COMPARATIVE FINANCIAL EFFICIENCY OF TRAINING SYSTEMS AND ROOTSTOCKS FOR ‘ALPINE’ NECTARINES (*Prunus persica var. nectarine)*

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature

Date

SUMMARY

Most nectarine orchards in South Africa are currently planted at a distance of 4 x 1.5 m (2 500 trees/ha). These trees are mainly sylleptically trained to a central leader, although many producers also use the proleptic route. The former produces relatively high yields early in the lifetime of the orchard. A problem with nectarine production in South Africa is the lack of efficient rootstocks in terms of aspects such as size-control and the use of nematode-resistant rootstocks. The aim of this study is to evaluate different training systems for nectarine production and to investigate the role of three rootstocks that play a dominant role in the peach industry in South Africa.

'Alpine' nectarines were planted in the winter of 2002 at Lushof near Ceres, Western Cape, South Africa (33º18'S, 19º20'E). The trees were trained according to four different training systems: a four-leader system (5 x 3 m; 667 trees/ha), a two-leader system (5 x 1.5 m; 1 333 trees/ha), a proleptically trained central leader (5 x 1 m; 2 000 trees/ha), and a sylleptically trained central leader (5 x 1 m; 2 000 trees/ha). The trees were planted on three different rootstocks: GF 667; SAPO 778; Kakamas seedling. The time spent per tree on pruning, thinning and picking was recorded. During harvest, the number of fruit and fruit mass per tree were recorded. Light measurements were recorded annually after summer pruning. The measurements were taken at different heights and at different depths in the canopy. To compare the training systems on an economic basis, the data from the trial together with projected data gathered from farmers and advisors were used to calculate the net present value (NPV) and internal rate of return (IRR) for each training system.

The results showed that rootstock only played a significant role when it came to fruit mass (fruit size). Fruit from trees on SAPO 778 were heavier, indicating bigger fruit, than fruit from trees on Kakamas seedling rootstocks and this can play a role in packout percentage and income. In terms of the training system, the four-leader system took the most time to manage per tree. However, this system took the least time to manage per hectare during the initial years.

No differences were found between the two central leaders. They both took the longest time to manage per hectare. The four-leader system produced significantly less fruit than any of the other systems during the first two years of production. In the third year of production, there was no significant difference found between the systems.

Light penetration seemed to be the poorest at the middle and bottom of the canopy for trees trained to a central leader. Because of the open centre of the four-leader system, light penetration into the middle of these trees was good, but poor light penetration occurred in the upper and outer parts of the canopy underneath the scaffold branches. Poor light penetration occurred in the parts lower than 1.5 m from the ground for all the systems. This was the area that was measured in this study.

The result of an economic comparison showed that according to the IRR rating, the four-leader system should be preferred. The final decision should however be made according to the NPV rating. Results obtained from NPV calculations did not lead to the same conclusions as could be made from the IRR calculations. According to the rating of the NPV at five percent discounting rate, the two-leader should be the preferred system, while the proleptically trained central leader system should be preferred at a ten percent discounting rate. This implies that when the opportunity cost is low, the two-leader system should be preferred, and when the opportunity cost is high, the proleptically trained central leader system should be preferred.

OPSOMMING

In Suid-Afrika word die meeste nektarien boorde tans aangeplant teen ‘n plantafstand van 4 x 1.5 m (2 500 bome per hektaar). Die bome word sillepties opgelei volgens ‘n sentrale leier sisteem, alhoewel baie produsente ook gebruik maak van die proleptiese roete. Die sentrale leier sisteem het wel bewys dat dit redelike hoë produksies vroeg kan lewer. ‘n Probleem met nektarien produksie in Suid-Afrika is die gebrek aan ‘n effektiewe onderstam ten opsige van aspekte soos groei-regulering en bestandheid teen aalwurm. Die doel van hierdie studie is om alternatiewe opleisisteme vir nektariens en die invloed van drie onderstamme wat ’n groot rol speel in perske produksie in Suid Africa te ondersoek.

‘Alpine’ nektarien bome is in die winter van 2002 aangeplant op Lushof naby Ceres, Wes-Kaap, Suid-Afrika (33º18’S, 19º20’E). Die bome is opgelei volgens vier verskillende sisteme: ‘n vier-leier sisteem (5 x 3 m; 667 bome/ha), ‘n twee-leier sisteem (5 x 1.5 m; 1 333 bome/ha), ‘n prolepties opgeleide sentrale leier (5 x 1 m; 2 000 bome/ha), en ‘n sillepties opgeleide sentrale leier (5 x 1 m; 2 000 bome/ha). Die bome is op drie verskillende onderstamme geplant: GF 667; SAPO 778; Kakamas saailing. Die tyd spandeer per boom op snoei, uitdun en pluk is geneem. Tydens pluk is die aantal vrugte en massa vrugte per boom gemeet. Ligmetings is gedoen na elke somersnoei. Die metings is gedoen op verskillende hoogtes en verskillende dieptes in die boom. Die bome is op ‘n ekonomiese basis vergelyk deur die netto huidige waarde (NHW) en die interne opbrengskoers (IOK) van elke sisteem te bepaal deur inligting van die proef te gebruik saam met inligting ontvang van produsente en raadgewers.

Die resultate wys dat die onderstam slegs ‘n rol speel by vruggewig. Vrugte van bome op SAPO 778 onderstamme het vrugte produseer wat swaarder is wat dui op groter vrugte as vrugte van bome op Kakamas saailing onderstamme. Die aspek kan egter van belang wees die uitpak persentasie en inkomste verkry. In terme van opleistelsel het die vier-leier sisteem die langste per boom geneem om te bestuur. Per hektaar het die sisteem egter die minste tyd geneem om te bestuur.

Daar is geen verskil gevind tussen die twee sentral leiers. Albei het die langste per hektaar gevat om te bestuur. Die vier-leier sisteem het betekenisvol minder vrugte produseer as die ander sisteme in die eerste twee jaar van produksie. In die derde jaar van produksie was daar egter geen verskil tussen die sisteme nie.

Lig penetrasie blyk om die swakste te wees vir sentrale leiers aan die onderkant en in die middel van die boom. Lig penetrasie in die middel van die vier-leier bome is goed as gevolg van die oop struktuur van die bome. Swak lig penetrasie kom egter voor in die boonste buitenste dele van die boom aan die onderkant van die raamtakke. Swak lig penetrasie het voorgekom in dele onder 1.5 meter van die grond by al die sisteme. Dit is die gedeelte wat in die studie gemeet is.

Die resultate volgens die IOK berekening wys dat die vier-leier sisteem die gunsteling keuse moet wees. Die finale besluit lê egter by die rangorde volgens die NHW berekening. Die resultaat van die NHW rangorde is nie dieselfde as dié van die IOK nie. Volgens die NHW resultate met ‘n verdiskonterings koers van vyf persent is die twee-leier sisteem die gunsteling keuse. Volgens die NHW resultate met ‘n verdiskonterings koers van tien pesent is die prolepties opgeleiede sentral leier sisteem egter die gunsteling keuse. Dit beteken dat met lae geleentheidskoste die twee-leier sisteem voorkeur geniet en met hoë geleentheidskoste die prolepties opgeleide sentrale leier die gunsteling sisteem is.

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CHAPTER I

INTRODUCTION AND OBJECTIVES

1.1 BACKGROUND

In 2004 South Africa produced 210 000 tons peaches and nectarines, making it the fourth largest producer of peaches and nectarines in the southern hemisphere (OABS, 2004). Seventeen percent of the total 1417 hectares of nectarines planted in South Africa comprise of the cultivar ‘Alpine’ (OABS, 2004). ‘Alpine’ is an early dessert nectarine with a bright red skin colour and a good taste. In the 2003/2004 season a total of 273 740 cartons of ‘Alpine’ was exported mainly to the UK and Europe (OABS, 2004). Currently most nectarine orchards in South Africa are planted at distances of 4 × 1.5 meter and trained sylleptically according to the central leader system (Huysamer, 1997).

1.2 MOTIVATION

It has been shown that the central leader system used on nectarines can produce relative high yields. This system does however have certain disadvantages. Light interception with a central leader system is less sufficient than with a multi-leader system or an open-vase system. Gaps are created between the trees in the top parts. If the central leader is trained sylleptically, basal dominance must be managed. If the central leader trained proleptically, strong wood higher up in the tree can develop and give rise to overshadowing. Because all growth is directed into one leader, tree height management is important. Another problem with nectarine production in South Africa is the lack of efficient rootstocks in terms of aspects such as size-control and the use of nematode-resistant rootstocks. The use of multiple-leader trees may have advantages over the problems mentioned above.

1.3 METHODOLOGY

An ‘Alpine’ nectarine orchard was planted in August 2002 at Lushof farm near Ceres, Western Cape, South Africa (33º18’S, 19º20’E). The trees were trained according to four different training systems, namely a four-leader system (5 x 3 m; 667 trees/ha), a two-leader system (5 x 1.5 m; 1 333 trees/ha), a proleptically trained central leader (5 x 1 m; 2 000 trees/ha), and a sylleptically trained central leader (5 x 1 m; 2 000 trees/ha). The trees were planted on three different rootstocks, namely GF 667, SAPO 778, and Kakamas seedling. The time spent per tree on pruning, thinning and picking was recorded. During harvest, number of fruit and fruit mass per tree were also recorded. Light measurements were recorded annually after summer pruning. The measurements were taken at different heights and at different depths in the canopy. To compare the training systems on an economic basis, the data from the trail together with projected data gather from producers and advisors were used to calculate the net present value (NPV) and internal rate of return (IRR) for each training system.

1.4 OBJECTIVES

The aim of this study is to evaluate different training systems for nectarine production and to investigate the role of three rootstocks that play a dominant role in the peach industry in South Africa. The four different training in combination with the three different rootstocks would be compared in terms of time necessary for winter and summer pruning, fruit thinning and picking. Yield would be recorded as well as yield efficiency. Light utilization of the four different training systems will be investigated to identify possible problem areas in terms of light penetration. Using all the available information the different training systems will be compared on an economic basis with the use of capital budgeting methods. The objectives for this study are:

- To investigate how rootstock will influence production and labour input.
- To compare the four different training systems in terms of production and labour input.
- To examine the light penetration into the canopy for the four different training systems.
- To make an economic comparison of the four different training systems using capital budgeting methods.

1.5 LAYOUT

This thesis is written in ‘publication’ style and consists of a literature overview and three ‘publications’. In the literature study (Chapter II) an overview is given of nectarine production in South Africa, including a description of the different training systems and rootstocks commonly used. Chapter (III) is the first of the 'publication' where the different training systems and rootstocks are compared in terms of production and labour input. The second 'publication' (Chapter IV) investigates the role of light in the different training systems. The third 'publication' (Chapter V) compares the different training systems on an economic basis. Chapter VI is a summary of the conclusions made in the different 'publications'.

1.6 REFERENCES

OABS, 2004. Key deciduous fruit statistics. PO Box 25, Paarl 7620, South Africa

HUYSAMER, M., 1997. Integrating cultivar, rootstock and environment in the export driven South African deciduous fruit industry. *Acta Horticulturae*, 451:755-760

CHAPTER II

LITERATURE STUDY

2.1 INTRODUCTION

In 2004 South Africa was the fourth largest producer of peaches and nectarines in the southern hemisphere, producing 210 000 ton. In 2003 South Africa exported 7 223 tons, making it the fourth biggest exporter of nectarines and peaches in the southern hemisphere after Chile, Argentina and Australia. Worldwide, South Africa was the 14th biggest producer of peaches and nectarines, with China being the biggest, producing 5 782 000 ton in 2004 (OABS, 2004).

Peach production in South Africa increased by more than 30% from 2001 to 2004, the biggest increase in production of any deciduous fruit grown in South Africa (OABS, 2004). 'Alpine' is the dominant nectarine cultivar produced in South Africa. 'Alpine' is an early dessert nectarine and was bred by the ARC Infruitec-Nietvoorbij in South Africa. It was released in 1997. It is a cross between 'Sunlight' and 'May-Glo' nectarines (http://www.fishercapespan.com/sites/products). 'Alpine' nectarines have a bright red skin colour with a good taste. It is harvested middle to late November and has good storage ability for 4 weeks at -0.5ºC (Stargrow, 2004). The 237 hectares of 'Alpines' currently planted comprise 17% of the total area under peach and nectarine production on South Africa. In the 2003/2004 season a total of 273 740 cartons of 'Alpine' was exported mainly to the UK and Europe (OABS, 2004).

It is therefore impossible to ignore the importance of nectarine production in South Africa, especially that of 'Alpine'. Currently most nectarine orchards are planted at distances of 4 × 1.5 meter and trained sylleptically according to the central leader system (Huysamer, 1997). It has been shown that these orchards can produce relative high yields. This system does however have certain disadvantages. Light interception with a central leader system is less efficient than with a multi-leader system or a open-vase system. A central leader system grows in height because all the energy for growth is channeled into one leader. If trained sylleptically, basal dominance must be managed. If trained proleptically, strong wood higher up in the tree can develop and give rise to overshadowing. If the cost per tree is high this can be a factor. In South Africa the cost of nursery trees is however still relative affordable. The questions is whether a multiple-leader systems would be more labour and light efficient and still relate to higher income that a central leader system.

During the past 40 years there have been remarkable changes in apple production systems to improve the efficiency of apple orchards. Even is South Africa there have been changes in apple production systems. Robinson (1997) showed how size-controlling rootstocks for apples have significantly reduced tree vigour, measured as trunk cross-sectional area, without affecting fruit quality significantly. Worldwide, as well as locally, there has also been a tendency to use more intensive orchard systems such as the ‘Super Spindle’ system to produce high yields earlier in the lifetime of the orchard (Weber, 2000a). The option of a vigor controlling rootstock as well as more intensive training systems have made it possible for producers to plant at increasingly higher densities. Over the years these higher density plantings have shown increased apple production per hectare substantially during the early years (Palmer et al., 1989; Weber 2000b; Widmer and Krebs, 2001; Robinson and Hoying, 2002).

In many parts of the world peach and nectarine systems have adjusted much more slowly. The low density ‘Open Vase’’ training system was one of the first systems to be used on peaches and is still used in many parts of the world today as the predominant training system for peaches. One of the reasons that peach tree training was slow to evolve is because of the lack of a effective size-controlling rootstock for stone fruit (Layne, 1974). Only very recently did DeJong et al. (2005) identify three rootstocks for California peach and nectarine production that reduce trunk circumference, reduce pruning and still produce adequate fruit size and crop yields. Only one of these rootstocks is currently being commercially propagated. In South Africa systems for peach and nectarine production developed parallel with that of apples (Stadler and Stassen, 1985a).

2.2 LIGHT ENVIRONMENT IN AN ORCHARD

A big influence on the change in production system is the need to utilize the light environment within an orchard as efficiently as possible. One of the most important factors in the design of an efficient orchard system is the interception, penetration and distribution of daily sunlight by and into the tree canopy. Summer pruning is seen as an essential tool to manage growth in higher density peach orchards (Stadler and Stassen, 1985a).

The importance of sufficient light interception begins with the photosynthesis. Photosynthesis is the process by which a plant uses water and CO_2 to produce O_2 and organic compounds (carbohydrates) through a series of integrated chemical reactions. These chemical reactions take place in the chloroplasts, which are situated in leaves of green plants (Ksenzhek, 1998). The energy needed for these chemical reactions is provided through the absorption of sunlight. Sunlight is radiated at different wavelengths from the sun to the earth's surface. Radiation that can be absorbed by the leaves and be used as energy has wavelengths between 400 and 700 nm and is called photosynthetically active radiation (PAR) (Ksenzhek, 1998). PAR is measured in µmol.s^{-1}.m^{-2}. Research has shown that at levels of unlimited PAR, photosynthesis is inhibited by other factors such as the rate of carbon exchange between the leaf and the atmosphere (Yunus, 2000). DeJong and Doyle (1985) found that the carbon exchange rate (CER) of a peach leaf is saturated at more or less 800 µmol.s^{-1}.m^{-2} PAR. The whole canopy CER would however be saturated at about 1 600 µmol.s^{-1}.m^{-2} PAR (Giuliani et al. 1998). Very few studies have shown whole fruit tree canopies to absorb such high levels of PAR. Another factor that can inhibit photosynthesis under natural conditions is temperature. Tan and Buttery (1986) found an increase in photosynthetic rate as temperature increased at low PAR levels. They also found that an increase in PAR increased the optimum temperature for the photosynthetic rate. It is however very difficult and expensive to increase the temperature in a commercial orchard. It would thus be more appropriate to attempt to increase PAR levels in an orchard to increase the photosynthetic rate.

Higher light interception has been found to increase apple production (Robinson and Lakso, 1989). Robinson and Lakso (1989) reported that the yield of ‘Empire’ and ‘Redchief Delicious’ apples trees increased linearly with an increase in light interception (Figure 1). Figure 2.1 shows the relationship between cumulative yield and PAR interception for four orchard systems.

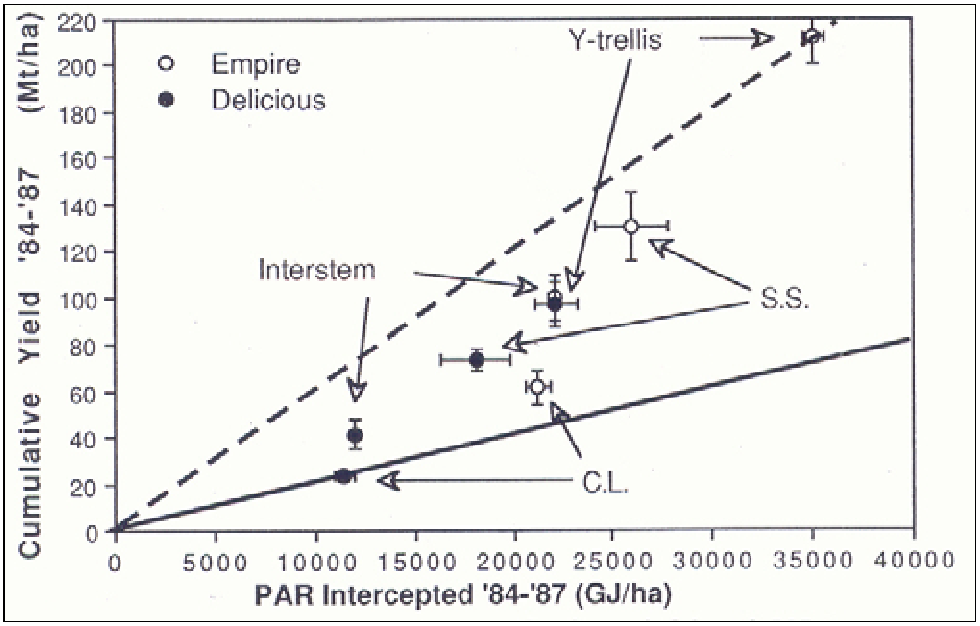

Figure 2.1: Relationship between cumulative yield and PAR intercepted for 4 orchard systems (±S.E.). The solid line is the regression through the origin for the Delicious Central Leaders and the dotted line is for the Empire Y-trellis. A steeper slope indicates greater efficiency. (Source: ROBINSON, T. L. AND LAKSO, A. N., 1989. Light interception, yield and fruit quality of ‘Empire’ and ‘Delicious’ apple trees grown in four orchard systems. ***Acta Horticulturae*** **243:175-184)**

Guiliani et al. (1998) also found a linear relationship for whole-canopy photosynthesis and the amount of light intercepted by a three-year-old ‘Redgold’ nectarine orchard. It is thus important for a tree to intercept a high percentage of the available light to produce high yields. Light intercepted by an orchard is measured as the amount of available light intercepted by the canopy and not striking the orchard floor (Rom, 1991). Jackson and Palmer (1972) have stated that 70% light interception is the optimum for a mature orchard. Light intercepted is a function of the leaf surface area of the tree canopy, measured as the leaf area index (LAI) of a tree. LAI is the ratio of leaf area to ground area on one side of the tree (Jackson, 1980). One way of increasing the LAI and reducing the amount of light that falls on the orchard floor is by planting at higher densities. Hampson et al. (2004) proved that LAI increased with higher planting density, and hence light interception increased. In an experiment they compared a ‘slender spindle’, ‘tall spindle’ and a ‘Geneva Y’ trellis system and found that to achieve a light interception of at least 50 percent, a planting density of between 1 800 and 2 200 trees/ha was needed for ‘Royal Gala’ and ‘Summerland McIntosh’ apple trees, depending on the system used.

