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RESULTS OBTAINED BY PRUNING OVERCROWDED AVOCADO ORCHARDS

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SUMMARY

A large percentage of avocado orchards in South Africa are currently in an overcrowded state. Trees in these orchards have become so tall that they are difficult to spray or harvest. Results show that orchards in the initial phase of congestion can be selectively or mechanically pruned without adversely affecting yield. Trees that are already in a seriously congested condition have developed bare stems at their base with most of the foliage in the treetops. These denuded areas can be rehabilitated by more drastic pruning actions but without the need to staghorn the trees. When drastic pruning is fully applied immediately after harvest, one year's yield will, however, be lost. A pyramidal tree shape is preferred in order to get an open V-shape in the work row. The tree height must not exceed 80% of the row width and possibly less where the work rows are not strictly north-south orientated or where the trees are on a slope. Current research is not only examining post-harvest pruning but also the correct follow-up summer pruning that needs to be applied. A complete orchard management program is essential to support the pruning actions so that controlled growth can take place, and production and fruit quality optimized. Additional advantages from a pruning program include more uniform and smaller trees where orchard operations and spray activities will be easier and cheaper.

Keywords: *Persea americana* Mill., pruning strategies, pyramidal shape, light interception, light penetration.

INTRODUCTION

By 1904 there were already a few West Indian avocado seedling trees in South Africa but the first real establishment of trees occurred in the early 1930's. The avocado industry, however, only developed rapidly from 1960 onward (Du Rand, 1990; Toerien *et al*., 1992). In 1991 avocados were widely distributed with 45.1% of the trees in the Letaba area (Tzaneen), 25.7% in the Nelspruit area (including Kiepersol), 17.8% in the Zoutpansberg area (Levubu), 10.9% in Natal and 0.5% near Rustenburg (Van Zyl and

Ferreira, 1995). By 1995 there were about 1.9 million avocado trees in South Africa (Ernst, 1996).

Conventional plantings were extensive in the 1970's with between 100 to 200 trees per hectare. In the latter part of the 1980's more intensive orchards were established with 200 to 400 trees per hectare (Köhne, 1993; Stassen *et al*., 1995).

Extensive plantings, depending on the soil fertility, fared well for the first 14 to 16 years but thereafter tree crowding occurred. Not only did yields decline but trees became enormous. Avocado jungles came into being with little or no light penetration into the tree canopy (Snijder and Stassen, 1995).

When the economic situation forced producers into more intensive plantings of 400 trees per hectare, in an attempt to achieve higher production in the initial years, crowding started occurring already after only five years where trees had been planted in the fertile soil of old banana plantations. On less fertile soil, crowding of trees started occurring after eight years. Originally it was in such orchards that the philosophy of removing trees on the diagonal was implemented to try and avoid overshadowing (Köhne and Kremer-Köhne, 1992; Snaddon and Reay, 1998) but the remaining trees filled the space thus generated within two years (Stassen *et al*., 1995). Growth was then mainly confined to the treetops and a tunnel effect was created. Tree thinning without a proper manipulation program (Stassen and Davie, 1996a) was not the ultimate solution.

The South African avocado industry was therefore in a dilemma as most of the established orchards were to a greater or lesser extent jungle like. This gave rise to economic and cultivation problems. Methods to overcome the problems were only partially successful and in most cases only improved matters temporarily and sometimes even aggravated the situation.

The basic problem with over-crowded orchards is insufficient light (Stadler and Stassen, 1985; Stassen and Davie, 1996b). Several researchers have studied different aspects of the light problem in fruit trees. According to Hasketh and Barker (1967), net photosynthesis and production of dry mass per surface unit are related to the amount of light that is intercepted. It would appear that maximum photosynthesis occurs at 30 percent or more of the full sunlight intensity (Heinecke, 1966). The percentage of the total sunlight intensity mentioned above is evidently not always adequate for the normal development of vegetative and reproductive buds (Bergh, 1974). Palmer (1977a; b) and Jackson *et al*. (1977) found that flower-bud differentiation, in apple trees, is more sensitive to shading than vegetative growth. Heinecke (1966) reports insufficient colouring of apples if the light intensity is below 40 percent, whereas if it is lower than 50 percent, fruit size is adversely affected. Jackson (1978) confirms that high light interception is a prerequisite for optimal yields, whereas shading causes a reduction in flower-bud formation, fruit size and fruit color.

