1.5	0	1.35	12.37 b	9.26 b
Edranol	5.5 x 3	0	0	6.08 a	17.2 a
	4 x 1.5	0	0	7.54 b	22.4 b
Ryan	5.5 x 3	0	0	4.96 a	11.9 a
	4 x 1.5	0	0	5.80 b	13.8 b

Spacing of 4 x 1.5 m are not at this stage being generally recommended in South Africa (Stassen *et al*., 1997a) but indications are that some cultivars, even at 1667 trees/ha, can be maintained on medium to low-potential soils by applying the correct pruning techniques along with the necessary nutrient management. Razeto *et al*. (1998) achieved a yield of 44 $t \cdot ha^{-1}$ in the seventh year with unpruned 'Bacon' avocados planted at 4 x 2 m but production subsequently declined as no pruning programme was implemented.

4. Cincturing

To determine whether vigorously growing trees can be forced to be more fruitful, pruned and unpruned trees were cinctured at various times. The results are summarised in Table 4. To see whether cincturing has a carry-over effect on the subsequent harvest the yields for that year are also included in the results.

Cincturing produced significant increases in yield for vigorously growing pruned and unpruned trees. Cincturing, from February until as late as May, can be applied as a tool to force vigorously growing trees into higher yields.

5. Bio-regulators

It is realised that certain circumstances can give rise to vigorous growth. The question is whether growth can be controlled with growth inhibitors especially with a crop such as the avocado that is easily stimulated into vegetative growth.

Three chemical compounds were used, namely, uniconazole (Sunny®), paclobutrazol (Cultar®) and chlormequat chloride (Cycocel®).

The results show that there are no significant differences between the various treatments except where Cultar® was sprayed twice. There is a tendency for one Cultar® spray (0.4% at flowering) or two Sunny® sprays (0.7% at flowering and 0.3% on the summer flush) to have a beneficial effect on yield.

Table 4. Yield figures for 30- to 42-month-old 'Hass' avocado trees that were cinctured from February to May in 1997.

Treatment	Yield ($t \cdot ha^{-1}$)			
	5 x 2.5 m pruned trees		5 x 5 m unpruned trees	
Date of cincturing	1997	1998	1997	1998
29-02-97	6.7 a	6.3 a	6.2 a	6.5 a
20-03-97	6.5 a	6.0 a	5.1 a	7.5 a
02-04-97	6.1 a	4.9 a	5.3 a	6.7 a
16-04-97	7.0 a	6.3 a	6.0 a	4.2 a
04-05-97	6.7 a	6.6 a	4.7 a	5.3 a
16-05-97	6.7 a	5.9 a	4.4 a	7.1 a
Untreated controls	2.5 b	9.0 a	2.5 b	9.9 a

Favourable reactions were obtained when Sunny® was sprayed twice (1% as described by Erasmus and Brooks [1998] and 0.5% on the summer flush) on twenty-year-old pruned 'Fuerte' trees to give a yield of 16.6 $t \cdot ha^{-1}$ as opposed to 9.7 $t \cdot ha^{-1}$ for the control while treated 'Hass' trees of the same age gave a yield of 16.2 $t \cdot ha^{-1}$ with 7.0 $t \cdot ha^{-1}$ for the control (E. Schäfer 1999 – personal communication, Dow Agro Sciences, SANACHEM). Bio-regulators can probably be usefully employed as another "tool" to be used in conjunction with pruning for effective orchard management.

It must always be borne in mind that these substances must be used in accordance with registration requirements and in such a way that no residues are detectable on the fruit when harvested. According to E. Schäfer, 1999 – personal communication, Dow Agro Sciences, SANACHEM), Sunny® requires a 60 day withholding period when used at a dosage of 0.5% on the summer flush.

Table 5. The effect of growth inhibitors on yield of pruned, 54-month-old, vigorously growing, 'Hass' trees planted at 5 x 2.5 m.