Not only is light interception important, but light distribution within the tree canopy plays just as vital role in light utilization. An adequate amount of light is necessary throughout the whole canopy to stimulate reproductive development and fruit quality. The amount of available light decreases towards the centre or the bottom of a tree canopy where the LAI is the highest. Many researchers, including Johnson and Lakso (1991) used Beer’s Law of light attenuation to illustrate how in theory light intensity decreases as it is distributed deeper into the tree canopy. Beer’s Law states that:

$$I / I^0 = e^{-KL}$$

where: I is the light intensity below a leaf area index of L

I^0 is the light intensity above the canopy

K is the light extinction coefficient

L is the leaf area index

Figure 2.2 illustrates how less light is available as the leaf area index increases.

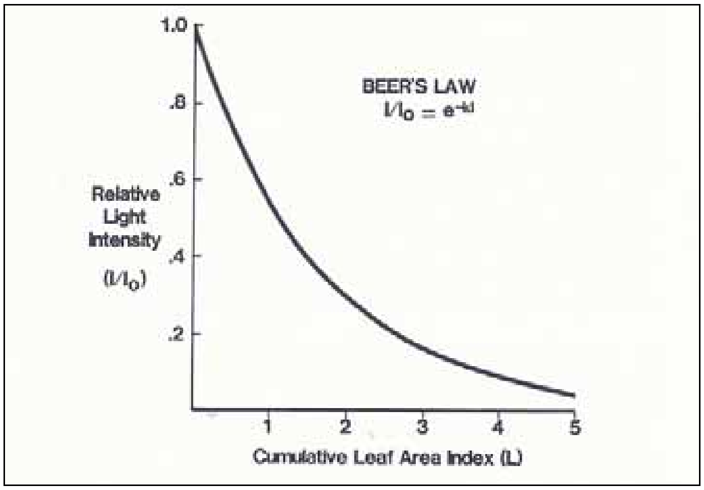

Figure 2.2: Beer's Law of light attenuation. Light intensity decreases as an exponential decay function through the canopy. (Source: JOHNSON, R. .S. AND LAKSO, A. N., 1991. Approaches to modeling light interception in orchards. *HortScience* 26(8):1002-1004)

Rom (1991) has shown how light decreases inside the first 0,5 to 1,0 m from the canopy edge in 'Delicious' apple tree training to a central leader. See Figure 2.3.

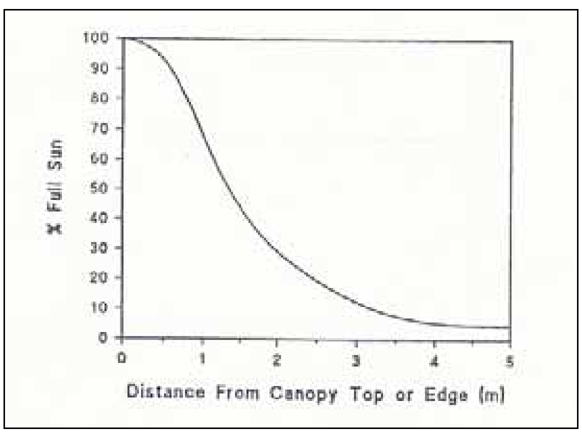

Figure 2.3: Light intensity decreases from the top of the tree canopy to the interior bottom of the canopy. Graph represents data collected from six replicate 'Delicious' trees in eastern Washington. (Source: ROM, C. R., 1991. Light thresholds for apple tree canopy growth and development. *HortScience* 26(8):989-992)

This reduction in available light has a profound effect of the efficiency of a fruit tree. Jackson et al. (1971) found that "Cox's Orange Pippin" apples on the outside of the trees were larger in size and better coloured than fruit from the inside of the canopy from the same tree. Jackson and Palmer (1977) also found that by shading "Cox's Orange Pippin" apple trees to receive 11% of full sunlight, shoot growth was significantly influenced. The number of shoots, and total shoot length and weight were significantly reduced compared to trees that were unshaded. They also found a reduction in flower bud formation in the shaded trees, which had residual negative effect on the percentage of flowers which set fruit in the following year. Consequently, fruit set and fruit size were reduced remarkably in the shaded trees. This variation in light levels within a canopy thus has a significant effect on apple production. Génard and Baret (1994) reported a variation in light levels within the canopy of peach trees. Fruit position would therefore also have an effect on fruit quality. This was confirmed experimentally by Caruso et al. (1998). Fruit from the upper part of a 'Spring Lady' peach tree trained to a central leader were larger in size than fruit from the lower part of the same canopy.

The minimum threshold for photosynthesis is said to be a 30% of full sunlight (Cain, 1972). It is therefore of utmost importance that the whole canopy receives sufficient light and that it is distributed throughout the whole canopy for a tree to perform efficiently.

2.3 ORCHARD SYSTEMS

Light interception is a function of canopy size and shape. These factors are influenced by the choice of rootstock, training system and planting density.

2.3.1 Rootstock

The choice of rootstock is one of the most effective methods by which to manage tree growth and canopy size. Size-controlling rootstocks reduce vigour and can thus reduce the time spent on pruning and managing the desired tree canopy. As previously mentioned, a size-controlling rootstock for stone fruit is not available. In the past peach trees worldwide were predominately grafted on seedling rootstocks (Rom, 1983). These rootstocks were effective in low density planting as they produced vigorous trees. Because of the high vigour of peach seedling rootstock as well as other limitations such as their susceptibility to nematodes, producers were forced to look at alternative rootstocks as production systems intensified. Clonal rootstocks such as the peach-almond hybrid 'GF 677' were developed. The performance of a rootstock is dependent on its ability to adapt to the local environment. Table 2.1 tabulates various rootstock problems and how the different major peach producing countries are affected by these problems. According to Rom (1982) the three major problems facing rootstocks in South Africa are nematodes, waterlogging and vigour control. The development of a suitable rootstock under South African conditions is thus specific to the problems facing peach production areas in South Africa. The present study will concentrate on three different rootstocks used commonly under South African conditions.

Table 2.1: Peach rootstock problems related to nursery and orchard production as reported in the survey. (Source: ROM, R. C., 1982. The peach rootstock situation: an international perspective.)

	Problem												
Country	Nematodes	Water Logging	Drought	Soil Diseases	Alkalinity	Nutrition	Vigor Control	Hardiness	Soil Insects	Longevity	Productivity	Propagation	Compatibility
Argentina	X	X	X		X	X	X	X		X	X	X	X
Australia	X			X	X		X				X	X	
(Tasmania)		X					X						
Brazil	X												
Canada	X			X				X		X		X	
Chile	X	X				X							
Czechoslovakia					X	X		X			X	X	
France		X		X									
Greece	X	X		X	X	X						X	X
Hungary					X					X			
India	X	X		X						X		X	X
Israel	X						X						
Italy	X	X		X	X	X	X			X	X	X	X
Japan	X					X	X					X	
Korea		X		X				X		X			
New Zealand	X	X		X					X	X			
Mexico	X	X	X	X	X	X					X	X	X
Romania		X		X	X			X	X			X	X
South Africa	X	X					X						
Spain	X	X			X								
Taiwan				X									
United States	X	X	X	X				X	X	X			
Uruguay		X		X						X			
Yugoslavia	X	X			X	X				X		X	
Zimbabwe	X			X		X		X					
% of all countries	68	64	12	56	44	36	28	28	12	40	20	44	24

2.3.1.1 Kakamas seedling:

In South Africa, as in the rest of the world, the peach seedling was used as the primary rootstock for peach production. Wallace (1896) reported on peach production in South Africa as early as the 19th century. The first production peach in South Africa seems to be the 'St-Helena' cling peach. This peach was planted all over South Africa and in some of the more northern parts it adapted so well that it became known as the 'Transvaal yellow peach'. 'Kakamas' is a selection of this 'Transvaal' yellow peach (De Wet, 1952). 'Kakamas' seedling became the standard for rootstock selection because of its ability to adapt very well to the South African conditions. Over the years, certain limitations have put some pressure on the popularity of this rootstock. As with most peach seedling rootstocks (Rowe and Catlin, 1971), 'Kakamas seedling' is very sensitive to wet conditions (Stassen and Van Zyl, 1982). This has limited the use of this rootstock in the south western parts of the country where winter and early spring rainfall create waterlogged conditions. Waterlogged soils are soils in which the water has displaced all the oxygen and anaerobic conditions are created. The sensitivity of peach roots is due to the fact that under anaerobic conditions a toxic hydrogen cyanide (HCN) gas or prussic acid is formed in the plant. This prussic acid is derived from prunasin, a cyanogenic glycoside which is hydrolyzed under anaerobic conditions (Rowe and Catlin, 1971; Du Preez, 1980). Even short periods of waterlogging can cause these toxic concentrations to increase slightly, which causes a quick and irreversible die-back of the plant (Du Preez, 1980).

Another disadvantage of the 'Kakamas' seedling rootstocks is its susceptibility to nematodes. The root-knot nematode (*Meloilogyne* spp) and ring nematode (*Criconemella xenoplax*) are commonly associated with peach tree diseases. Stassen and van Zyl (1979) showed that the 'Kakamas' seedling rootstock is very susceptible to root-knot nematode infestation. Symptoms of nematode infestation include dying back of shoot tips, poor differentiation of bearing shoots and a reduction in fruit size and overall fruit production (Stassen, 1996).

The 'Kakamas' seedling rootstock is also very susceptible to soils with free lime. Free lime causes iron, zinc and manganese cations to take on an insoluble carbonate form. This means that the tree cannot assimilate these cations. The effect of free lime can thus become visible by way of iron, zinc and manganese deficiencies, which include yellowing of leaves, inhibited photosynthesis, reduced leaf area and, consequently, a reduction in crop (Du Preez, 1980).

2.3.1.2 SAPO 778

Peach producing countries all worldwide, including France (Renuad et al., 1988), Italy (Di Vito et al., 2002), Spain (Albás et al., 2004), the USA (DeJong et al., 2004) and South Africa (Du Toit, 2005) initiated trails to identify promising clonal rootstocks to overcome the problems facing seedling rootstocks. One of the clonal rootstocks that enjoyed popularity in South Africa is the complex interspecies hybrid 'SAPO 778'. This clonal rootstock was bred by F. Zaiger (Zaiger's Genetics, Inc., Modesto, CA) in California (Lötze, 1997). The peach seedling 'Siberian C', native to Canada, was included in the clone because of its good productivity and its ability to be fruitful early in the lifetime of the tree.

'SAPO 778' has proved to be better adapted to wet soils than 'Kakamas' seedling (Lötze, 1997). In an experiment carried out over nine years in soils with a pH of 5.5, exposed to wet conditions in the winter months, trees on 'SAPO 778' rootstocks produced more fruit and better fruit size than trees on 'Kakamas' seedling rootstocks. 'SAPO 778' is more vigorous than 'GF 677' and 'Kakamas' seedling in terms of vegetative growth (Stassen et al., 2006 – personal communication). 'SAPO 778', however, gives delayed foliation symptoms in low chilling areas (Stassen et al., 2006 – personal communication).

2.3.1.3 GF 677

The 'GF 677' rootstock is a peach-almond hybrid that originated from a rootstock development programme in France, where rootstocks were identified that overcame the problem with calcareous soils and cold and wet springtime developing conditions often found in the southwest of France (Renaud et al., 1988). 'GF 677' has become very popular as a clonal rootstock worldwide (Rom, 1983). By 1978 23% of the total peach production area in France was utilized by ‘GF 677’ rootstocks (Rom, 1982). Even in Italy, the second largest peach and nectarine producing country in the world (OABS, 2004), ‘GF 677’ has become the most utilized rootstock because of its tolerance to replanting problems and calcareous soils and its ability to produce good yields (De Salvador et al., 2002). ‘GF 677’ also performs well in soils with free lime (Rom, 1982). Lötze (1997) found that under South African conditions, ‘GF 677’ produced significantly better yields than ‘Kakamas’ seedling in soils with a high pH.

‘GF 677’ has however been proven to be very vigorous (Klenyán et al., 1998; De Salvador et al., 2002; Albás et al., 2004), which can have a negative effect on some fruit quality characteristics (De Salvador et al., 2002). De Salvador et al. (2002) also noted that ‘GF 677’ can be sensitive to watterlogging. ‘GF 677’ has also poor resistance to any root-knot nematodes (DiVito et al., 2002).

2.3.2 Training systems

According to Stassen and Davie (1996) a training systems is “the structure to which the tree canopy will be shaped to make fruit more accessible and expose the total leaf canopy and bearing shoots to the optimal light required for the different plant functions”. Fruit trees can be trained to four basic shapes: 1) multi-leader free standing systems, 2) single-leader free standing systems, 3) palmette trellis systems and 4) V-systems. All over the world the different shapes have been modified and adapted to be as efficient as possible under the conditions of specific areas. For example, in some parts of France peach trees were trained to a cup shape with and open centre, made possible with three to four scaffold branches (Hugard, 1980), whereas in Italy the same type of open-centre system was often trained with five to six scaffold branches for peach trees (Sansavini, 1983). Because of the difference in training procedures in different production areas this study will concentrate only on the training systems as used for peach production under South African conditions.

2.3.2.1 The open-vase system

The open-vase system is a type of multi-leader free standing system. It is the system most commonly used all over the world as low density planting system (Figure 2.4). Tree density and the number of primary scaffold, as well the overall tree shape varies in the different production areas. Stadler and Stassen (1985b) described an open-vase trained tree under South African conditions to consist of a short stem of 30 to 60 cm on which multiple main scaffold branches are grown outwards at an angle of 40 to 70º. Side bearing branches are grown on the main scaffolds and spaced 50 to 60 cm apart. The leaders of the main scaffolds and bearing branches are kept dominant by removing any competitive growth, including water shoots (Bergh, 1972). Tree height is limited to 4 m. These trees are planted at a low density of 300 to 400 trees per hectare (Sansavini, 1983).

A major disadvantage of this system is the overshadowing of the lower outside parts of the tree canopy, under the main scaffolds. Because the trees are broader at the top, the top overshadows the bottom part of the canopy. Figure 2.5 shows how the light intensity decreases to below 30% of full sunlight in a round shaped open-vase system for a 'Delicious' apple tree (Looney, 1991).

Figure 2.4: The traditional "open vase" peach tree is less uniform and thus more costly to maintain. (Source: Day, K. R., DeJong, T. M., Johnson, R. S., 2005. Orchard-system configurations increase efficiency, improve profits in peaches and nectarines. *California Agriculture*, 59(2):75-79)

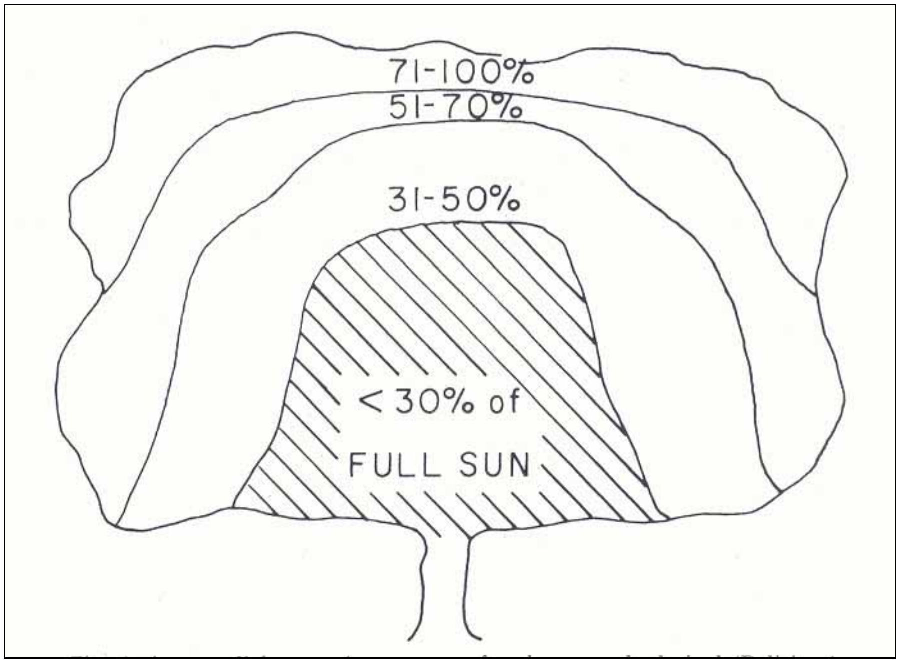

Figure 2.5: Average light zonation patterns for three standard sized 'Delicious' apple trees. Grid position within both the North-South and East-West grids were summed individually and then assigned to the appropriate light zone. (Source: Looney, N. E., 1968. Light regimes within standard size apple trees as determined spectrophotometrically. *Proceedings of the American Society for Horticultural Science*, 93:1-6)

Other disadvantages include limited bearing space, water shoots on the inside of the tree canopy as well as structural support needed for older scaffold branches (Stadler and Stassen, 1985b).

2.3.2.2 The closed-vase system

According to Cain (1972) an angled hedge-row surface will receive more even light distribution within the canopy than trees with a vertical surface and he proposed that a pyramidal-shape hedge with an angle of 20º to the vertical on each side would be ideal. Bergh (1974) stated further that to be more practical in terms of harvesting trees must be spaced so that they do not grow into each other, but still obtain a pyramidal shape. The closed-vase system is a free standing multi-leader system with a pyramidal canopy shape. See Figure 2.6. Strydom (1985) described the closed-vase system under South African conditions. These trees are developed from a relatively short trunk with three of four dominant leaders. Side scaffolds are developed on the leaders from a height of 50 cm above the ground, with a spacing of 50 to 70 cm between the scaffolds, depending on the planting distance. To from a pyramidal shape the side scaffolds should become weaker and shorter with wider crotch angles the higher they are situated in the tree. Trees trained to this system are preferably planted at densities of 600 to 1 000 trees per hectare.