A lack of sufficient light results in unproductive areas within the tree and where the trees overlap. The bearing surfaces shift higher up in the tree and further away from the centre with a decline in production (Stassen *et al*., 1995).

The secret, however, lies in optimizing light interception throughout the orchard and ensuring light penetration into the canopy of each individual tree. Snijder and Stassen (1995) found that the light intensity inside a dense avocado orchard was seven percent of the total sunlight and this could be improved to 58 percent by selective pruning.

Sunlight interception of an orchard is governed by row orientation, planting system, tree shape and height (Cain, 1972; Stadler and Stassen, 1985; Stassen *et al*., 1995; Stassen and Davie, 1996b). Sunlight penetration into the tree canopy is determined by tree dimensions, tree shape and the development of the tree branch hierarchy (Heinecke, 1963; 1964; 1966; Stadler and Stassen, 1985; Snijder & Stassen, 1995; Stassen *et al*., 1995; Stassen and Davie, 1996b).

A great deal of research has been done which showed that a hedgerow system, with trees closer together in the rows and with more space between rows, is the best way for improving light interception in an orchard (Cain, 1972; Stadler and Stassen, 1985; Stassen & Davie, 1996b). It must be clearly understood that the primary purpose of the work-row is to provide sufficient light interception by the total leaf canopy of the hedgerow. In addition it provides access to the orchard for sprayers, picking carts and other activities. The ideal spatial orientation of the trees should be such that optimal light utilization occurs over the total leaf canopy during the day depending on the sun's movement across the horizon. Normally it should be as close as possible to a north-south orientation but can be adapted according to latitude, siting, occurrence of sunburn and other practical considerations (Stassen and Davie, 1996b).

The tree height must not surpass 80 percent of the width between rows so that the tree tops of one row do not overshadow the lower parts of the adjacent row (Stassen and Davie, 1996b).

In this article attention will be focused on strategies to improve light interception and penetration in order to revitalize crowded orchards.

MATERIALS AND METHODS

The principles for pruning and shaping older avocado trees were developed in a 16 year-old 'Hass' orchard in the Kiepersol area (Snijder and Stassen, 1995). This development formed the basis for selective pruning i.e. pruning actions to specifically cut back or remove branches with pruning shears, saws and handheld power tools. After 14 years these specific trees were congested and alternate rows had already been removed. Two years later the orchard was again in a congested state. Pruning trials were done and systems initiated that were successful with regard to the development of new bearing wood and improved yield. The pruning action consisted of selecting one to four vertical frame branches as leaders. The remainder, especially those in the top of the tree are cut back to horizontal side shoots in order to reduce the canopy density and

allow light penetration into the tree. The trees are shaped to taper from the base to the top. In this way sunlight can penetrate into the tree and an open V-shaped working row is established in a north-south direction. Summer pruning is done by removing upright water-shoots during the summer flush of these trees and light penetration was improved from 11 to 40%. Tree height was not reduced during the first year. The procedure described above will be referred to in the rest of the article as initial selective pruning. This approach was further tested under semi-commercial conditions. Along with the selective procedure, mechanical pruning using tractor driven circular saw blades to shape trees, were also investigated. The pyramidal shape principle was applied throughout. In a severely overcrowded situation initial drastic semi-mechanical or mechanical pruning was done as recommended by Stassen (1999) and as summarized below.

Select the vertical leaders by using those available but not more than four, preferable less. Head these leaders at a height equivalent to 70 to 80% of the north-south row width. Thereafter, cut out all other vertical leaders. Cut angled leaders and other branches back to achieve a pyramidal tree shape. At the base of the tree the side branches in the work-row are cut back to about 1.5 m in length and in the top to about 300 to 500 mm. In this way an open V-shape is created in the work-row.

Ensure that the old bare stumps and branches at the base of the tree get sufficient sunlight by pruning away obstructing branches. In about three weeks dormant buds will give rise to re-growth on even the oldest branches. Strong vertical water-shoot development must be prevented and managed.

Trials were conducted on private farms in the Kiepersol area (near Nelspruit) in the Mpumalanga province and in the Levubu area near Louis Trichardt in the Northern Province. Initial pruning was done after harvest in all instances and this was followed up by maintenance selective and/or mechanical pruning as necessary.

RESULTS AND DISCUSSION

Most of the investigations involved large trial blocks and it was difficult to persuade producers to leave un-pruned controls. Comparisons are therefore made with the yield situation before and after pruning. Considerable practical experience was gained and various techniques developed.