Treatment	Yield ($t \cdot ha^{-1}$)
0.4% Cultar® (full bloom)	7.83 a
0.7% Sunny® (full bloom) + 0.3% Sunny®(flush)	7.71 a
Control (no chemical sprays)	6.92 ab
0.4% Cycocel® (full bloom)	6.83 ab
0.7% Sunny® (full bloom)	6.76 ab
0.4% Cycocel® (full bloom) + 0.4% Cycocel® (flush)	6.51 ab
0.4% Cultar® (full bloom) + 0.4% Cultar® (flush)	4.77 b

6. Mechanical pruning

Pruning actions must preferably be less labour intensive. Various mechanical or semi-mechanical actions are being examined to speed up the process and make it more cost effective. It will, however, always be necessary to annually make certain selective cuts especially to enhance light penetration into the inside of the canopy. In Table 6 results are presented where pruning was done during two different periods and using two methods.

Table 6 does not provide consistent proof that selective pruning is better than mechanical pruning. With the 4 x 1.5 m spacing 'Hass', 'Fuerte' and 'Edranol' produced significantly higher yields when only selective pruning was applied. Selectively pruned 'Pinkerton' on the other hand produced significantly less than the mechanically pruned trees at the 4 x 1.5 m spacing. At the 5.5 x 3 m spacing for 'Fuerte' a significantly poorer production was achieved where mechanical pruning applied in the post-harvest period was followed up by selective pruning in the summer period. For 'Pinkerton' and 'Edranol' at the wider spacing there was no significant difference between the three pruning treatments.

Mechanical pruning at the right time and of the right intensity may have advantages and research in this direction needs to be refined before definite recommendations can be made.

CONCLUSIONS

Avocado trees can be shaped and trained with simple practical manipulation techniques. To optimise light utilisation and simplify actions, it is suggested that central leader pyramid shaped trees are planted at a density of 600 trees/ha or more in a rectangular pattern with a north/south row orientation. Harvest data are currently only

available for four harvest seasons or less but indications are that there is merit in this philosophy despite errors made during the initial development stages.

Table 6. Yield (t.ha^{-1}) achieved with 43-month-old avocado trees that since the previous harvest were given selective (SEL) and mechanical (MEC) pruning treatments in the post-harvest (PH) and summer periods (SP).

		Yield per pruning treatment (t·ha^{-1})		
		1. Selective	2. Combination selective/mechanical	3. Combination mechanical/selective
		PH SP	PH SP	PH SP
Cultivar	Spacing (m)	SEL SEL	SEL MEC	MEC SEL
Hass	5.5 x 3	9.3 a	7.7 ab	5.8 b
	4 x 1.5	13.7 a	8.5 b	7.0 b
Fuerte	5.5 x 3	6.2 a	6.2 a	2.8 b
	4 x 1.5	5.3 a	1.8 b	1.0 b
Pinkerton	5.5 x 3	8.1 a	7.5 a	7.0 a
	4 x 1.5	9.3 b	13.0 ab	15.0 q
Edranol	5.5 x 3	17.2 a	15.1 a	14.3 a
	4 x 1.5	22.4 a	9.8 b	13.2 b

Cultivars such as Hass, Pinkerton and Edranol can easily be maintained within a spacing of 5.5 x 3 m to 4 x 1.5 m. The higher densities are at this stage of an experimental nature, to refine manipulation techniques, but are providing useful information which can be used in future for planning more intensive orchards for certain cultivars.

Soils with a high nitrogen retention capacity necessitate more drastic pruning actions and this has a negative influence on yield in the initial years if narrow spacings are involved. If no pruning is done, however, such orchards can become overcrowded in less than 60 months after planting.

Cincturing and growth regulators may be of value as additional “tools” to manage growth, especially under conditions that promote plant vigour. In the case of growth inhibitors, registered application recommendations and nil residue tolerance must be strictly complied with. Good nitrogen management and tree fruit load , however, remain the more acceptable ways of controlling growth vigour.

Combinations of selective hand pruning and mechanical pruning must be further investigated to speed up the pruning process.

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