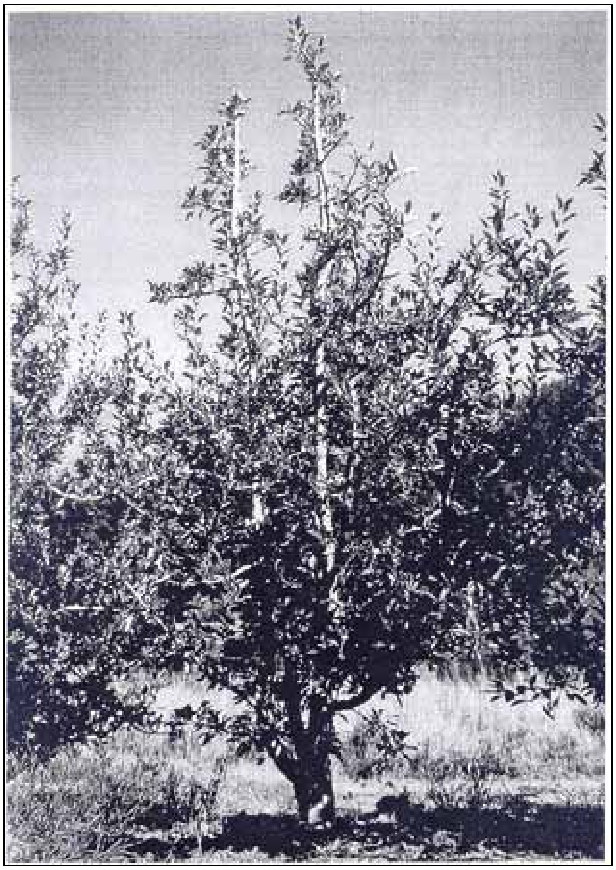

Figure 2.6: Full-bearing closed-vase tree. Note the dominant main and subordinate scaffolds and pyramid form. (Source: Strydom, D. K., 1985. The closed vase: An alternative training system for apples and pears. *Deciduous Fruit Grower*, 35:360-364)

The closed-vase system with a pyramidal shape was developed from the open-vase with a vase shape by keeping the leaders more upright and developing lateral branches from the base upwards a broader base with an slope of approximately 20° from the top is thus developed. The difference between the open- and closed-vase systems is the angle at which the three or four dominant scaffolds are grown and the angle of the lateral shoots. The dominant scaffolds of the closed-vase system are grown at a much smaller angle giving the tree a smaller, more upright pyramidal canopy (compare Figure 2.4 and 2.6). The advantage that the closed-vase has over the open-vase includes an earlier bearing, more efficient tree canopy, which allows higher density plantings to produce higher volumes (Bergh, 1974). Light distribution within the canopy of the closed-vase system can however be problematic. The canopy still had areas of heavy shading in the lower inner parts.

2.3.2.3 The central leader system

The trend to train apple and pear trees to a single leader free-standing system was soon followed for peach trees. Many variations of the central leader system exist, including the vertical axe, solaxe, slender spindle and super spindle. All these variations have the same basic shape which comprises a single main scaffold to which lateral shoots are attached around so that the canopy will form a pyramidal shape (Stadler and Stassen, 1985b). Because of the vigorous growing habit of stone fruit trees discussed earlier, the use of the central leader system on peach trees can be restrictive. Summer pruning is necessary to manage tree growth. Without this tool it is impossible to maintain high density peach orchards (Stadler and Stassen, 1985a).

Fochessati (1981) initially discussed the training of peach trees to a central leader under South African conditions. According to him the ideal central leader tree would consist of a dominant central leader surrounded by smaller less dominant bearing laterals. The diameter ratio between the leader and the lateral should be at least 3 to 1. He explained that to obtain a dominant leader and to get the lateral shoots at the desired positions, the trees should be cut back to 15 to 20 cm above the bud union just after planting. The tree is thus trained sylleptically. One shoot is selected to become the dominant leader. According to Jacobs and Strydom (1993) using the sylleptic route causes wide-angled plagiotropic sylleptic shoots to develop because of poor apical dominance and strong apical control of the dominant leader. This specific growing pattern is ideal to form a pyramidal canopy shape. Basal shoots that tend to grow too vigorously should however be headed back to weaken the growth. Any lateral shoot developing lower than 30 to 40 cm from the ground ought to be removed. The upper lateral shoots should also be removed so that the vertical shoot can remain dominant (Jacobs and Strydom, 1993). Stadler and Stassen (1985b) explained that in South Africa the lateral shoots are positioned in a spiral form around the central leader so that shoots are not on top of one another. Fochessati (1981) recommended a planting distance of 1 to 2 m in the row and 4 to 4.5 m between rows (1 111 to 2 500 trees per hectare) when training peach trees to a central leader.

A central leader tree can also be trained proleptically where the trees are not cut back after planting. This method of training trees to a central leader is more common in pome fruit production where trees do not easily form sylleptic shoots. Jacobs and Strydom (1993) explained that when using the proleptic route on trees with strong apical dominance and poor apical control lateral shoots with narrow crotch angles develop. These shoots compete heavily with the chosen dominant shoot and the tree can easily loose its central leader. Care should thus be taken to ensure that the vertical leader of the tree is kept dominant. Since stone fruit trees typically have poor apical dominance and strong apical control, the proleptic route can be considered when training peach trees to a central leader.

The tree size of a central leader system is smaller than an open-vase and thus produces less fruit per tree, but because of the higher density plantings of the central leader type, a higher yield per hectare can be produced (Marini et al., 1995) without a significant decreasing fruit size (Bassi et al., 1985). The central leader also produces a high yield early on (Bassi et al., 1985). Because the smaller tree size of the central leader, light distribution within the canopy will be more sufficient than within the open-vase. Fochessati (1981) advises however that to avoid shading, attention should be given to the canopy areas 1 to 1.8 m above the ground. This was confirmed by Robinson et al. (1991) who showed how the poor light distribution occurred in the areas 0.5 to 2 m from the ground in the canopy of 11-year old ‘Empire’/M.7 apple trees trained to a central leader system. See Figure 2.7. High establishment and maintenance costs are two of the greatest disadvantages of the central leader system.

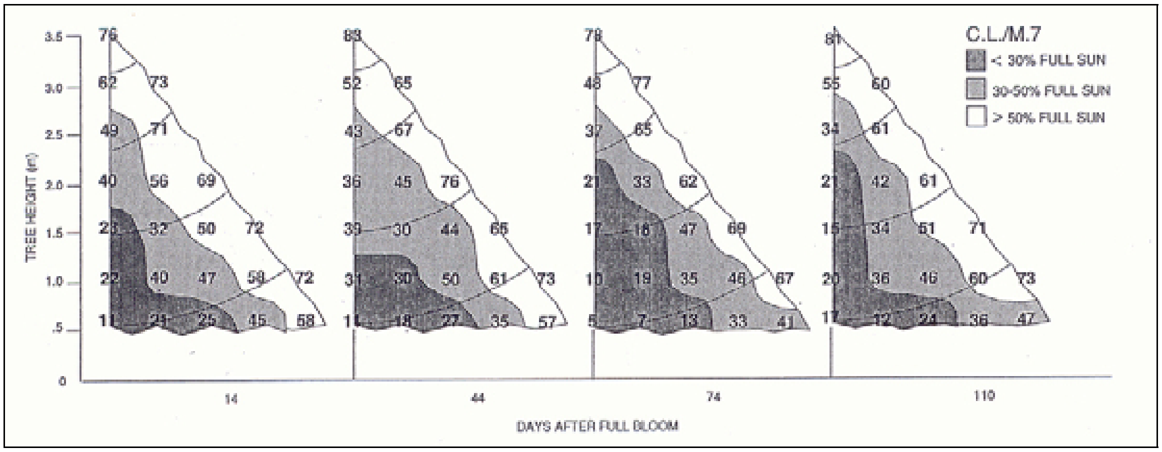

Figure 2.7: Canopy light distribution pattern at four times during the growing season for 11-year old 'Empire'/M.7 apple tree trained as central leaders. Values are percent full sun as determined by fisheye photography, n = 3. (Source: Robinson, T. L., Lakso, A. N. & Ren, Z., 1991. Modifying apple tree canopies for improved production efficiency. *HortScience*, 26(8):1005-1012)

2.3.2.4 The palmette system

The possibility of training a tree to a palmette form with the help of a trellis system dates back as far as the 19^{th} century (Wardle, 1883). The popularity of the palmette training system actually only started to increase in the mid-1950's when an inventive grower from Italy, Baldassari, chose to use this system rather than the traditional vase- or pyramidal-shaped trees (Corelli-Grappadelli, 2000). This caused producers in Italy to train many apple and pear trees to the palmette system after World War II (De Wet, 1966). In South Africa the palmette training system was first implemented on apple trees in 1959 (Berg, 1975).

Stadler and Stassen (1985c) described a peach tree trained to a traditional palmette system as having single main shoot with a few lateral scaffolds at opposite sides within the row direction. This system was originally implemented on apple and pear trees. The vigorous growing habit of stone fruit trees made it difficult to train peach trees to this system. Some modifications were however made and today the palmette system is one of the most successful training systems in Italy for peach production (Corelli-Grappadelli, 1997).

De Wet (1966) and Bergh (1974) explained the ideal form of the traditional palmette system under South African conditions. According to them two scaffold branches should be as far possible be positioned opposite to each other with an angle of 45º to 60º to the main stem. The bottom scaffold should not be lower than 35 cm from the ground. The distance between successive scaffolds should be between 45 and 85 cm. The side scaffolds should decrease in size and length as they are positioned higher up on the main stem. The width of the bottom scaffolds should not exceed 2 m. The top part of the tree should not end in a pair of scaffolds, but rather a single vertical extension. Tree height is preferably restricted to 4 m. To develop the side scaffolds at the desired position, the main stem is tipped in the winter at the appropriate height and the central leader and two scaffolds are chosen from the developing shoots the following year. Figure 2.8 shows the traditional palmette system used on apple trees.

Figure 2.8: Ten-year-old apple trees with well balanced branches. (Source: De Wet, A. F., 1966. Growing fruit trees to the Palmette shape. *Deciduous Fruit Grower*, 16:90-95

To adjust the palmette system for more vigorous growing trees, like plums, Bergh (1981) suggested a few modifications. He suggested the side scaffolds be developed in one season by tipping the main stem in the summer months. This would induce more lateral growth from which side branches can be chosen. Lately there has been a trend to avoid these heading cuts (Corelli-Grappadelli, 2000). If trees are well feathered it should not be necessary to cut back the central leader. This would reduce labour cost, reduce unwanted vegetative growth and accelerate production in the developing years (Corelli-Gappadelli, 2000). Bergh (1981) also suggested that the side scaffolds should rather be developed at an angle of 90º on the main stem to reduce over-vigorous growth.

The initial aim of the palmette system was to increase orchard efficiency and profitability. Studies have shown that this system is capable of these requirements. Because of the narrow canopy shape, light is distributed evenly throughout the whole canopy (Corelli and Sansavini, 1989). The palmette system is also capable of producing similar yield to other systems, such as the central leader system (Allison and Overcash, 1987). Because of the 'flat' canopy surface of the palmette it can be more efficient in some agricultural practices, such as pesticide spraying or picking. This system can however be very expensive to establish when using a trellis system.

2.3.2.5 The 'Y'-shaped system

Another fairly popular training system used in South African peach production that requires a trellis system is the Tatura. This system was developed by the Irrigation Research Institute in Tatura, Australia (Chalmers et al., 1978). This system consists of two scaffold limbs per tree growing out perpendicular to the row directions. These two scaffolds are grown at an angle of 60 to 70º from the horizontal level in the direction of the corresponding scaffolds in the adjacent rows. The scaffolds are limited to a height of 3.5 m and a 2 m gap is kept between the ends of two scaffolds in adjacent rows. Bearing branches are developed on the two main scaffolds. Figure 2.9 shows the 'Y'-shaped Tatura system used on peach trees.

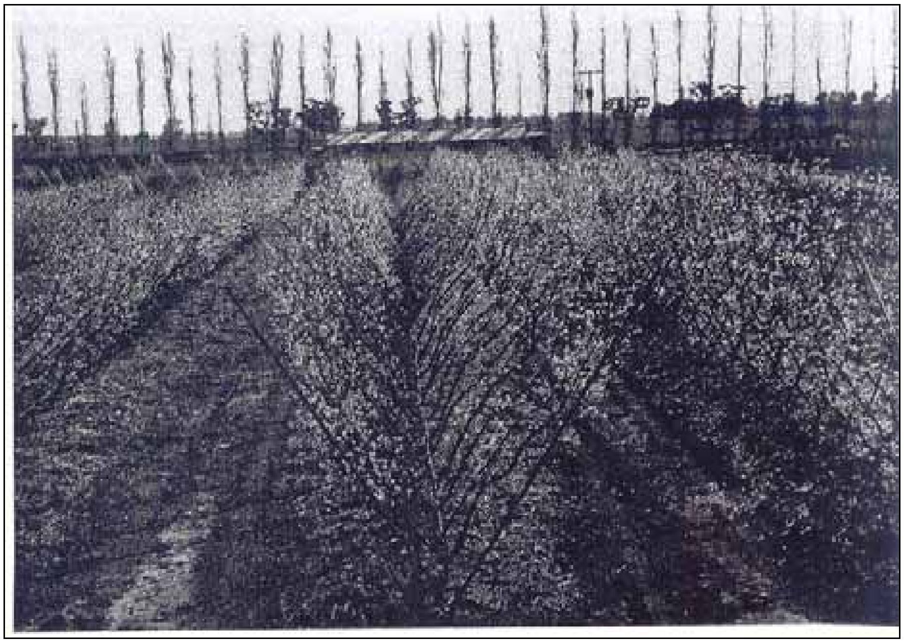

Figure 2.9: Tatura Trellis system showing rows of peach trees spaced at 6m. (Source: Chalmers, D., van den Ende, B. & van Heek, L., 1978. Productivity & mechanization of the Tatura trellis orchard. *HortScience*, 13(5):517-521)

Chalmers et al. (1978) found that the Tatura system produced yields that were just as good as or even better than production from other experiments carried out at more or less the same time. Production was also much higher than the commercial peach orchards in the same area. They also found that light interception and distribution with the 'V' of the system can be satisfied if the two meter gap between adjacent scaffolds is kept open. The Tatura system was originally designed to be mechanically pruned and picked (Chalmers et al., 1978) but in South Africa all pruning and picking is done manually, which is labour costly (Stadler and Stassen, 1985c).

Free standing 'Y'-shaped trees have also been popular for many years. These trees are also trained to two main scaffolds perpendicular to the row direction, but without the use of a trellis system. In some cases the two primary scaffolds can also be grown parallel to the row direction. The free standing Kearney Agricultural Center Perpendicular-V (KAC-V), developed in California for manual harvesting, has received lot of attention (DeJong et al, 1994). According to DeJong et al. (1994) the KAC-V, a hybrid between the open-vase and Tatura systems, is said to:

- increase production in the developing years of the orchard,
- produce yield equal to or greater than the open-vase at full bearing and thereafter,
- avoid unnecessary intensive summer pruning to maintain tree size,
- simplify tree structure so that cultural practices such as pruning, thinning and picking can be carried out more easily,
- and maintain or improve the light distribution characteristics with in the canopy of an open-vase system.

According to DeJong et al. (1994) the tree consists of two main scaffolds, grown perpendicular to the row direction, with an ideal angle of 25º to 40º from the vertical. Bearing branches are developed on the main scaffolds. Tree height is generally restricted to 3.5 to 4.5 m. The desired tree shape is maintained by keeping the two main scaffolds dominant and by keeping the inside of the 'V' open and free from vigorous watersprouts. The appropriate planting distances range from 1.5 to 2 m between trees in the row and 4.5 to 5.5 m between rows (909 to 1 481 trees per hectare). In Figure 2.10 one can see the KAC-V with the two main scaffolds perpendicular to the row direction.

Figure 2.10: A trial orchard planted in 1982 introduced another alternative for high-density stone fruit orchards, the perpendicular V. This system maintained standard 18-feet row spacing but planted trees about 6 feet apart, affording the advantages of early high yields without the additional cost of new equipment for maneuvering in narrow row middles. (Source: http://CaliforniaAgriculture.ucop.edu)

Free standing 'Y'-systems can produce higher yields at full-bearing than the traditional open-vase system (DeJong et al., 1999) and a central leader system (Caruso et al., 1999). 'Y'-shape systems also have better light interception and distribution within the canopy than a central leader system (Singh et al., 2004) and the traditional open-vase system (Grossman and DeJong, 1998). De Salvador and DeJong (1989) that a 'Y'-shaped system intercepted 74% of the available light compared to 71% for an open-vase and 69% for a central spindle system. They also found that the light distribution within in the canopy of the 'Y' was 35% higher than the central spindle. Robinson et al. (1991) showed how a 'Y'-shaped tree has the best light distribution on the inside of the 'Y'. See Figure 2.11 Problems with shading may occur in the bottom of the 'Y'. The higher light interception and distribution can lead to the 'Y'-system producing more fruit of high quality. Caruso et al. (1998) found that of the total yield, a free-standing 'Y'-shaped system produced 74 percent first grade fruit compared to 63 percent produced by a central leader system.

Robinson et al. (1989) ascribed the better light interception of the ‘Y’-system to the architecture of the tree, where the arms of the ‘Y’ are allowed to grow over the row alley, thus intercepting light that would otherwise fall on the orchard floor. Caruso et al. (2001) however found that to obtain the ‘Y’-shape of this training system required more pruning than the central leader system in the developing years. They also found that this intense pruning of the young tree caused a later onset of fruit and lowered the quantity of early yield during the initial years.

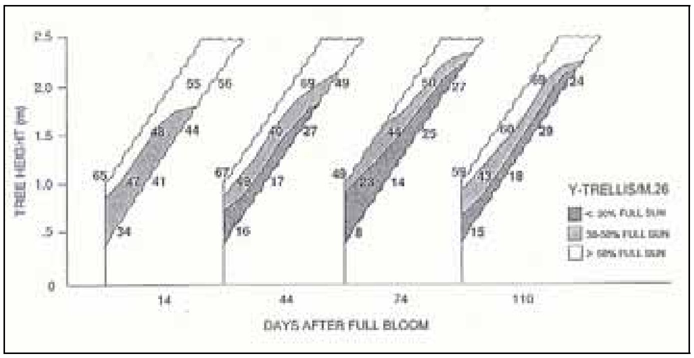

Figure 2.11: Canopy light distribution pattern at four times during the growing season for 11-year old ‘Empire’/M.26 trees trained as a Y-shaped hedgerow. Values are percent of full sun as determined by fisheye photography, n = 3. (Source: Robinson, T. L., Lakso, A. N. & Ren, Z., 1991. Modifying apple tree canopies for improved production efficiency. *HortScience*, 26(8):1005-1012)

2.3.2.6 The four-leader system

Another system recently used in South Africa for nectarine production is a low density four-leader system. The four-leader system shares many characteristics with that of the ‘Mikado’ system used for apple production. The ‘Mikado’ system was developed in the Netherlands as a low density ‘V’ system for apple and pear production (Widmer and Krebs, 1997). With this system vegative growth is partitioned into four equally strong branches from one trunk. The branches are oriented two on each side. See Figure 2.12. Widmer and Krebs (1997) described this system to have a efficient use of orchard space in terms of branch arrangement as well as efficient use of light to produce good quality fruit. In South Africa the four chosen leaders are headed a second time during summer pruning in the following year after planting. This is to allow the scaffolds to develop more horizontal.