In Table 1 the yield of ‘Hass’ avocado trees at Kiepersol (A), that were initially selectively pruned when they were 12 years old, is given. The trees were becoming congested in 1994.

The average yield in the four years before pruning was 9.7 $t \cdot ha^{-1}$ and the pruned trees yielded 11.4 $t \cdot ha^{-1}$. The trees are established on high potential soil and vigorous growth is experienced. Nitrogen leaf norms are still higher than they should be even though a management program has been implemented. The trees are completely pruned selectively and the height of the trees has been steadily reduced since 1997, to where they are currently being held at 5 m. Additional benefits are gained in that the fruit are at

a more reachable height and movement within the orchard is facilitated with more effective spraying made possible. Fruit size was also improved by as much as 2 to 4 counts with the peak size at counts 14 to 16.

Table 1. Yield of 16 year-old 'Hass' avocado trees (204 trees per ha) for four years before and four years after pruning.

Yield ($t \cdot ha^{-1}$)							
No pruning				Pruned			
1991	1992	1993	1994	1995	1996	1997	1998
11.9	5.0	15.3	6.4	11.7	11.4	10.0	12.3

In Table 2 the yield results of a 'Hass' avocado orchard in Levubu (B) are given for 1993 to 1995 (no pruning) and 1996 to 1999 (pruned).

Table 2. Yield of 11 year-old 'Hass' avocado trees (185 trees per ha) that were selectively pruned and shaped using an A-type frame.

Yield ($t \cdot ha^{-1}$)						
No pruning			Pruned			
1993	1994	1995	1996	1997	1998	1999
5.1	16.3	9.2	8.3	11.6	9.2	6.8

The orchard had during 1995, after seven years, started to become congested and trees were selectively pruned using a frame for shaping them. The height was immediately reduced from 7 to 5 m after harvesting in 1995. No further pruning was done until after harvesting in 1999. Crowding again developed within the orchard. The 1999 harvest was low but fruit set was low throughout the country and especially so in this particular area for that year. The biggest benefits were again in the fact that picking and spray actions were simplified and costs reduced.

Results of a 'Hass' and 'Fuerte' avocado orchard in Levubu, that initially had poor yields and has only been well cared for and managed since 1995, are presented in Table 3. The soil has about 20% clay and growth vigor can be easily controlled. In 1997, after harvesting, the height of the trees was reduced from 7 to 4 m. This action was carried out with tractor mounted circular saw blades. The sides of the trees were just lightly pruned by mechanical means.

From Table 3 it appears that good yields were obtained after pruning in 1998. The yield can obviously not be attributed entirely to pruning but also to good nutrient and orchard management. What it does show is that good yields are possible after drastic heading under mild growth conditions. In 1999 the yields were, however, very poor. This

situation can be ascribed to poor weather conditions in the area during flowering and fruit set, but also possibly to the residual effect of the high 1998 yields.

Table 3. Yields of 10 year-old 'Hass' (278 trees per ha) and 'Fuerte' (185 trees per ha) that were mechanically headed to 4 m.

	Yields ($t \cdot ha^{-1}$)				
Cultivar	No pruning			Pruned	
	1995	1996	1997	1998	1999
Hass	0.26	0.82	5.37	22.92	4.58
Fuerte	0.57	1.20	6.60	17.45	3.49

Table 4 provides results for 18 year-old 'Hass' orchards in the Kiepersol area (D) that were extremely congested. The lower parts of the trees in the orchard were virtually bare to a height of four meters. The 8 m high trees are established on high potential soil (35 to 50% clay).

Table 4. Yields of 18 year-old 'Hass' avocado trees (204 trees per ha) that were mechanically pruned.

Yields ($t \cdot ha^{-1}$)				
No pruning			Pruned	
1995	1996	1997	1998	1999
6	8	6	0	7
10.1[z]				16.2[z]

[z]E. Schaefer (1999); unpublished results on the use of Sunny®. Dow Agro Sciences, SANACHEM

From Table 4 it would appear that the trees are producing relatively poorly. After harvesting in 1997 the trees were drastically pruned as described by Stassen (1999). This meant that the tree height was reduced by heading the trees at 4 m and shaping them to a pyramidal form in order to establish an open-V workrow. In 1994 and again in 1998 sixty trees were sprayed, in flower, with Sunny® (50 $g \cdot liter^{-1}$ uniconazole) as recommended by Erasmus and Brooks (1998). In 1998, Sunny® was additionally sprayed at 0.5% on the summer flush. Bio-regulators must be used in accordance with registration requirements and in such a way that no residues are detectable on fruit at harvest.