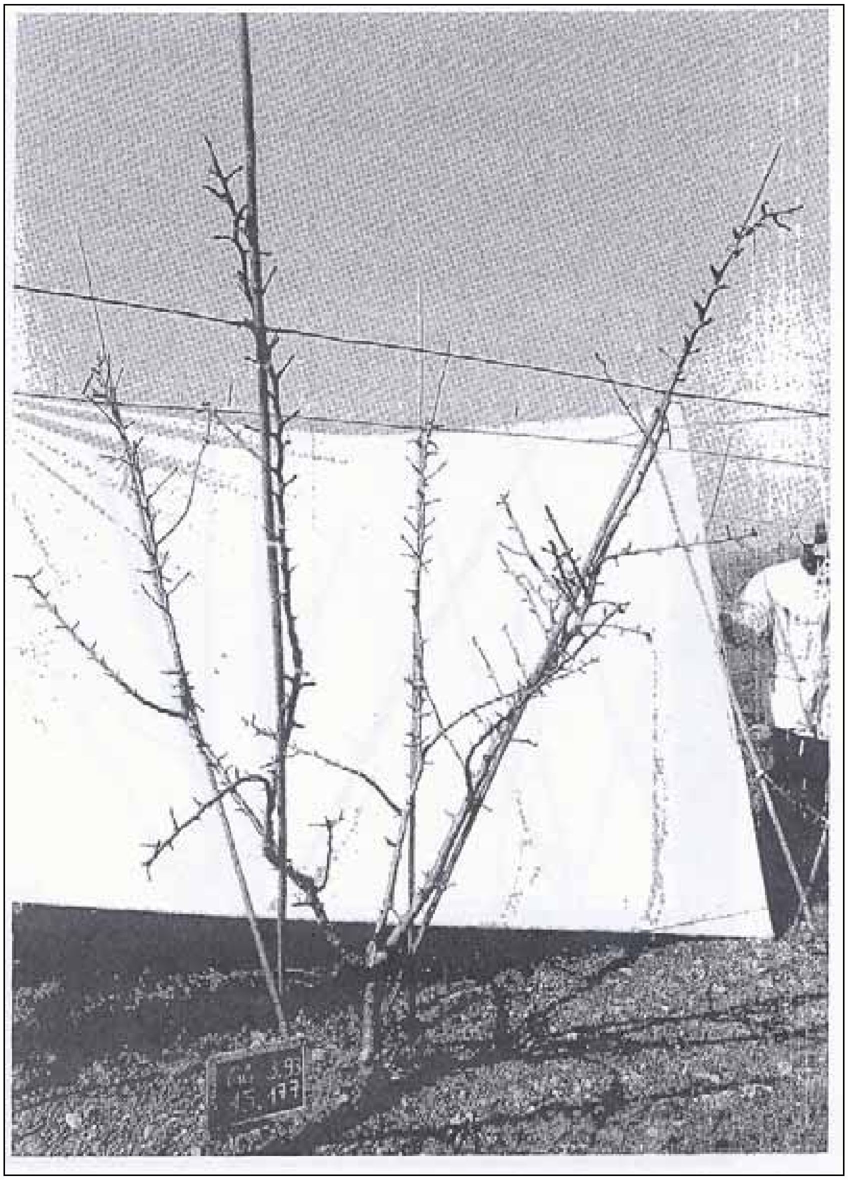

Figure 2.12: 'Mikado' with the pear variety 'Conference' on quince 'A' with four fruiting elements arranged in a 'V' in the 5th year (planted as one-year-old trees). (Source: WIDMER, A. & KREBS, C., 1997. 'Mikado' and 'Drilling' (triplet) – two novel training systems for sustainable high quality apple and pear production. *Acta Horticulturae* 451:519-528)

2.3.3 Tree density

When planting a new orchard, one of the key decisions that has to be made is at what densities the trees need to be planted. The trend during the last 20 year has been to plant at higher densities. Numerous studies have shown that planting at higher densities can increase yield per hectare, not only for apple production (Weber, 2000; Widmer and Krebs, 2001; Robinson and Hoying, 2004) but for peach production as well (Phillips and Weaver, 1975; Bargioni et al., 1985; Caruso et al., 1997; Marini and Sowers, 2000). Another good reason for planting at higher densities is that it increases fruit production early on. Leuty and Pree (1980) found that with higher planting densities increased yield by more than 67% during the first four years after planting for three different peach cultivars.

An increase in tree density does, however, not always mean an increase in fruit production. Widmer and Krebs (2001) found that when they planted apple trees at densities of 3 000, 4 000, 5 000 and 6 000 tree per hectare the increase in yield was not proportional to the increase of tree density. They concluded that the higher input cost of trees exceeding a density of 3 000 per hectare was not justified by the increase in yield. Some studies have shown that higher density plantings result in decreased fruit size (Layne et al., 1981; Caruso et al., 1997; Marini and Sowers, 2000).

Tree density is rather closely associated with the training system used. Trees that are trained to reach a smaller canopy size can be more conducive to higher densities. Tree density for a specific training system can also differ under different environmental conditions. The ideal tree density will therefore depend on the training system used together with production potential of a specific site.

2.4 FINANCIAL EVALUATION METHODS

To compare the different training systems on a financial basis a method must be used to identify the training system that would be the most beneficial to an investor in the long run. This method is called capital budgeting. When doing capital budgeting there are many techniques to compare and rank different investment opportunities, each with its own advantages and disadvantages.

One of the main requirements when choosing a training system is that it starts producing a commercial yield earlier during the lifetime of the orchard so that the investment made in the orchard can be returned as soon as possible. The payback method is a capital budgeting technique that is commonly used and is easy to understand. It determines the time it takes to recover the cost of an investment from the cash flow it generates. So the training system that takes the least time to recover from the initial investment would be preferred. This method has however a number of disadvantages. One of them is that it ignores the cash flow after the payback-period (Correia et al., 1993).

To eliminate the problem of ignoring the importance of ‘after-payback-cash-flow’ and to take in to account the time value of money, a technique is used to determine the net present value (NPV) of an investment opportunity. The net present value of a project is defined as “the present value of the project’s future cash flow minus the cost of the project” (Shapiro, 1990). In other words the net present value of a project is estimating the future cash flow of that project, discounting the estimated future cash flow at the required rate of return (cost of capital) and subtracting the initial cost of the project (Correia *et al*, 1993). The formula to determine net present value is:

$$NPV = \sum_{t=1}^{n} \left\{ C_t / (1+k)^t \right\} - I$$

where: C_t is the net cash flow at time t

I is the cost of investment

k is the required rate of return (cost of capital)

To decide whether a project is worthwhile investing in, the following rule should be followed (Vernimmen *et al*, 2005):

$NPV > 0$ Invest

$NPV < 0$ Do not invest

Shapiro (1990) also stated that if the NPV of two or more projects are all greater than zero, the one with the highest NPV should be preferred.

Another method of comparing different projects is to determine the internal rate of return (IRR) for each project. The IRR is the discount rate that causes the present value of net future cash flows of a project to equal the initial cost of the investment (Correia et al., 1993):

$$\sum_{t=1}^{n} \left\{ C_t / (1+r)^t \right\} - I = 0$$

where: *r* is the internal rate of return

In other words, the IRR is the discount rate which causes NPV to equal zero. This discount rate (*r*) is determined by trail and error. The NPV are calculated for several values of *r* until the point is reached where NPV turns from positive to negative (Shapiro, 1990). If the IRR of a project exceeds the cost of capital, the project should be accepted, but if the IRR is less than the cost of capital, the project should be rejected. If two or more projects are compared, the project with the highest IRR should be the preferred choice.

Using the method of calculating the NPV and the IRR of a project usually produces the same conclusion when deciding on a future investment. However, there are several different types of projects that pose potential difficulties in analysing capital budgeting. Dependent projects are projects whose acceptance depends on the acceptance or rejection of other projects. A mutually exclusive project is one whose acceptance will rule out the acceptance of another project. It is therefore necessary to determine which project is the best, when facing mutually exclusive projects (Van Horne and Wachowicz, 1995). Ranking of the best project is done on the basis of the NPV and IRR. Conflict in rankings according to NPV and IRR may occur. According to Van Horne and Wachowicz (1995) there are three reasons for this conflict in rankings. Firstly, there may be scale differences, where the initial cash outflows are different for the mutually exclusive projects. Secondly, different cash flow patterns of different projects can cause conflict in rankings. Thirdly, if projects have unequal projected lifespans, it can result in conflicting rankings. If however there is a difference in rankings according to the NPV and IRR methods, in the case of mutually exclusive projects with conflicting rankings the final investment decision should rather be made according to the ranking of the NPV method (Correia et al., 1993).

This methods of capital budgeting has been used in many studies to compare different orchard systems for fruit trees. Marini and Sowers (2000) wanted to compare two training systems, the central leader and the open-vase systems, for peach trees in terms of tree growth, yield and profitability. To compare the systems in terms of tree growth, they used the trunk cross-sectional area (TCA), the tree height and tree spread of the different trees. To compare the systems in terms of yield, they used the marketable yield ton per hectare for each system. But to evaluate to profitability of the systems they compared the cumulative NPV of each. Weber (2000b) compare three different training systems planted at different densities for ‘Jonagold’ apple trees. He made the economic comparison based on the calculation of NPV of future cash flow to the initial cash outflow of the different systems. Uzunoz and Ackay (2006) used the method of NPV and IRR calculation to investigate the profitability and feasibility of peach and apple production in Turkey and came to the conclusion that, based on positive NPV findings, producing these fruit could be one of the most important forms of income for farmers in the researched area in Turkey.

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CHAPTER III

THE ROLE OF THE TRAINING SYSTEM AND ROOTSTOCK USED FOR NECTARINES ON PRODUCTION AND LABOUR INPUT DURING THE INITIAL YEARS AFTER PLANTING A NECTARINE ORCHARD

Abstract

A study was carried out to evaluate different orchard systems for nectarine (*Prunus persica var. nectarina*) production in terms of labour inset and yield aspects. An 'Alpine' nectarine orchard was planted in the winter of 2002 at Lushof farm near Ceres in the Western Cape, South Africa. The trees where trained according to: a four-leader system (5 x 3 m; 667 trees/ha); a two-leader system (5 x 1.5 m; 1 333 trees/ha); a proleptically trained central leader (5 x 1 m; 2 000 trees/ha) and a sylleptically trained central leader (5 x 1 m; 2 000 trees/ha). The trees were planted on three different rootstocks namely GF 677, SAPO 778 and Kakamas seedling. Time spent per tree for pruning, thinning and picking were recorded. Yield aspects comprised of number of fruit and mass of fruit per tree. The four-leader took the longest time to manage per tree but per hectare it took the least time, while the two central leaders took the longest time per hectare to manage. A significant difference in production was recorded in the first two years with the four-leader systems producing the least fruit per hectare. No significant difference between the different systems was found in the third year of production. Rootstock only played a significant role when it came to fruit mass, where trees on SAPO 778 produced heavier fruit with a higher mass than trees on Kakamas seedling and GF 677.

3.1 INTRODUCTION

A radical change in training systems for use on apple and pear trees has been taking place worldwide over the last 40 years. The use of new training systems for peach trees has been slower. The open-vase system as described by Bergh (1972), planted at a distance of 7 × 7 m, was for many years the preferred training system for peaches in South Africa (Stadler and Stassen, 1985a). Cain (1972) suggested that a pyramidal tree shape would be more efficient and changed from the rounded open-vase shape. Bergh (1976) recommended and described a pyramidal close-vase system. Fochesatti (1981) then described the training of peaches to the central leader. These training systems are discussed by Stadler and Stassen (1985b). The palmette system that was traditionally designed for apple trees was modified and described by Bergh (1974). Chalmers et al. (1978) developed a 'V' system (Tatura system), as described by Stadler and Stassen (1985c). Stadler and Stassen (1985b) referred to the results described by Hugard (1980), Fochessati (1981) and Sansavini (1983), and came to the conclusion that due to the limited space, no strong scaffold branches must be allowed for the central leader system, but only bearing branches and shoots that are non-permanent. This developed into a central leader with bearing shoots arranged spirally around it, without branches and old wood that would cause overshadowing. The trend has mainly been to train the central leader sylleptically, where the tree is cut back after planting and the dominant central leader, with lateral shoots developing during the same season, is chosen from the developing shoots (Jacobs and Strydom, 1993).

Currently most of the 1 417 hectares (OABS, 2004) of nectarine orchards in South Africa are planted at a distance of 4 x 1.5 m (Jacobs and Strydom, 1993). These trees are mostly trained sylleptically to the central leader system described by Stadler and Stassen (1985b). The main driving force behind the idea of using higher density plantings is to decrease the number of years required for the orchard to reach maximum light interception and full crop production. It has been shown that these orchards can produce relatively high yields, especially in the initial years (Leuty and Pree, 1980; Caruso et al., 1997; Marini and Sowers, 2000). However, higher densities increase the establishment cost significantly (Widmer and Krebs, 2001). The lack of a size-controlling rootstock for stone fruit (Layne, 1974) also causes a problem with higher densities and therefore summer pruning is important to control vigorous watershoots (Stadler and Stassen, 1985a). Trees require more management which increases labour cost. The Kakamas seedling rootstock has been the primary rootstock used in South Africa for many years (De Wet, 1952). This rootstock is however very sensitive to waterlogging (Stassen and Van Zyl, 1982) and susceptible to root-knot nematode infestation (Stassen and Van Zyl, 1982). There are however many questions among producers about lower density plantings, savings on plant material and labour cost, keeping trees smaller, and using alternative rootstocks.

The aim of this study is to investigate alternative training systems for peaches and compare them to the currently used central leader system. Time necessary for winter and summer pruning, fruit thinning, picking and yield would be recorded as well as yield efficiency.

The questions that required answering were:

- Should other systems with two of more leaders to fill the space and give more bearing volume be considered?
- Should a wider spacing and multiple leaders to divide the growth, limit the height of the trees and reduce planting material cost, but that would take longer to fill the allocated space and to reach breakeven point be considered?
- Which is best way to train ‘Alpine’ nectarine trees: 1) sylleptically or 2) proleptically?
- What role does the rootstock play in terms of growth, yield and fruit size?

3.2 MATERIALS AND METHODS

‘Alpine’ nectarines were planted in August 2002 at Lushof near Ceres in the Western Cape region, South Africa (33º18’S, 19º20’E), in a north-south row direction. Four different training systems were used and combined with three commercial rootstocks.

The rootstocks used were GF 677 (GF), Kakamas seedling (K) and SAPO 778 (SAPO). The training systems used were a sylleptically trained central leader (SS), a proleptically trained central leader (SP), a two-leader system (2-L) and a four-leader system (4-L). The trees where planted on a ‘Tukulu’ soil type with a gravel content of 60% and a clay content of 5 to 8%. Each rootstock was combined with each training system to form 12 rootstock-training system combinations. The two central leader systems were planted at a spacing of 5 x 1 m to give 2 000 trees per hectare. Planting density for the two-leader system was 5 x 1.5 m to give 1 333 trees per hectare. The four-leader system was planted at a density of 5 x 3 m to give 667 trees per hectare. All the trees were planted at a constant distance of five meters between the rows. The layout of the study is a complete randomized block design. Each combination was planted in plots of five trees with three repetition blocks. Only the three inside trees of each plot were monitored in the experiment.

After planting, structural pruning was carried out in the summer of 2002/2003 to train the trees according to the different systems. Trees that were to be trained sylleptically according to the central leader, as well as the two-leader and four-leader system, were cut back to more or less 20 cm from the ground immediately after planting. The trees that were to be trained proleptically were left untopped. Four shoots, two on each side of the tree trunk, were chosen for the four-leader system to become dominant. These four shoots were again cut back during the summer to form a step effect. This four-leader system was trained according to the instructions given by a French consultant, Mr Alric Charbit, who was the adviser for this commercial farm. For the two-leader system two shoots parallel to the row direction were chosen to become the dominant leaders. One shoot was chosen for the sylleptically trained central leader to become dominant. After the dominant leaders were chosen, shoots thicker than one third of the leader were removed. Shoots that formed a narrow crotch angle with the leader were removed. All thin wood on the frame shoots was removed at a scissor length from the leader. A planting done near Stellenbosch in the Western Cape, South Africa during 2004 was used to verify the first year of training. Figures 3.1 – 3.4 (Addendum A) show the four different training systems, two years after planting.

All the pruning, thinning and picking was done by farm workers of Lushof. The same techniques and methods were used on the trail trees as used in their commercial orchards. Training systems on the farm include the four-leader and a proleptically trained central leader used on older trees. For the pruning three workers were used: one worker per tree. For the thinning and picking six workers were used: two workers per tree. The purpose of the trial was to determine the most economically efficient system. Minimal pruning was done and the objective was to ensure that the desired tree shape was maintained.

In the winter of 2003 no pruning was done except for the heading cuts after planting. In the summer of 2003/2004 fruit was harvested on 9th and 13th December. The number and mass of fruit per tree were recorded. In March 2004 summer pruning was done. Minimum pruning was done to keep the desired canopy shape and to keep the leaders dominant. Shoots that competed with the leaders in thickness and position as well as watersprouts were removed. The inside of the two-leader system and the four-leader system was kept open in the middle by removing the strong growth in those areas. The pruning time per tree and mass pruned per tree were recorded.

Trunk circumference was measured in May 2004, using a standard measuring tape. In August 2004 winter pruning was done for the first time. Pruning included the removal of strong upright shoots, keeping the scaffolds to a single leader as well as keeping the overall tree shape as desired. The pruning time per tree and mass pruned per tree were recorded. In September 2004 thinning was done and only the trees on Kakamas seedlings rootstock on the different systems were recorded. Fruit were thinned to two fruit per 30 cm shoot and three fruit were left on shoots longer than 30 cm. Time per tree for this action was recorded. Summer pruning was done on 3rd November 2004, and the time per tree as well as the pruning weight per tree were recorded. Picking was done three times in December 2004. Time involved for picking per tree, the fruit per tree and mass of fruit per tree were recorded.

Summer pruning was done in April 2005 and the same type of data as for the November pruning was recorded. Trunk circumference was measured in May 2005 with a standard measuring tape. Winter pruning was done in July 2005. Tree shape was maintained, strong upright growth was removed and bearing wood was selected. Pruning time per tree and mass pruned per tree were recorded. Soil samples for root-knot nematodes were taken in August 2005.

Fruit were thinned in September 2005. Flower thinning was done first by removing the flowers on the top third of each shoot. After that fruit thinning was done when the fruit was more or less thumb-size. Two fruit on a 30 cm shoot were left. Three fruit were left on shoots that were longer than 30 cm. Time taken for fruit thinning per tree was recorded. No summer pruning was necessary in 2005. Fruit were picked three times in December 2005. Again the time picked per tree, fruit per tree and mass fruit per tree were recorded.

Irrigation and fertilization were done by the same pulsating drip system used for the commercial orchards on the same farm. Packout percentages, prodution prices, labour and plant materials cost required for any calucaltions were obtained from information gathered by Lushof farm.

A second trial was planted during 2004. For this trial ‘Alpine’ nectarines were planted in August 2004 on Kakamas seedling rootstocks at the Welgevallen Experimental farm in Stellenbosch. The trees were trained according to four different growing systems, namely a proleptically trained central leader, a sylleptically trained central leader, a two-leader system, and a KAC-V system. The KAC-V system used in this trail was developed by DeJong et al. (1994) and was discussed in Chapter 2. The trees that were to be trained according to the central leader system were planted at a distance of 4 x 1 m (2 500 trees per hectare) and the two-leader and KAC-V systems were planted at a distance of 4 x 1.5 m (1 667 trees per hectare). All the trees were planted at a distance of four meters between the rows to keep the row widths constant.

The same structural pruning was applied to the trees planted at Stellenbosch, as for the trees in the first trial planted at Ceres. After planting, the trees trained proleptically were left untopped. The trees of the other three training systems were cut back to more or less 15 cm above the ground. One shoot for the sylleptically and proleptically trained central leaders was chosen from the developing buds to become the dominant vertical leader. Two opposite shoots parallel to the row direction were chosen for the two-leader system and two opposite shoots perpendicular to the row for the KAC-V system were chosen to become the dominant scaffolds. After the frame shoots were chosen, more structural pruning was done in November 2004. All the shoots thicker than one third of the leader were removed. Shoots that formed a narrow crotch angle with the leader were also removed. All thin wood on the frame shoots was removed a scissor length from the leader.

More structural pruning was done in June 2005. Dominant leaders from the two-leader and KAC-V systems that had an incorrect growing direction were cut back to lateral shoots that formed a more appropriate angle either within or perpendicular to the row direction. All shoots thicker than one third of the leader were removed. Shoots that formed a narrow crotch angle with the scaffold were removed. Shoots that grew within the “V” of the two-leader and the KAC-V systems were also removed. The time it took to carry out structural pruning per tree was recorded each time. Figures 3.5 - 3.8 show the different tree structures for the different training systems after structural pruning.

First thinning was done during winter pruning when the necessary shoots of the correct length were selected. About ten shoots of 30 cm or longer were selected per tree. Flower thinning was done in July 2005. The top third flowers on each shoot were stripped manually when the trees were in full bloom. Fruit thinning was done when the fruit were thumb-size. One fruit per 30 cm shoot was left and each tree had more or less ten fruit on. The time it took to carry out flower and fruit thinning per tree was recorded.

The fruit was harvested in December 2005 for the first time. The time it took to pick each tree was recorded. The volume and weight of fruit on each tree were also recorded.

3.3 RESULTS AND DISCUSSION

Table 3.1 shows that up until 2003 rootstock effects were not significant. However, in both 2004 and 2005 rootstock played a significant role on fruit weight; fruit from trees grown on SAPO 778 rootstocks were significantly heavier than fruit from trees grown on GF 677 or Kakamas seedling rootstocks (Table 3.3).

In 2004 trunk circumference of trees on SAPO 778 rootstocks was significantly larger than trees on GF 677 or Kakamas seedlings (Table 3.3). In November 2004 trees on SAPO 778 also took significantly longer to prune than trees on the other rootstocks (Table 3.2). In 2005 trees on GF 677 took significantly longer to thin than trees planted on the other rootstocks.

Results from soil samples taken showed that root-knot nematode *Criconematinae* and *Meloidogyne* occured in the soil. No trees planted on SAPO 778 rootstock were affected by the nematodes. Trees planted on GF 677 and Kakamas seedling rootstock showed visual symptoms and two trees on Kakamas seedling rootstocks died.

From Table 3.4 – 3.6 it is clear that the training system effect were significant. During 2003 time spent on training the four-leader system per tree was significantly longer than time spent other systems. Because of the less dense planting of 667 trees per hectare, however, less time was spent per hectare. In 2003 the first commercial yield was picked. The four-leader system produced less fruit per tree and had fewer trees per hectare. This reduction in fruit caused the four-leader to have the lowest yield efficiency.

In both 2004 and 2005 the four-leader system took significantly longer per tree for both summer and winter pruning. Although the two central leaders took the shortest time per tree to prune there was no significant difference between them in terms of the time spent in the orchard on any pruning done. In terms of time it took per hectare to prune, the four-leader system was significantly different. The four-leader system took the least time per hectare to prune except for the March 2005 summer pruning where there were no significant difference in time between the systems. Per hectare the two central leaders took the most time to prune. Again there were no significant differences between the two central leaders. The four-leader system induced the biggest trunk circumference in both 2004 and 2005 followed by the two-leader and the two central leaders. It took significantly longer to carry out thinning per tree for the four-leader system, followed by the two-leader and the central leaders. Per hectare however the results are again inverted and the four-leader took the shortest time took prune and the two central leaders the longest time.

In 2004 and 2005 the four-leader system took a significantly longer time to pick, but that is because it produced the most fruit per tree and thus the most fruit weight per tree. It also gave the best yield efficiency (mass of fruit (kg) per centimeter (cm) trunk circumference). The two central leaders took the least time to pick per tree and also gave the least fruit per tree and total fruit weight per tree, as well as the lowest yield efficiency.

The two-leader and the central leader produced more fruit (ton) per hectare than the four-leader in 2004 by a significant margin. In 2005 however there was no significant difference in fruit (ton) produced per hectare between the different training systems.

Table 3.7 shows that tree training in 2004 and 2005 took significantly longer per tree for the two systems with more than one dominant leader on the Welgevallen farm at Stellenbosch. The two central leader systems took longer to train per hectare, and the two-leader system took the least time. Thinning the proleptically trained central leader took significantly longer per tree as well as per hectare than any of the other systems. Similar results were seen for the winter and summer pruning, where the two central leader systems took significantly longer per tree and per hectare. The sylleptically trained central leader and the two-leader system took longer to pick but also gave higher yield per hectare by a significant margin than the KAC-V and proleptically trained central leaders.

2.4 CONCLUSIONS

Results showed that fruit weight is influenced by rootstocks. Indications are that fruit from trees on GF 677 rootstocks were smaller. However, one has to keep in mind that the amount of fruit per tree also plays a role. Although the difference was not significant, GF 677 rootstocks produced 143 fruit per tree in 2004 in comparison with

SAPO 778 which produced 129 fruit per tree. In 2005 GF 677 produced 176 fruit per tree and SAPO 778 rootstocks produced 158 fruit per tree. Trees on Kakamas seedling rootstocks had more or less the same amount of fruit production per tree as SAPO 778 but there was a significant difference in fruit weight between the two rootstocks. It can thus be said that the SAPO 778 rootstock produced larger fruit than Kakamas seedling rootstocks, but one has to be careful to presume that GF 677 produces smaller fruit, because it can be due to the fact that it bore more fruit per tree. These findings are in accordance with those of Lötze (1997) who found that SAPO 778 as rootstock induces better fruit size than Kakamas seedling rootstock.

The fact that it took longer to summer prune the trees on SAPO 778 rootstocks in 2004 is because there were more strong shoots to be removed than in the case of the other two rootstocks. This, and the fact that SAPO 778 had the biggest trunck circumference, can be due to the more vigorous growing habit of the SAPO 778 rootstock.

The reason for the overall poor fruit weight might be that the trees bore too much fruit in their second year of bearing overall. In the first year after planting (2003) the trees had an average yield of 2.2 ton per hectare. In the second year of bearing the trees produced an average yield of more than 15 ton per hectare. There might have been too much fruit left on the trees after thinning in 2004. That might explain the lower yield of 19 ton per hectare in their third year of bearing.

Thinning and picking costs for 2003 were not recorded and had to be calculated by using the results from 2004 and multiplying by the factor of yield for 2003 over the yield for 2004 for each specific system.

Tables 3.8 – 3.10 showed the total time needed for training, pruning, thinning and picking per hectare for the different rootstocks and training systems during each year, as well as the accumulated yield from 2003 to 2005. Only the initial period of the ‘Alpine’ nectarine orchard, from planting in 2002 until the third yield, was recorded. Any conclusions are therefore only focusing on this specific period. Trees planted on GF 677 rootstocks required the most labour accumulated from 2002 to 2005, although the difference between the rootstocks was not significant. No significant difference was found between the accumulated yields of the different rootstocks. Significant differences were however found between the different training systems. Throughout the entire experiment, the four leader systems required the least labour annually. Thus the total labour required from 2002 to 2005 was also significantly less for the four-leader system than the other systems. No significant differences were found in the labour required between the other system. However, the two-leader system required the most total labour accumulated from 2002 to 2005. Accumulated yield for the four-leader system was significantly less than for the other systems. The two-leader system had the highest accumulated yield from 2003 to 2005, but not by a significant margin. Looking at the results from the labour required during the first two years after planting for the trees planted at the Welgevallen Experimental farm in Stellenbocsh, one can see that the proleptically trained central leader needed the most labour, followed by the sylleptically trained central leader, the two-leader and the KAC-V system. No significant difference was however found between the two-leader and the KAC-V.

In conclusion, the four-leader system required the least amount of time spent in the orchard, but also produced the lowest yield per hectare over the first two years of bearing. On the other hand the two-leader system required the most time spent in the orchard, but also produced the highest accumulated yield. Comparing the accumulated yield of the two-leader system with that of the four-leader system, one can see that the two-leader system produced 11.17 ton/ha more than the four-leader system over a four year period from planting. This means that with a packout percentage of 50 percent first class, 35 percent second class and 15 percent third class and with a price of R10 000 per ton for first class, R4 000 per ton for second class and R500 per ton for third class, the two-leader system had an income of R72 325 per hectare more than the four-leader system four years after planting. These packout percentages were taken from the average on the farm, because trees from the trail were affected by root-knot nematodes and therefore produced smaller fruit. If labour cost is calculated at R7 per hour then the two-leader system would have only required R2 733 per hectare more in labour cost than the four-leader system over the first four years after planting. One should however keep in mind that the two-leader system had a higher planting density, and plant material cost would be R9 990 per hectare more than for the four-leader system if the cost per tree is calculated at R7.

The choice of training system and rootstock should however be based on the factors that are most influential on a specific farm, and all the advantages as well as disadvantages for a specific training system and rootstock on that farm should be taken in account. For most producers it is important to get an early return on their investment. On the other hand, labour cost is becoming a factor to take into account.

3.5 REFERENCES

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ADDENDUM A

Figure 3.1: A four-leader system planted at Lushof farm near Ceres after structural pruning. Note the two leaders to the left side and the two leaders to the right side.

Figure 3.2: A two-leader system planted at Lushof farm near Ceres after structural pruning. Note the leaders within the row direction.

Figure 3.3: A proleptically trained central leader system planted at Lushof farm near Ceres after structural pruning.

Figure 3.4: A sylleptically trained central leader system planted at Lushof farm near Ceres after structural pruning.

Figure 3.5: A sylleptically trained central leader system planted at Welgevallen Experimental farm in Stellenbosch after structural pruning.

Figure 3.6: A two-leader system planted at Welgevallen Experimental farm in Stellenbosch after structural pruning.

Figure 3.7: A proleptically trained central leader system planted at Welgevallen Experimental farm in Stellenbosch after structural pruning.

Figure 3.8: A KAC-V system (DeJong, 1999) planted at Welgevallen Experimental farm in Stellenbosch after structural pruning.

ADDENDUM B

Table 3.1: The effect of rootstock on tree training, trunk circumference and yield in 2003 for 'Alpine' nectarines at the Lushof farm near Ceres

	Tree Training		**TC 2003**	**Yield 2003**			
	Time/tree	Time/ha		Fruit/tree	Kg/tree	Efficiency	Ton/ha
Rootstock	*(sec)*	*(hours)*	*(mm)*		*(kg)*	*(kg/cm)*	*(ton)*
SAPO 778	74.76	27.26	134.3	26.67	3.03	0.239	2.0546
Kakamas	70.34	24.01	129.7	26.50	2.76	0.237	2.0246
GF 677	68.32	22.81	129.4	22.75	2.63	0.220	2.4851
	NS	NS	NS	NS	NS	NS	NS
Source							
Rootstock	0.4291	0.1357	0.1402	0.7605	0.8139	0.9214	0.2179
System	<0.0001**	0.0062**	<0.0001**	0.0024**	0.0013**	0.0002**	<0.0001**
Combo	0.2186	0.2354	0.0104*	0.6302	0.5746	0.7625	0.5210

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.2: The effect of rootstock on summer pruning and winter pruning in 2004 and 2005 for 'Alpine' nectarines at the Lushof farm near Ceres

	Summer pruning 2004 (Mar)			**Winter pruning 2004**			**Summer pruning 2004 (Nov)**		
Rootstock	Time/tree *(sec)*	Mass/tree *(kg)*	Time/ha *(hours)*	Time/tree *(sec)*	Mass/tree *(kg)*	Time/ha *(hours)*	Time/tree *(sec)*	Mass/tree *(kg)*	Time/ha *(hours)*
SAPO 778	220	3.13	85.226	81.94	0.537	35.767	98.39a	0.256	35.409a
Kakamas	202	2.86	72.760	96.58	0.576	33.639	69.96b	0.240	26.355b
GF 677	114	2.64	77.362	104.39	0.531	36.041	80.42ab	0.207	29.950ab
	NS	NS	NS	NS	NS	NS		NS	
Source									
Rootstock	0.3808	0.4420	0.2829	0.3052	0.7956	0.8298	0.0208*	0.1349	0.0301*
System	0.0002**	<0.0001**	0.0002**	0.0002**	0.0496*	0.0657	<0.0001**	<0.0001**	0.0359*
Combo	0.6745	0.4638	0.2627	0.0601	0.9610	0.0509	0.1252	0.3478	0.7454

Rootstock	**Summer pruning 2005 (Mar)**			**Winter pruning 2005**		
SAPO 778	182.94	2.14	66.669	202.64	1.21	70.605
Kakamas	163.08	1.98	62.635	189.36	1.14	68.386
GF 677	156.78	1.85	58.915	178.64	1.03	71.061
	NS	NS	NS	NS	NS	NS
Source						
Rootstock	0.376	0.2114	0.1958	0.5796	0.4012	0.9222
System	<0.0001**	0.006**	0.7216	<0.0001**	<0.0001**	0.0224*
Combo	0.3682	0.1631	0.4501	0.2753	0.3201	0.2092

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.3: The effect of rootstock on trunk circumference (TC), time spent of thinning and yield parameters in 2004 and 2005 for 'Alpine' nectarines at the Lushof farm near Ceres

	TC	**Thinning**		**Yield**						
	2004	**2004**		**2004**						
		Time/tree	Time/ha	Time/tree	Time/ha	Fruit/tree	Mass/tree	Mass/fruit	Efficiency	Ton/ha
Rootstock	*(mm)*	*(sec)*	*(hours)*	*(sec)*	*(hours)*		*(kg)*	*(g)*	*(kg/cm)*	
SAPO 778	214.6a			287.72	111.51	128.94	12.57	97.49a	0.0585	17.230
Kakamas	201.3b	376.1	144.1	244.72	96.01	117.69	11.40	96.86a	0.0573	14.978
GF 677	200.6c			295.97	109.02	142.86	11.80	82.60b	0.0557	15.388
				NS	NS	NS	NS		NS	NS
Source										
Rootstock	0.0266*			0.1098	0.3058	0.182	0.4822	0.042*	0.7894	0.2418
System	<0.0001**	0.0097**	0.0199*	<0.0001**	0.0004**	.<0.0001**	<0.0001**	0.7239	0.01*	0.002**
Combo	0.0171*			0.5306	0.3581	0.4645	0.8240	0.9582	0.2931	0.6217
	TC	**Thinning**		**Yield**						
Rootstock	**2005**	**2005**		**2005**						
SAPO 778	249.08	192.42	67.231b	483.11	171.58	158	16.088	101.8a	0.0612	19.636
Kakamas	234.22	205.03	76.154ab	444.11	163.02	155	15.319	98.8b	0.0598	19.582
GF 677	227.50	235.61	87.256a	491.67	177.46	176	14.243	80.9b	0.0681	18.387
	NS	NS		NS	NS	NS	NS		NS	NS
Source										
Rootstock	0.1922	0.1415	0.0096**	0.4782	0.6251	0.2886	0.3814	<.0001**	0.4781	0.6087
System	<0.0001**	<.0001**	0.0027**	<.0001**	0.0147*	<.0001**	<.0001**	0.4623	0.0003	0.2646
Combo	0.1656	0.6077	0.2852	0.2219	0.4419	0.1184	0.1592	0.2388	0.2917	0.2352

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.4: The effect of training system on tree training, trunk circumference and yield in 2003 for 'Alpine' nectarines on the Lushof farm near Ceres

Training system	**Tree Training**		**TC 2003**	**Yield 2003**			
	Time/tree *(sec)*	Time/ha *(hours)*	*(mm)*	Fruit/tree	Mass/tree *(kg)*	Efficiency *(kg/cm)*	Ton/ha *(ton)*
Four leader	134.92a	24.997a	159.1a	7.44b	0.81b	0.05b	0.53b
Two leader	50.49b	18.693b	140.1b	35.56a	3.88a	0.28a	2.52a
Proleptic central leader	49.27b	27.373a	116.1c	26.56a	3.01a	0.26a	3.09a
Sylleptic central leader	49.86b	27.700a	106.0d	31.67a	3.52a	0.35a	2.61a

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.5: The effect of training system on summer pruning and winter pruning in 2004 and 2005 for 'Alpine' nectarines at the Lushof farm near Ceres

Training system	Summer pruning 2004 (Mar)			Winter pruning 2004 (Aug)			Summer pruning 2004 (Nov)		
	Time/tree *(sec)*	Kg/tree *(kg)*	Time/ha *(hours)*	Time/tree *(sec)*	Mass/tree *(kg)*	Time/ha *(hours)*	Time/tree *(sec)*	Mass/tree *(kg)*	Time/ha *(hours)*
Four leader	260a	4.64a	49.131b	145.00a	0.646a	28.635	132.41a	0.351a	24.53b
Two leader	235a	3.02b	83.148a	98.48b	0.588a	36.466	79.10b	0.203b	29.30ab
Proleptic central leader	183b	2.01c	94.897a	76.96c	0.555ab	42.449	52.74c	0.171b	32.90a
Sylleptic central leader	157b	1.85c	86.501a	56.78c	0.404b	33.046	67.44bc	0.212b	35.56a
						NS			
Training system	**Summer pruning 2005 (Apr)**			**Winter pruning 2005 (Jul)**					
Four leader	241.7a	3.10a	44.78	287.8a	1.32a	53.319b			
Two leader	172.7b	2.22b	63.93	194.7b	1.16b	72.081a			
Proleptic central leader	128.7b	1.73b	70.76	141.4bc	0.97c	76.111a			
Sylleptic central leader	127.4b	1.98b	71.48	137.0c	0.98c	78.559a			

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.6: The effect of training system on trunk circumference (TC), time spent on thinning and yield parameters in 2004 and 2005 for 'Alpine' nectarines at the Lushof farm near Ceres

Training system	TC 2004	Thinning 2004		Yield 2004						
		Time/tree	Time/ha	Time/tree	Time/ha	Fruit/tree	Mass/tree	g/fruit	Efficiency	Ton/ha
	(mm)	*(sec)*	*(hours)*	*(sec)*	*(hours)*		*(kg)*	*(g)*	*(kg/cm)*	
Four leader	267.1a	438.1a	81.2a	361.09a	66.89b	188.59a	17.271a	91.58	0.065a	11.52b
Two leader	220.8b	524.9a	194.4b	315.44a	116.8a	143.70b	13.500b	93.95	0.061a	18.00a
Proleptic central leader	166.7c	252.9b	140.0b	218.52b	121.4a	84.81c	8.509c	100.33	0.051b	17.02a
Sylleptic central leader	167.6c	288.5b	160.2b	209.59b	116.96a	92.22c	8.463c	91.77	0.051b	16.93a
								NS		
Training system	**TC 2005**	**Thinning 2005**		**Yield 2005**						
Four leader	309.5a	326.8a	60.551b	718.8a	133.17b	277.0a	26.13a	94.33	0.089a	17.43
Two leader	247.0b	218.0b	80.735a	496.5b	183.85a	164.7b	15.10b	91.68	0.061b	20.13
Proleptic central leader	200.2c	161.7c	89.814a	339.0c	187.55a	106.4c	10.20c	95.86	0.053b	20.40
Sylleptic central leader	191.1c	137.6c	76.420a	337.6c	178.18a	103.9c	9.43c	90.76	0.048b	18.85
								NS		NS

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.7: The effect of training system on tree training, summer and winter pruning, trunk circumference, thinning and yield in 2004 and 2005 for 'Alpine' nectarines at the Welgevallen Experimental farm in Stellenbosch