As to be expected the results indicate that trees, already showing a high degree of die-back at the base, which are then drastically pruned, would for one year have no yield. The following year there was a yield equivalent to the yield before pruning. Where fruit

set and development was stimulated and growth was inhibited by Sunny®, a good yield was attained in 1999.

This trial showed that trees can be fully rehabilitated as regards the previously bare lower parts of avocado trees. Three weeks after trees were pruned and the lower levels exposed to light, dormant buds on even 18 year-old stems, started developing. Results show that pruning alone is not the complete solution but other “tools” should be employed to develop a complete management program.

The advantage was, however, that the same yield was achieved on a smaller tree. Spraying and other costs have been drastically reduced.

In Table 5 results of an orchard that is presently 12 year old are shown. The ‘Hass’ orchard in the Kiepersol area (E) has a history of good yields and effective nitrogen management. No vigorous water-shoot growth was experienced. The trees were pruned immediately after harvest in 1998.

Table 5. Yield results ($t \cdot ha^{-1}$) with different pruning strategies in a 12-year-old ‘Hass’ orchard (204 trees per ha).

No pruning applied			Different pruning treatments
1996	1997	1998	1999
21.0	23.7	14.9	Selective pruning of the whole tree 19.9 a[z] Selective pruning of tree tops 25.4 a Mechanical pruning of one side 20.2 a Mechanical pruning of both sides 10.7 b Standard pruning (open up work rows) 11.5 b

[z]Means with the letter in the column are equal according to the Tukey test at $P \leq 0.05$.

Results show that selective pruning of the whole tree, and an even lighter selective pruning, by only making the tops narrower for better light penetration, as well as the mechanical pruning of one side at an angle of 10^{o}, gave equivalent yields. However, where both sides are simultaneously pruned at an angle and where the work rows were cut open vertically, the yields were significantly lower.

Over the past year or two approximately 1000 ha of avocado orchards have been pruned. These results will also be available shortly. With the information thus far obtained it is clear that avocado trees can be successfully pruned. Pruning is, however, not a one off process and the initial drastic pruning after harvest must be followed up

with light spring and summer pruning (Stassen, 1999). Various strategies can be applied but it would seem that selective or light mechanical pruning and gradual height reduction, as described above, give good results in situations where crowding has not reached serious proportions. Poorer results are achieved when pruning trees on high potential soil, and the best results, on soil where growth can be controlled. Indications are that the use of growth regulators and other growth control mechanisms may improve yield results.

In cases of serious congestion where tree stems are denuded for many meters more drastic action is called for. Staghorning, however, is not recommended. As suggested by Stassen (1999) the trees can be headed at 80% of the row width and shaped to a pyramidal form. Thereafter a follow-up management programme must be in place.

Other strategies may be followed, such as, pruning one side, preferably the eastern side first. The main point is to regenerate growth in the denuded areas as soon as possible. The degree of overshadowing still caused by the tops of the trees or adjacent trees will determine the level of success achieved by this initial pruning.

CONCLUSIONS

Despite the fact that most of the results had to be compared with the situation that existed prior to pruning, and subsequently, important information was gathered. The following are noted:

Initial pruning of older trees is a drastic step and will trigger certain reactions. Growth stimulation, development of dormant buds and therefore new shoots, removal of reproductive material and improving light interception by the tree are some of the reactions obtained that can be advantageously or detrimentally applied.

Avocado trees can be successfully pruned if certain principles are adhered to.

Pruning alone is not necessarily capable of dramatically improving yield. Initial pruning must be supported by correct and timely summer pruning. A management program must be developed for controlled growth to take place. In particular, nitrogen management, soil potential, girdling and chemical manipulation may have value as “tools” to support the process.

There must be differentiated between lightly congested and heavily congested orchards. In the first case the lower parts of the trees are still partially functional and can be maintained by selective or light mechanical pruning, especially of the tree-tops. It can then in a year or two be followed up by reducing the height of the tree. Heavily congested orchards bear mainly in the tree-tops and can only be rehabilitated by getting sufficient light penetrating to the old wood in order to stimulate re-growth and through wound stimulation.