Training system	**Tree training 2004 & 2005** Time/tree *(sec)*	Time/ha *(hours)*	**Thinning 2005** Time/tree *(sec)*	Time/ha *(hours)*	**Summer pruning 2005** Time/tree *(sec)*	Time/ha *(hours)*
KAC-V	45.5a	21.06	174.9c	80.99c	74.8b	34.64c
Two leader	42.5ab	19.66	198.1bc	91.74c	79.0b	36.60c
Proleptic central leader	35.4bc	24.60	304.3a	211.31a	91.5a	68.16a
Sylleptic central leader	34.1c	23.66	218.6b	151.79b	73.1b	50.79b
		NS				
P-values	0.0117*	0.0634	<0.0001**	<0.0001**	0.0001**	<0.0001**

Training system	**TC 2005** *(mm)*	**Yield 2005** Time/tree *(sec)*	Fruit/tree	Mass/tree *(kg)*	Mass/fruit *(g)*	Time/ha *h/ha*	Ton/ha *(ton)*	Efficiency *(kg/cm)*
KAC-V	86.02	59.0	13	1.469	0.114	27.33b	2.447b	0.0107
Two leader	87.44	55.3	9	1.085	0.117	41.67a	3.094ab	0.0113
Proleptic central leader	86.04	60.0	11	1.239	0.111	24.58b	1.738c	0.0100
Sylleptic central leader	84.88	62.3	11	1.294	0.113	43.24a	3.234a	0.0107
	NS	NS	NS	NS	NS			NS
P-values	0.3853	0.5666	0.0598	0.0549	0.4638	<0.0001**	0.0014*	0.5368

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.8: Total training, pruning, thinning and picking time per hectare and accumilated yield from 2002 to2005 for each rootstock used on 'Alpine' nectarines at Lushof farm near Ceres

	Year			Total	Accumulated
	2002-2003	**2004**	**2005**	**2002-2005**	**Yield**
	Total labour	Total labour	Total labour		2003-2005
Rootstock	*(h/ha)*	*(h/ha)*	*(h/ha)*	*(h/ha)*	*(ton/ha)*
SAPO 778	63.43	409.68	376.09	849.2	37.9
Kakamas	61.52	366.52	370.75	831.84	35.45
GF 677	58.23	396.33	402.29	856.85	37.45
	NS	NS	NS	NS	NS
Source					
Rootstock	0.4671	0.9149	0.5664	0.9021	0.5628
System	<0.0001**	<0.0001**	0.0036*	<0.0001**	0.0006**
Combo	0.3135	0.3736	0.5222	0.3624	0.6029

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.9: Total training, pruning, thinning and picking time per hectare and accumilated yield from 2002 to2005 for each training system used on 'Alpine' nectarines at Lushof farm near Ceres

	Year			Total	Accumulated
	2002-2003	**2004**	**2005**	**2002-2005**	**Yield**
Training	Total labour	Total labour	Total labour		2003-2005
system	*(h/ha)*	*(h/ha)*	*(h/ha)*	*(h/ha)*	*(ton/ha)*
Four leader	31.81b	250.38b	291.83b	574.02b	29.48b
Two leader	67.35a	496.13a	400.97a	964.46a	40.65a
Proleptic central leader	74.14a	427.90a	438.27a	940.31a	40.41a
Sylleptic central leader	71.00a	432.96a	401.11a	905.07a	38.41a

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

Table 3.10: Total training pruning, thinning and picking time per hectare from 2004 to 2005 for each training system used on 'Alpine' nectarines at Welgevallen Experimental farm in Stellenbosch

	Year 2004-2005
Training system	Total labour *(h/ha)*
KAC-V	139.42c
Two leader	150.45c
Proleptic central leader	308.24a
Sylleptic central leader	230.56b
P-value	<0.0001*

Means within columns with the same letter do not differ significantly at P=0.05 (LSD)

CHAPTER IV

THE ROLE OF LIGHT DISTRIBUTION IN THE LOWER CANOPY OF FOUR DIFFERENT TRAINING SYSTEMS USED FOR 'ALPINE' NECTARINES

Abstract

Light penetration into the tree canopy was evaluated for four different training systems for nectarine (*Prunus persica var. nectarina*) orchards. 'Alpine' nectarines were planted in the winter of 2002 and the trees where trained to four different training systems, namely a four-leader system (5 x 3 m; 667 trees/ha), a two-leader system (5 x 1.5 m; 1 333 trees/ha), a proleptically trained central leader (5 x 1 m; 2 000 trees/ha) and a sylleptically trained central leader (5 x 1 m; 2 000 trees/ha). Light measurements where taken with a single point quantum sensor (LI-189, LI-COR, Nebraska, USA) after summer pruning in 2004 and 2005 at different heights and at different depths in the canopy. In 2006 an AccuPAR Linear Ceptometer, Model LP-80 (Decagon Devices, Pullman, Washington USA) was used to make measurements at different heights at different depths in the canopy. Results show that poor light penetration occurred at the bottom (0.5 – 1.5 m) in the middle (0 – 100 cm) of the central leader trees. Because of the open centre of the four-leader system, poor light penetration occurred at a height of 1.0 to 1.5 m, 60 to 100 cm vertical from the tree trunk where the dominant leaders stretch out.

4.1 INTRODUCTION

Photosynthesis is the process by which a plant uses water and CO_2 to produce carbohydrates and releases O_2. For this process to take place, the plant relies on the energy of the sun (light). The amount of carbohydrates that the plant produces is thus to an extent dependent on the amount of light it absorbs (Ksenzhek, 1998). Research has shown that the amount of fruit per tree is linearly correlated to the amount of light it intercepts (Robinson and Lakso, 1989). The effect of light on fruit quality is also evident. It has been shown that a light interception of 70 percent of full sunlight is optimum for a mature orchard (Jackson and Palmer, 1972). Light penetration into the canopy is just as vital for a tree to be efficient. Using Beer's Law of light attenuation, Johnson and Lakso

(1991) showed how light levels decreases as light is distributed deeper into the tree canopy. Cain (1972) stated that the minimum threshold for photosynthesis is 30 percent of full sunlight. The effect of this decrease in light levels into the tree canopy therefore has a significant effect on fruit production. Heinicke (1966) found that fruit size and colour of two apple cultivars were correlated with the degree of exposure of sunlight. Caruso et al. (1998) found that fruit from the upper part of a ‘Spring Lady’ peach tree trained to a central leader were larger in size than fruit from the lower part of the same canopy.

Tree shape and size will determine light interception and penetration. Although the traditional open-vase system has a high light interception because of the big canopy, light distribution to the inner and lower parts is often poor (Looney, 1991). Cain (1972) suggested that a pyramidal tree shape would result in better light interception, with more even light distribution. Robinson et al. (1991) however pointed out that such a system also receives insufficient light in the lower inner parts of the canopy if the necessary care is not taken. Changes in training system design have been made to accommodate better light penetration within the canopy.

The aim of this study is to examine light interception and distribution of different training systems used for peach trees. The author would like to observe the uniformity of light distribution and point out any problem areas regarding shading within the different tree canopies.

4.2 MATERIALS AND METHODS

An experimental ‘Alpine’ nectarine orchard was planted in August 2002 at Lushof near Ceres in the Western Cape region, South Africa (33º18’S, 19º20’E), in a north-south row direction. The trees were trained according to four different orchard systems. The training systems used were a sylleptically trained central leader (SS), a proleptically trained central leader (SP), a two-leader system (2-L) and a four-leader system (4-L). The two central leader systems were planted at a spacing of 5 x 1 m to give 2 000 trees per hectare. Planting density for the two-leader system was 5 x 1.5 m to give

1 333 trees per hectare. The four-leader system was planted at a density of 5 x 3 m to give 667 trees per hectare. The trees where planted on a Tukulu soil with a gravel content of 60 percent and a clay content of five to eight percent. All the trees were planted at a distance of five meters to keep the row widths constant. The layout of the study is a complete randomized block design. Each training system was planted in plots of five trees with three replicated blocks. Only the inside three trees planted on Kakamas seedling rootstock of each plot was monitored in the experiment. Trees planted on other rootstocks were not monitored during this experiment. This was done to keep the measuring time as short as possible so that the angle of the sun at the beginning of the measurements did not differ from the angle at the end of the measurements.

All the necessary pruning was done by the farm workers of Lushof. Pruning was kept to a minimum and work was mainly done to ensure that the desired tree shape was maintained. After pruning was done in March 2004, light measurements were taken using a light meter with a quantum sensor (LI-189, LI-COR, Nebraska, USA). This light meter uses a single point sensor to measure photosynthetically active radiation (PAR) in $\mu mol.s^{-1}.m^{-2}$ photon units. The measurements were taken at a height of 0.5 m, vertical with the tree trunk (0 cm) as well as 30 cm and 60 cm from the trunk. These measuring points where only used to develop a protocol for future light measurements. An aluminium frame was used to obtain the exact measuring points in the tree. Measurements were taken at noon, on a cloudless day. The quantum light meter was held on the outside, above the tree canopy, to measure the maximum available light.

After the November summer pruning in 2004 light measurements were taken with the same quantum meter as before. The measurements were taken at three different heights from the ground, namely 0.5 m, 1.0 m and 1.5 m, at different depths in the tree canopy namely 0 cm, 20 cm, 40 cm, 60 cm, 80 cm 100 cm and 120 cm vertical from the tree trunk. An aluminium frame with the marked measuring points was placed in the tree canopy in an east-west direction in order to mark the exact measuring points. Measurements were taken at noon, on a cloudless day. The quantum light meter was also held on the outside, above the tree canopy, to measure the maximum available light.

Post-harvest summer pruning was done in April 2005 and light measurements were again taken with the same quantum meter as before, and the same method was used as in the November 2004 light measurements.

In February 2006 light measurements were taken after post-harvest summer pruning, only on trees planted on Kakamas seedling rootstocks. This was to keep the measuring time as short as possible so that the angle of the sun at the beginning of the measurements did not differ from the angle at the end of the measurements. The measurements were made by using an AccuPAR Linear Ceptometer, Model LP-80 (Decagor Devices, Pullman, Washington USA). The AccuPAR light meter is a linear ceptometer consisting of an integrated probe and microcontroller. The probe is about 90 cm long and contains 80 photodiodes that are sensitive to the PAR waveband. The microcontroller allows the PAR to be measured in segments along the length of the probe. The light measurements were made at three heights, namely 0.5 m, 1.0 m and 1.5 m above the ground and the one end of the probe was held in the centre of the tree canopy with the other end stretching out to the east side of the canopy. Measurements were taken at noon, on a cloudless day. The probe was held on the outside, above the tree canopy, to measure the maximum available light.

All the measurements were taken in an east-west direction, perpendicular to the row orientation. Shading from adjacent trees would thus not influence on the measurements. Only the basal part of the tree canopy, up to 1.5 m from the ground, was measured for light distribution because that is the section where light penetration and distribution is the most limited and problematic. The data was not statically analyzed because of the different methods and instruments used during the measurements. The results should thus be used to identify different problem areas with in the canopy for each training system and not to compare the different training systems in terms of light interception and distribution.

4.3 RESULTS AND DISCUSSION

As previously mentioned (in section 4.2), the results gathered from the first light measurements were not intended to be used to compare the different systems but to become familiar with the equipment and strategies. Nonetheless, the results that were obtained did give an indication of the different light regimes within the trees.

Table 4.2 shows that the light penetration of the four-leader system was higher than that of the other systems at 0 cm. At 60 cm the proleptically and sylleptically trained central leader had a higher light penetration than the four-leader system. The two-leader system had a similar light interception pattern to the central leaders, but with less interception to the outside of the tree.

From the different points of measurement used in the second light measurement (Tables 4.3 and 4.4) the tree could be divided in different quadrants to form a grid system. The results taken with the point sensor meter provided a very negative view of the light distribution within the canopy. In 2005 the average maximum available light measured with the quantum light sensor was more or less 1 800 $\mu mol.s^{-1}.m^{-2}$ PAR. This means that any part of the tree canopy that received less that 540 $\mu mol.s^{-1}.m^{-2}$ PAR would receive less that 30 percent of the available light. Thus any position in the tree that received less than 540 $\mu mol.m^{-2}.s^{-1}$ PAR was not receiving sufficient light. According to the results in Table 4.4, many parts in the tree received less than 540 $\mu mol.s^{-1}.m^{-2}$ PAR. It seems that only a small part of the tree canopy received sufficient light for any of the training systems. This is because the quantum light meter is affected by shaded spots in the tree canopy. Because the quantum light meter has a single point sensor the measurement can be influenced if the point of measurement is directly in a shaded spot under a branch or a leaf. In an attempt to overcome this potential problem, the light measurements for 2006 were taken with a linear ceptometer. Using the different points of measurement taken with the linear meter, the tree could be divided in to different quadrants to form a grid system. The different growing systems had different light penetration characteristics within the grid. The layout and distribution of branches for the different systems within the grid are illustrated in Figures 4.1 – 4.4 (Addendum A).

Because of different layouts, the different systems also had different light interception and distribution within the grid as illustrated by Figures 4.5 – 4.8 (Addendum B).

The light measurement results for 2006 (Figures 4.5 - 4.8) taken with the linear ceptometer show that the light penetration patterns correspond with those of the growing patterns of the different training systems. The four-leader system again had the highest light penetration in the top part of the tree in the middle of the canopy. The light penetration decreased towards the outer parts of the tree canopy. The sylleptically trained central leader had the lowest light penetration at the bottom, in the middle of the tree canopy. The proleptically trained central leader had overall good light penetration, with the middle of the tree canopy receiving the least amount of light. The two-leader system received the highest amount of light at the outer side of the tree canopy. It must be mentioned that the height of 1.5 m was only the bottom 50% of the two-leader and two central leader systems.

4.4 CONCLUSIONS

Problems were encountered with the quantum light, hence in 2006 a linear ceptometer that can continuously measure PAR in segments along the length of the probe was used instead for the light measurements. The average maximum available light measured with the ceptometer was approximately 1 000 $\mu mol.m^{-2}.s^{-1}$ PAR. Thus any part of the tree canopy that receives less than 300 $\mu mol.m^{-2}.s^{-1}$ PAR will receive less than 30% of the maximum available light. In Figures 4.5 - 4.8 the areas in the tree canopy that receive less than 30% full sunlight are represented by the black ‘spots’. The results show that very few parts of the tree canopy receive insufficient light, except for the four-leader system that receives insufficient light in the outer and upper parts of the canopy directly underneath the leaders of the tree. This is because of the more vertical angle of the leaders that make it difficult for the incoming light to reach underneath them. Light penetration is still however possible in the bottom (less than 0.5 m from the ground), from under the leader, to the inside (75 to 105 cm vertical from the tree trunk) of the canopy. The two-leader system also receives insufficient light the area 1.0 to 1.5 m from the ground and 0 to 15 cm vertical from the trunk of the tree canopy. This may be because the middle of the ‘V’ of the two-leader system was not kept open enough during summer pruning. Light penetration to the lower and inner parts of the canopy underneath the structural branches is however sufficient. Light penetration for the proleptically trained central leader seems to be sufficient throughout the whole of the canopy, even in the basal part of the tree. The sylleptically trained central leader however received insufficient light in the area 0.5 to 1.0 m from the ground and 0 to 30 cm vertical from the tree trunk.

The results show that problem areas can occur in the canopy for any of the systems used in this trail. Caution should be taken when pruning the four-leader system so that the bearing branches on the angled dominant leaders do not cause overshadowing of the lower parts of the canopy. The inside of the ‘V’ of the two-leader system should receive special attention. If excessive growth in this area is not removed it can cause overshadowing of the inner parts of the canopy. Fochessati (1981) advised that strong branches must be avoided when training trees to a central leader system as those branches easily develop at the lower parts (1 to 1.8 m from the ground) of the canopy. This can be seen in the results from the sylleptically trained central leader. Vigorous shoots in the basal parts of the canopy should thus be removed as soon as possible before it becomes a problem.

Each training system has different problem areas regarding light penetration within the tree canopy because of the different growing habits. Special attention should thus be given to these areas, especially when doing summer pruning, so that the tree can be fully efficient when it comes to light utilization.

4.5 REFERENCES

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ADDENDUM A

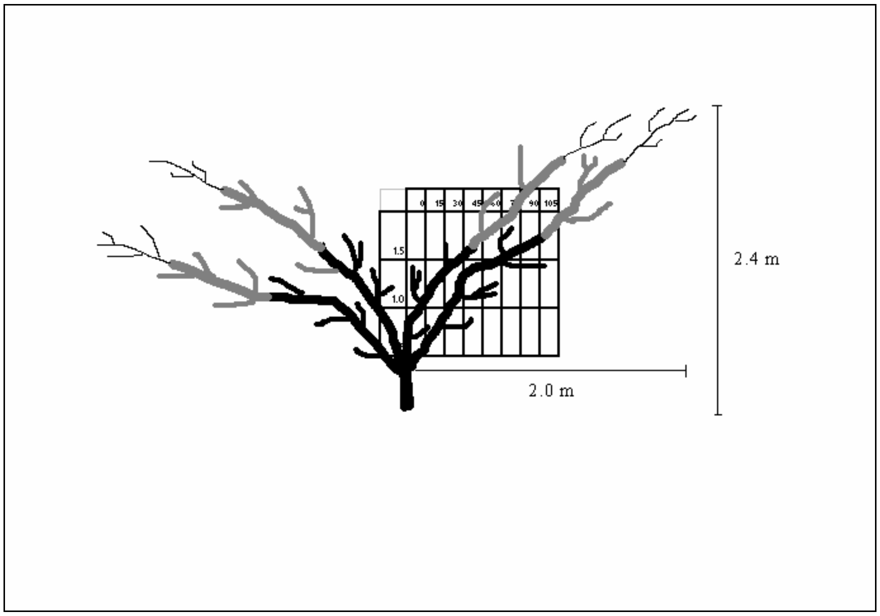

Figure 4.1: A schematic representation of the grid layout for the four-leader system. The grey lines represent the lengthening of the leaders from 2004 to 2005, and the thin lines represent the lengthening from 2005 to 2006.

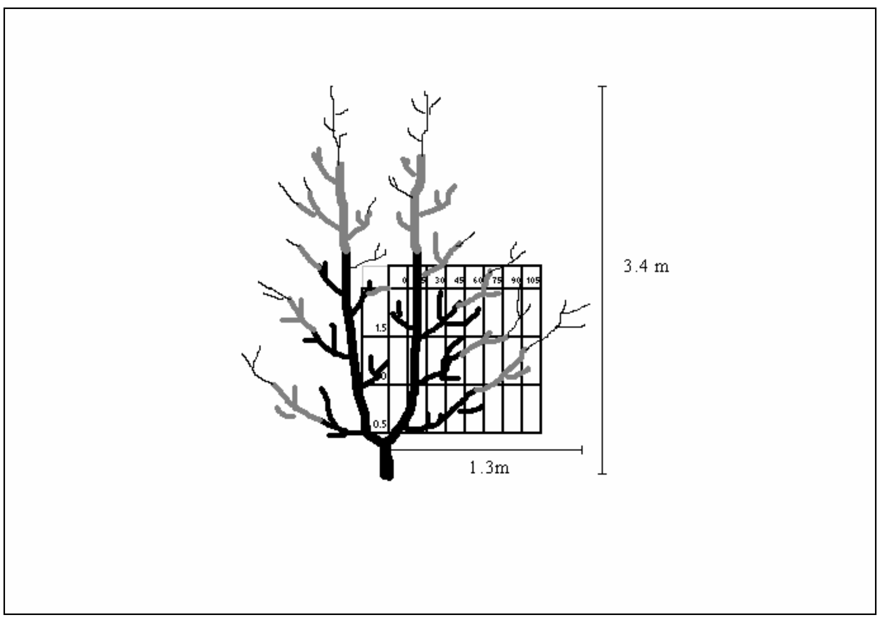

Figure 4.2: A schematic representation of the grid layout for the two-leader system. The grey lines represent the lengthening of the leaders from 2004 to 2005, and the thin lines represent the lengthening from 2005 to 2006.

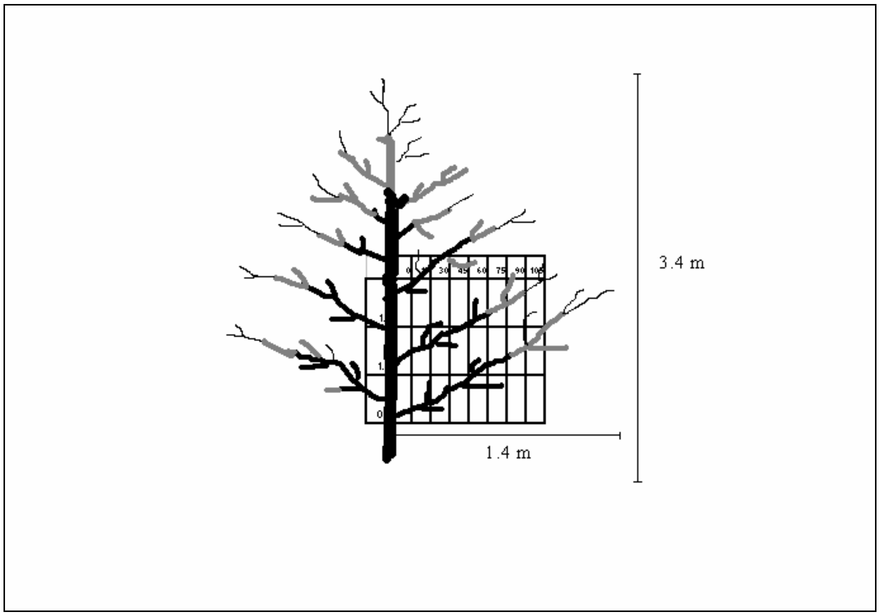

Figure 4.3: A schematic representation of the grid layout for the proleptically trained central leader system. The grey lines represent the lengthening of the leaders from 2004 to 2005, and the thin lines represent the lengthening from 2005 to 2006.

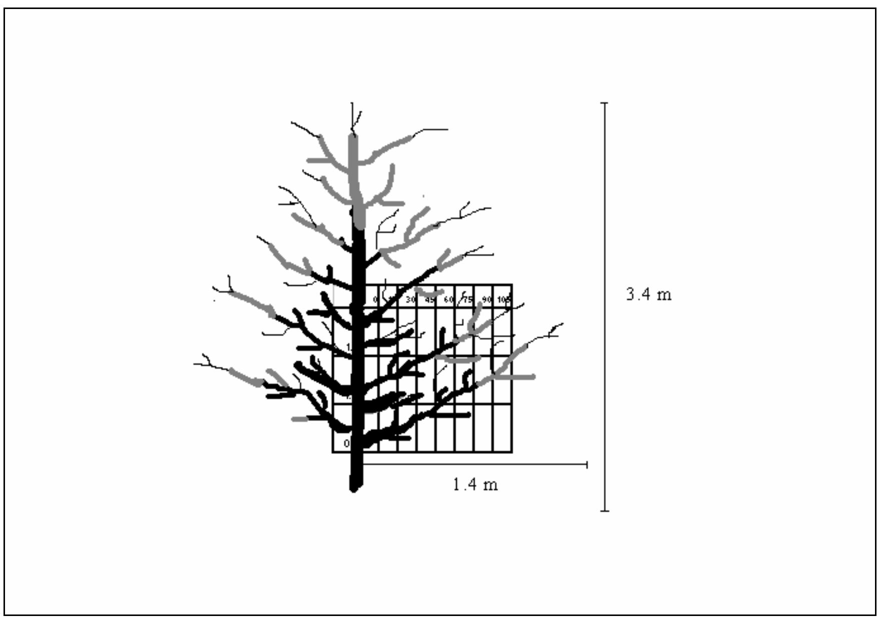

Figure 4.4: A schematic representation of the grid layout for the sylleptically trained central leader system. The grey lines represent the lengthening of the leaders from 2004 to 2005, and the thin lines represent the lengthening from 2005 to 2006.

μ mol.s^{-1}.m^{-2}				
0-200	201-400	401-600	601-800	801-1000

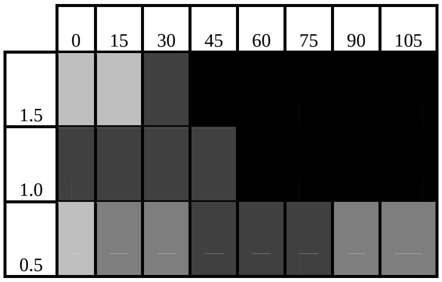

Figure 4.5: Light penetration within the measuring grid for the four-leader system after summer pruning for 2006 on 'Alpines' at the Lushof farm in Ceres.

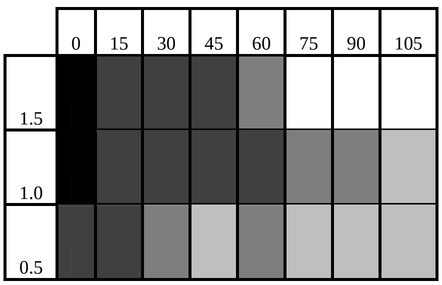

Figure 4.6: Light penetration within the measuring grid for the two-leader system after summer pruning for 2006 on 'Alpines' at the Lushof farm in Ceres.

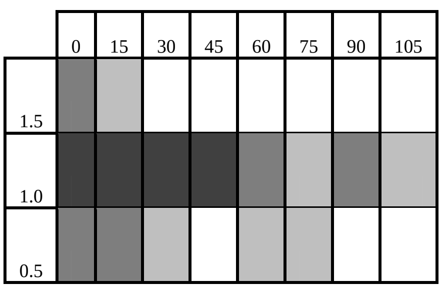

Figure 4.7: Light penetration within the measuring grid for the proleptic central leader after summer pruning for 2006 on 'Alpines' at the Lushof farm in Ceres.

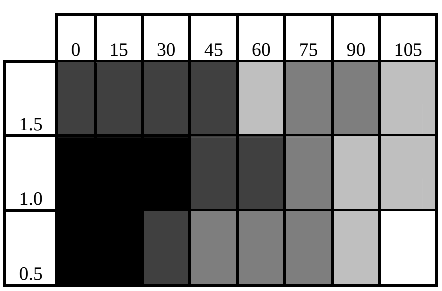

Figure 4.8: Light penetration within the measuring grid for the sylleptic central leader after summer pruning for 2006 on 'Alpines' at the Lushof farm in Ceres.

ADDENDUM B

Table 4.1: Effect of rootstock on light penetration (µ mol.m^{-2}.s^{-1}) at a height of 0.5 m above the ground in May 2004 for 'Alpine' nectarines at Lushof farm, Ceres after summer pruning

Rootstock	Distance vertical from the trunk (cm)		
	0	30	60
SAPO 778	323.5	587.5	939.7
Kakamas	482.0	623.3	935.2
GF 677	489.5	547.4	897.5

Table 4.2: Effect of training system on light penetration (µ mol.m^{-2}.s^{-1}) at a height of 0.5m above the ground in May 2004 for 'Alpine' nectarines at Lushof farm, Ceres after summer pruning

Training system	Distance vertical from the trunk (cm)		
	0	30	60
Four leader	1121.5	624.8	593.1
Two leader	196.1	390.3	743.3
Proleptic central leader	219.0	690.0	1232.9
Sylleptic central leader	190.1	639.3	1127.2

Table 4.3: Effect of training systems on light measurements (μmol.m^{-2}.s^{-1}) for November 2004 after summer pruning for 'Alpine' nectarines at Lushof farm, Ceres

Training system	Height from ground (m)	Distance vertical from the trunk (cm) 0	20	40	60	80	100	120
Four leader	**0.5**	577.1	295.9	164.1	277.6	439.6	610.4	1005.7
Two leader	**0.5**	123.5	198.9	284.7	738.6	930.6	1000.4	1051.4
Proleptic central leader	**0.5**	84.6	159.3	273.3	694.9	920.4	1189.7	1314.1
Sylleptic central leader	**0.5**	121.6	105.9	550.4	758.7	1073.5	1182.2	1345.9
Four leader	**1**	1330.4	925.4	609.6	279.8	514.2	754.7	979.7
Two leader	**1**	330.0	411.3	479.2	547.6	905.6	1137.2	1299.9
Proleptic central leader	**1**	224.9	302.2	483.5	710.2	988.7	1246.5	1498.2
Sylleptic central leader	**1**	261.5	302.3	637.4	985.1	1153.4	1397.9	1525.6
Four leader	**1.5**	1612.5	1606.9	1321.3	945.7	975.8	930.7	1017.9
Two leader	**1.5**	418.6	461.7	800.7	920.8	1216.6	1290.2	1473.9
Proleptic central leader	**1.5**	145.7	298.1	481.4	999.9	1210.4	1443.0	1600.2
Sylleptic central leader	**1.5**	436.3	434.3	938.1	1180.8	1325.8	1534.2	1671.7

Table 4.4: Effect of training systems on light measurements (μmol.m-2.s-1) for November 2005 after summer pruning for 'Alpine' nectarines at Lushof farm, Ceres

Training system	Height from ground (m)	Distance vertical from the trunk (cm) 0	20	40	60	80	100	120
Four leader	**0.5**	300.8	443.6	123.2	84.3	637.2	856.6	619.1
Two leader	**0.5**	533.2	213.3	333.9	311.5	332.9	281	372.8
Proleptic central leader	**0.5**	67.3	99.5	217.9	347	274.9	253.9	427.6
Sylleptic central leader	**0.5**	125.5	269.1	286.4	230.2	472.9	275.2	588.8
Four leader	**1**	1098.5	1054.5	808	237.3	382.1	493.7	573.4
Two leader	**1**	467.3	75.3	573.2	228.3	264	521.3	765.6
Proleptic central leader	**1**	262.3	206.2	173.4	261.6	585.3	1038	1093
Sylleptic central leader	**1**	265.2	160.4	288.7	631.1	705.7	818.9	1063.1
Four leader	**1.5**	1572.1	1572.1	1252.7	787.1	615.8	683.7	711.5
Two leader	**1.5**	563.7	100.2	357.8	430.1	634.6	508.7	997.9
Proleptic central leader	**1.5**	261.1	596.7	418.4	377.3	612.9	1064.2	1405.3
Sylleptic central leader	**1.5**	453.3	345.1	455.2	511.3	860.3	1093.9	1334.1

Table 4.5: Effect of training systems on light measurements (μmol.m-2.s-1) for February 2006 after summer pruning for 'Alpine' nectarines at Lushof farm, Ceres

Training system	Height from ground (m)	Distance vertical from the trunk (cm)							
		0	15	30	45	60	75	90	105
Four leader	**0.5**	695.7	563.9	438.2	367.9	367.6	371.7	400.5	426.6
Two leader	**0.5**	273.3	352.3	549.3	607.2	593.3	697.9	751.7	779.4
Proleptic central leader	**0.5**	58.6	119.3	239.9	436.5	450.7	550.4	724	817.8
Sylleptic central leader	**0.5**	426.8	474.2	735.8	871.1	795.1	798.3	888.9	859.8
Four leader	**1**	398.6	284.7	383.4	269.9	182.9	93.8	53.5	51.5
Two leader	**1**	113.6	241.2	313.3	349.7	298.2	418.2	539.5	621.7
Proleptic central leader	**1**	159.6	122.3	137.7	208.7	376.8	419.6	635.5	710.2
Sylleptic central leader	**1**	360.3	300.4	302.4	290.4	494.3	671.3	572.9	601.5
Four leader	**1.5**	785.3	633.8	296.3	127.3	61.5	45.9	64.6	138.9
Two leader	**1.5**	88.8	296.7	341.8	388.9	541.7	599.8	833.9	932.8
Proleptic central leader	**1.5**	218	226.9	275.4	308	624.4	530.5	555.5	740.7
Sylleptic central leader	**1.5**	489.9	710.4	811	875.2	885.2	804.4	986.1	902.8

CHAPTER V

FINANCIAL EVALUATION OF FOUR DIFFERENT TRAINING SYSTEMS USED FOR 'ALPINE' NECTARINES

Abstract

A financial comparison was made between four different training systems for nectarine (*Prunus persica var. nectarina*) orchards. 'Alpine' nectarines where planted in the winter of 2002 and the trees where trained to four different training systems namely a four-leader system (5 x 3 m; 667 trees/ha), a two-leader system (5 x 1.5 m; 1 333 trees/ha), a proleptically trained central leader (5 x 1 m; 2 000 trees/ha) and a sylleptically trained central leader (5 x 1 m; 2 000 trees/ha). Time spent per tree for pruning, thinning and picking were recorded from 2002 to 2005. The quantity of fruit per tree and fruit mass per tree were also recorded during harvest. The trees were compared in terms of production, value of production as well as margin above plant material and labour cost. The net present value (NPV) and internal rate of return (IRR) were calculated for each system. Results from the NPV and IRR calculations were conflicting in rankings. NPV at a discount rate of 5% indicate that the two-leader system should be preferred. NPV at a discount rate of 10% indicate that the proleptically trained central leader system should rather be preferred. This means that if opportunity cost is low, the two-leader system should be the preferred choice and if opportunity cost is high, the proleptically trained central leader should be the preferred system.

5.1 INTRODUCTION

Investing in a new orchard or replacing an existing one has become a big decision issue for fruit producers. Faced with the numerous and complex possibilities of cultivar, rootstock, training system and planting density combinations, an investor has to make some crucial choices. Wrong decisions do not come cheaply, because of the large sum of money required to invest into a new orchard. Investors and growers need to have sound knowledge of the potential advantages or disadvantages of different orchard systems available.

Comparing different orchard systems can be done by means of capital budgeting. Goedegebure (1986) showed how the method of calculating each system's net present value (NPV) can be used to make a useful comparison. The net present value of a project is defined as "the present value of the project's future cash flow minus the cost of the project" (Shapiro, 1990). In other words the net present value of a project is estimating the future cash flow of that project, discounting the estimated future cash flow at the required rate of return (cost of capital) and subtracting the initial cost of the project (Correia *et al*, 1993). In order to apply this method the actual annual cash-flow over the full lifespan of each system should be assessed. To decide whether a project is worthwhile investing in, the following rule should be followed (Vernimmen *et al*, 2005):

If $NPV > 0$ Invest

If $NPV < 0$ Do not invest

Weber (2000) also used the method of calculating the NPV to make an economic comparison of three different plantings for 'Jonagold' apples. To obtain the required basic economic data he interviewed more than 20 farmers in the specific area over a period of three years. In cases where not all the necessary data could be gathered, projections were made using existing information. Robinson and Hoying (2002) made an economic analysis of cash flow and profitability of seven different training systems for apple trees planted at two densities, using actual yields, fruit quality, material cost and labour inputs during the first nine years of the trail. They then projected the yield, quality and labour for years 10 to 22 (projected orchard lifespan), using the average yield for years 7 to 9.

Another method of comparing the profitability of different investments is the calculation of the internal rate of return (IRR) of each possible investment. The IRR is the discount rate that causes the present value of net future cash flows of a project to equal the initial cost of the investment (Correia et al., 1993). In other words, the IRR is the discount rate which causes NPV to equal zero. This discount rate (r) is determined by trail and error. The NPV are calculated for several values of r until the point is reached where NPV turns from positive to negative (Shapiro, 1990). If the IRR of a project exceeds the cost of capital, the project should be accepted, but if the IRR is less than the cost of capital, the project should be rejected. If two or more projects are compared, the project with the highest IRR should be the preferred choice. Mielke and Seavert (1998) calculated the IRR of three different training systems for two pear cultivars to determine the most economically efficient system. Robinson and Hoying (2002) also used the method of calculating the IRR to compare the different systems in the experiment mentioned above.

Using the method of calculating the NPV and the IRR of a project usually produces the same conclusion when deciding on a future investment. However, there are several different types of projects that pose potential difficulties in analysing capital budgeting. Dependent projects are projects whose acceptance depends on the acceptance or rejection of other projects. A mutually exclusive project is one whose acceptance will rule out the acceptance of another project. It is therefore necessary to determine which project is the best, when facing mutually exclusive projects (Van Horne and Wachowicz, 1995). Ranking of the best project is done on the basis of the NPV and IRR. Conflict in rankings according to NPV and IRR may occur. According to Van Horne and Wachowicz (1995) there are three reasons for this conflict in rankings. Firstly, there may be scale differences, where the initial cash outflows are different for the mutually exclusive projects. Secondly, different cash flow patterns of different projects can cause conflict in rankings. Thirdly, if projects have unequal projected lifespans, it can result in conflicting rankings. If however there is a difference in rankings according to the NPV and IRR methods, in the case of mutually exclusive projects with conflicting rankings the final investment decision should rather be made according to the ranking of the NPV method (Correia et al., 1993).

5.2 METHODS AND ASSUMPTIONS

‘Alpine’ nectarines were planted in August 2002 at Lushof farm near Ceres in the Western Cape region, South Africa (33º18’S, 19º20’E), in a north-south row direction. The trees were trained according to four different training systems. The training systems used were a sylleptically trained central leader (SS), a proleptically trained central leader

(SP), a two-leader system (2-L) and a four-leader system (4-L). The two central leader systems were planted at a distance of 5 x 1 m, giving 2 000 trees per hectare. Planting density for the two-leader system was 5 x 1.5 m or 1 333 trees per hectare. The four-leader system was planted at a density of 5 x 3 m to give 667 trees per hectare. The trees where planted on a Tukulu soil with a gravel content of 60 percent and a clay content of five to eight percent. All the trees were planted at a distance of five meters to keep the row widths constant. The layout of the study is a complete randomized block design. Each combination was planted in plots of five trees with three repetition blocks. Only the inside three trees of each plot were monitored in the experiment. Data regarding time spent in the orchard for planting, pruning, thinning and picking (labour cost) and yield aspects for 2002 to 2005 were recorded.

To compare the different systems, only the cost and income of the trees that would differ depending on the training system were used. This included plant material cost, labour cost and yield. Because of the different planting densities used in the trail the number of trees per hectare differed between the training systems. The cost of plant material would thus differ from training system to training system. The time spent in the orchard for planting, pruning, thinning and picking differed significantly per hectare for the different training systems. The cost of labour would thus differ depending on the training system used. The same applies for yield and income. All the other costs were assumed to be the same. This is because all the other costs, for example fertilizer cost per hectare and irrigation cost per hectare, were the same for all the different training systems. As previously mentioned, the same agricultural practices were applied to all the training systems. Because the costs other than labour and plant material are the same for all the training systems they have no effect on the comparison between the different systems.

The entire lifespan of a project should be taken into account when determining the NPV. Unfortunately only the first four years of the orchard’s performance could be determined during this study. To determine how the different systems would perform after the four years, full-bearing commercial orchards trained to the same systems were investigated. The necessary data regarding production cost and income for a commercial ‘Alpine’ orchard trained to a four-leader system in full bearing on the Lushof farm in Ceres was gathered from answers to a questionnaire completed by the owner of the Lushof farm. The same questionnaire was completed by several other farmers in the Villiersdorp and Ceres area in the Western Cape where commercial ‘Alpine’ orchards are trained to a central leader system. To simulate and project the underprovided information, the available information and knowledge was adapted with the help Mr Michiel Bester (2006 – personal communication).