Lightly congested trees can be pruned without adversely affecting yield. In the case of heavily congested orchards one years yield may have to be sacrificed. There should be a definite plan devised for a farm so that all the blocks would not be pruned at once.

The most important outcome of the pruning programs conducted thus far is the fact that tree size has been reduced and the lower stems can again produce bearer shoots. All orchard activities (spraying, picking and pruning) were simplified. Spraying can be more effectively carried out and costs decreased.

It is recommended that, whatever strategy is chosen, trees be pruned to a pyramidal shape so that the work row can have an open V-shape for better light utilization. The work row should preferably be North-South orientated if circumstances permit. Tree height should not be more than 80% of row width and on steep slopes or with east-west orientations, even less.

The pruning of old trees is an emergency measure and a congested situation should rather be averted. Current plantings must be better planned and at time be pruned. Pruning should not involve drastic cuts but rather shaping and judicious removal of the wrong type of growth and water-shoots.

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Table 1. Pruning treatments of avocado trees at different sites and with different soil potentials.

Site name; Initial pruning and locality	Planting date and area used for the trial	Spacing	Extent of encroachment and when reached	Tree height		Pruning treatments and dates		Soil type
				Before pruning	After pruning	Winter (after harvest) - Initial pruning - Maintenance pruning	Summer (October to January)	
A – OmegaTrust Selective pruning Kiepersol area	1982 1.5 ha	7m x 7m Hass/ Duke 7 (clonal)	Medium encroachment, lower branches starting to be denuded (1994)	7.0m	5.0m Height was gradually decreased during the 3rd and 4th year of pruning	- Initial selective pruning of the whole tree was done after the 1994 harvest (August 1994) -Selective maintenance pruning	Selective watershoot management (October and January annually)	High potential soils. (35-40% clay) High nitrogen levels.
B – Lushof Trust Selective pruning Levubu area	1988 2 ha	9m x 6m Hass/ Edranol seedling	Lightly encroached, trees starting to grow into each other (1995)	7.0m	5.0m at first pruning	- Initial selective pruning of the whole tree with A-frame structure (5.5m high, 4.5m wide at the base and 2.8m wide at the top) (August 1995) - No maintenance pruning until after harvest 1999	No summer pruning	Medium potential soils (15-20% clay) Normal nitrogen levels
C – Tevrede Farms Mechanical pruning Levubu area	1989 7 ha Fuerte 11 ha Hass	9m x 6m Fuerte/ Duke7 (clonal) 9m x 4m Hass/ Duke7 (clonal)	Light encroachment, trees were too tall (1997)	8.0m	4.0m during first pruning	-Drastic mechanical heading of trees to 4m and only light vertical pruning of sides. (after harvest 1997) - No maintenance pruning	No summer pruning	Medium potential soils (20% clay) Normal nitrogen levels
D – A.P.Vos & Sons Mechanical pruning Kiepersol area	1981 5 ha Uniconasole [z] (Sunny) treatments applied to only 60 trees in the same area	7m x 7m Hass/ Duke7 (clonal)	Severe encroachment Denuded area up to 4m plus (1994)	8.0m	4.0m Height was decreased during first pruning	- Drastic mechanical pruning. Reduced height and width and tapered trees to a pyramidal shape, two months after harvest in 1997. - No maintenance pruning	Light summer pruning by mechanical removal of 200-300 mm of shoot-tips during December/ January.	High potential soils (35-50% clay) High nitrogen levels
E – Selde So Compari-son between mechanical and selective pruning Kiepersol area	1987 2.5 ha trial 24 trees / treatment Three rows were pruned and the data trees were selected in the middle row **	7m x 7m Hass/ Duke 7 (clonal)	Lightly encroached, trees starting to touch each other (1997)	6.5m	Tree height will be decreased to 5 m after harvest in 1999	- Initial pruning 1. Selective pruning of whole tree as described. 2. Selective pruning only of tree tops in first year. 3. Mechanical pruning of one side (10^0 from the vertical) 4. Mechanical pruning of both sides (10^0 from the vertical) and 25^o at the top 5. Control – standard vertical pruning of both sides. Started in August 1998 - Selective maintenance pruning	Mechanical pruning removing 100 -150 mm of shoot-tips during December 1998	Medium potential soil. (25-30% clay) Normal nitrogen levels.

[z] E.Schaefer – unpublished results. Dow Agro Sciences, SANACHEM

**Data were statistically analysed at $P \leq 0.01$. Results with the same letter do not differ significantly.