Only the above mentioned specified costs and the income were used in the comparison between the different training systems. The trees were accepted to be at full bearing in year six. The economic lifespan of the orchards were assumed to be 12 years. Packout percentages were calculated at 51 percent for export sales, 34 percent for local sales and 15 percent for other uses for all the different training systems. Product prices were calculated at R10 000 per ton for export, R4 000 per ton for local and R500 per ton for the other uses for all the training systems. Plant material cost was calculated at R15 per tree and labour cost at R7 per hour. Labour cost for planting was calculated using a rate of 7.8 minutes, the time it takes one worker to plant a tree. The NPV and the IRR of each training system were calculated. The NPV was calculated using the following formula:

$$NPV = \sum_{t=1}^{n} \left\{ C_t / (1+k)^t \right\} - I$$

where: C_t is the net cash flow at time t

I is the cost of investment

k is the required rate of return (cost of capital)

The NPV was determined at a discount rate of 5% and 10%. The IRR was calculated using the following formula:

$$\sum_{t=1}^{n} \left\{ C_t / (1+r)^t \right\} - I = 0$$

where: r is the internal rate of return

5.3 RESULTS AND DISCUSSION

Tables 5.1 – 5.4 (Addendum A) shows the annual production, production value, and specified costs, as well as the NPV and IRR of the different training systems used in the trial at Lushof farm near Ceres. Figures 5.1 – 5.8 gives a summary of the data in Tables 5.1 – 5.4 in chart form.

From the results one can see that the four-leader system had the lowest gross production and therefore also the lowest gross production value during the initial years (1 to 3). This was due to the lower planting density of the four-leader system. Production increased however, as leaf area increased to fill the allocated space, and at full bearing the four-leader had the same gross production value as the other systems. The two-leader system had the highest production value during the first four years (Figures 5.1 and 5.2). The establishment cost (plant material) in year 0 was the highest for the two central leaders, because of the higher density planting. The total specified cost of the two central leaders was also the highest during the first three years (Figure 5.3). The four-leader system had the highest total specified cost during year 4. After year 4, until year 12, the two central leaders had a slightly higher total specified cost than the four-leader and two-leader systems (Figure 5.4). The margin above the specified cost was higher for the four-leader system in year 0 (establishment), but margins were the lowest during years 2 to 5. Very little difference was found in the margin above the specified cost of the different systems from years 6 to 12, but the four-leader system had a slightly higher margin (Figure 5.4). Figure 5.5 shows that the four-leader system had the highest cumulative margin above the specified cost from years 0 to year 2, whereafter it had the lowest cumulative margin. The two-leader system had the highest cumulative margin above the specified cost from year 3 to year 12. The two-leader system had the highest NPV ranking at a discount rate of 5%, followed by the proleptically trained central leader, the sylleptically trained central leader and the four-leader system (Figure 5.6). In Figure 5.7 it is clear that the proleptically trained central leader had the highest NPV ranking at a discount rate of 10%, followed by the sylleptically trained central leader, the four-leader system and the two-leader system. The IRR was the highest for the four-leader system, followed by the two-leader system, the proleptically trained central leader and the sylleptically trained central leader. The IRR though, is not seen as a relevant method in this partial analysis.

5.4 CONCLUSIONS

Looking at the results from Tables 5.1 - 5.4, one should keep in mind that only specific costs were included to compare the different training systems. The margin above the specified cost should thus not be confused with “profit”. The results from the NPV calculations are only based on partial analysis. These results are only used to compare the difference between the training systems, not to estimate the total profitability of each training system.

Although the four-leader system has a low establishment cost and demands low canopy maintenance (pruning and thinning) in the initial years, it is slow to produce high yields in the early years. The central leaders on the other hand has a very high establishment cost, but produces a relative high yield early on. The two-leader system produces the highest yield during the initial years, but has a lower maintenance cost than the two central leaders. At full bearing all the systems produce the same yield and there is very little difference in maintenance cost between the different systems. The greatest influence of training system on profitability is thus during the initial years after planting. This period is thus very important to producers, as, in this case, they prefer to see returns on the investment as soon as possible.

When looking at the results from the NPV and IRR calculations one can see that there is a conflict in preference ranking between the two methods. As previously discussed, when this is the case, one should rather accept the results from the NPV calculations. When calculating the NPV at a discount rate of 5%, the two-leader was found to be the preferred system. When calculating the NPV at a discounting rate of 10% however, the two-leader system was not the most favourable one, the proleptically trained central leader was. What this implies is that the choice of training systems is sensitive to the opportunity cost of money. Opportunity cost is described as the ‘cost of the road not taken’ (Shapiro, 1991). It is the benefits forgone on the next-best-valued alternative when choosing a specific investment. The opportunity cost of funds thus depends on the rate of interest at which money can be invested (cost of capital) (Shapiro, 1991). If the opportunity cost is low then the preferred choice of system should be the two-leader system. When the opportunity cost is higher, in this case double, the proleptically trained central leader should be the preferred choice. It is thus suggested that in practice the final decision should be based on a capital budget for the whole farm, with different practices, and with the relevant after-tax cost of capital according the circumstances prevailing on that specific farm.

5.5 REFERENCES

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ADDENDUM A

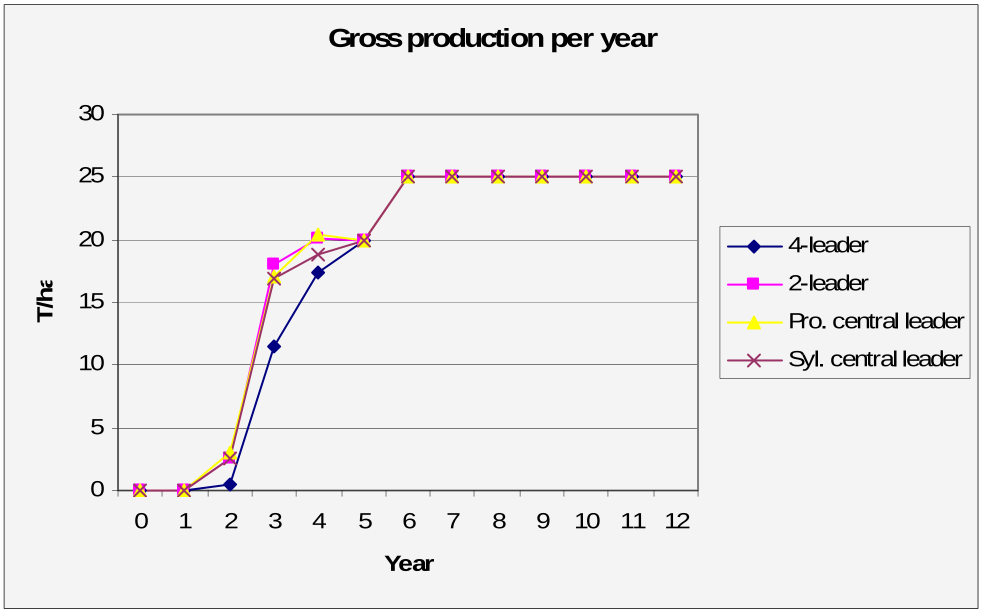

Figure 5.1: Gross production per year of an 'Alpine' orchard at Lusfhof farm near Ceres trained to four different training systems from year 0 to year 12.

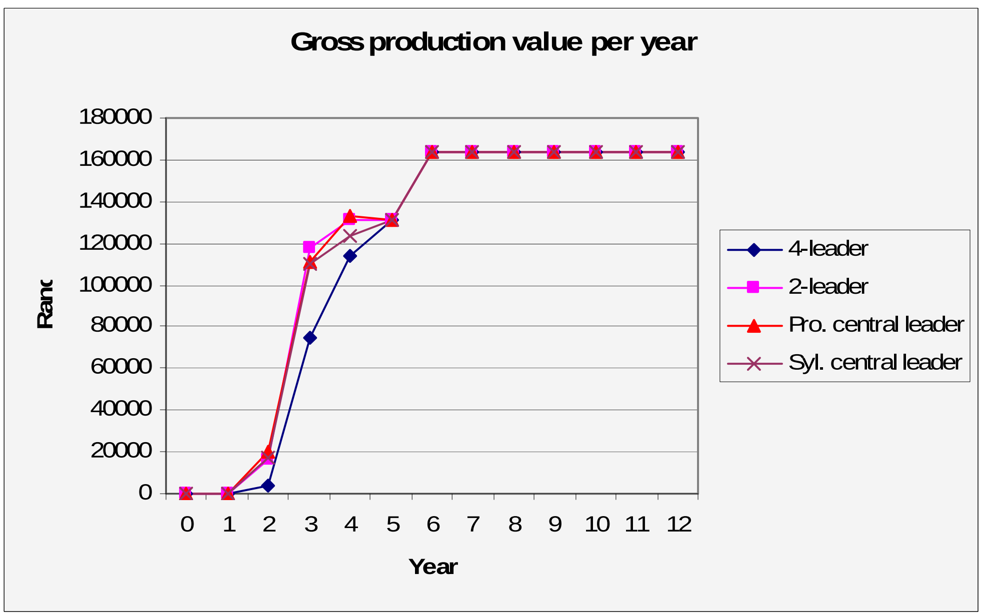

Figure 5.2: Gross production value per year of an 'Alpine' orchard at Lushof farm near Ceres trained to four different training systems from year 0 to year 12.

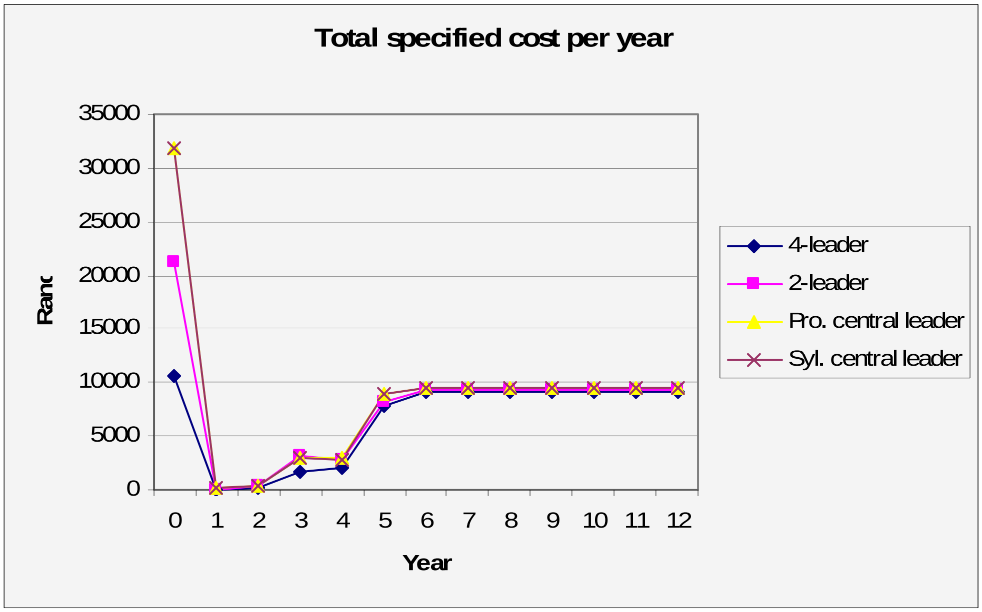

Figure 5.3: Total specified cost per year of an 'Alpine' orchard at Lushof farm near Ceres trained to four different training systems from year 0 to year 12.

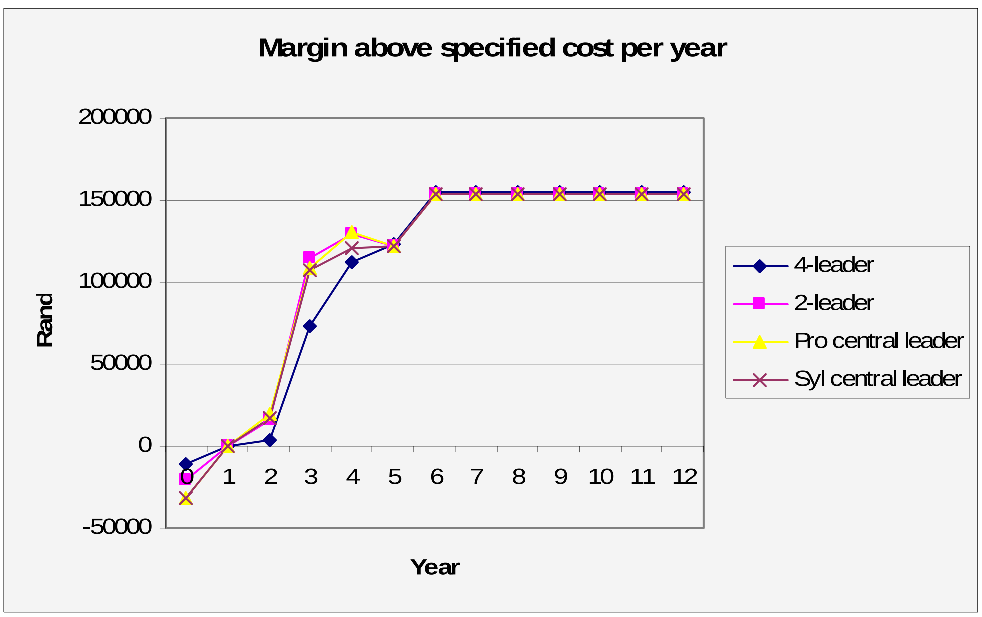

Figure 5.4: Margin above specified cost per year of an 'Alpine' orchard at Lushof farm near Ceres trained to four different training systems from year 0 to year 12

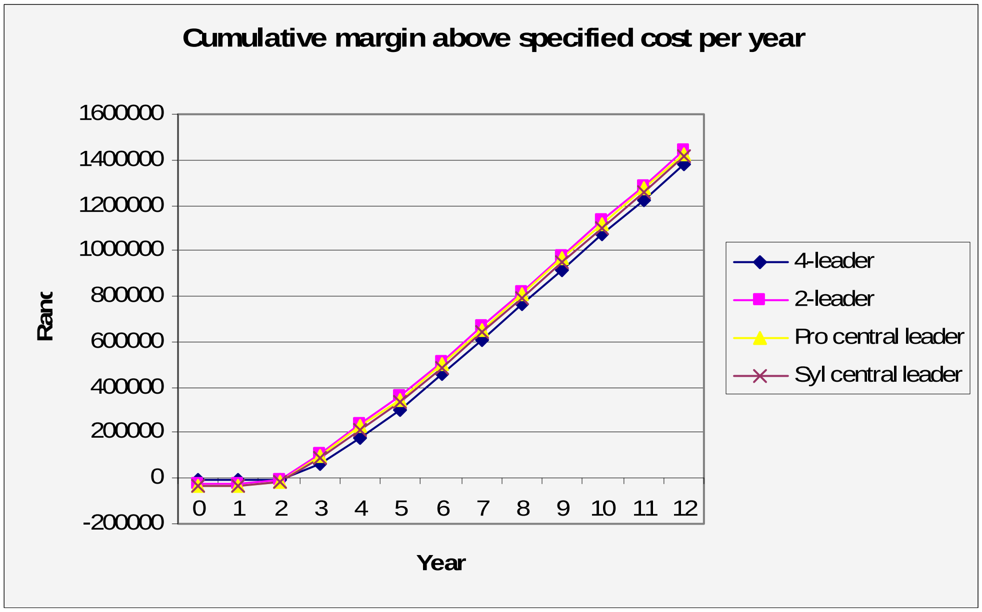

Figure 5.5: Cumulative margin above specified cost per year of an 'Alpine' orchard at Lushof farm near Ceres trained to four different training systems from year 0 to year 12.

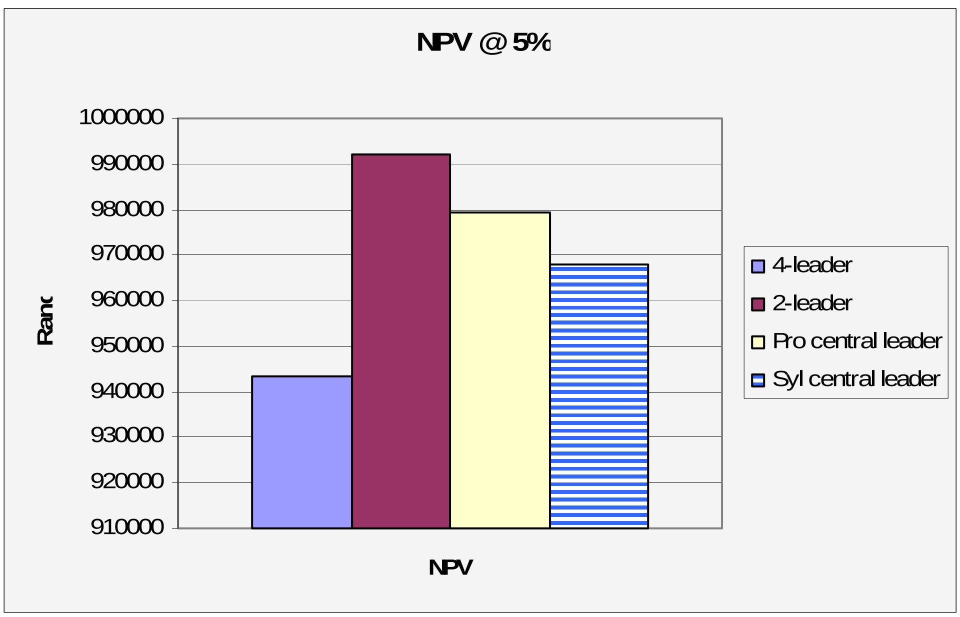

Figure 5.6: Net present value at 5% discount rate of an 'Alpine' orchard at Lushof farm near Ceres trained to four different training systems from year 0 to year 12.

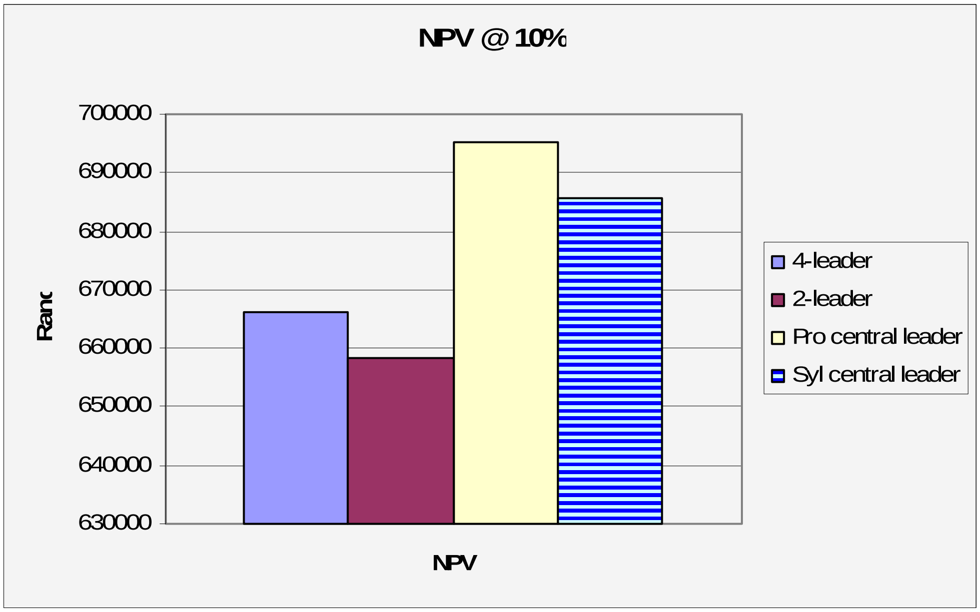

Figure 5.7: Net present value at 10% discount rate of an 'Alpine' orchard at Lushof farm near Ceres trained to four different training systems from year 0 to year 12.

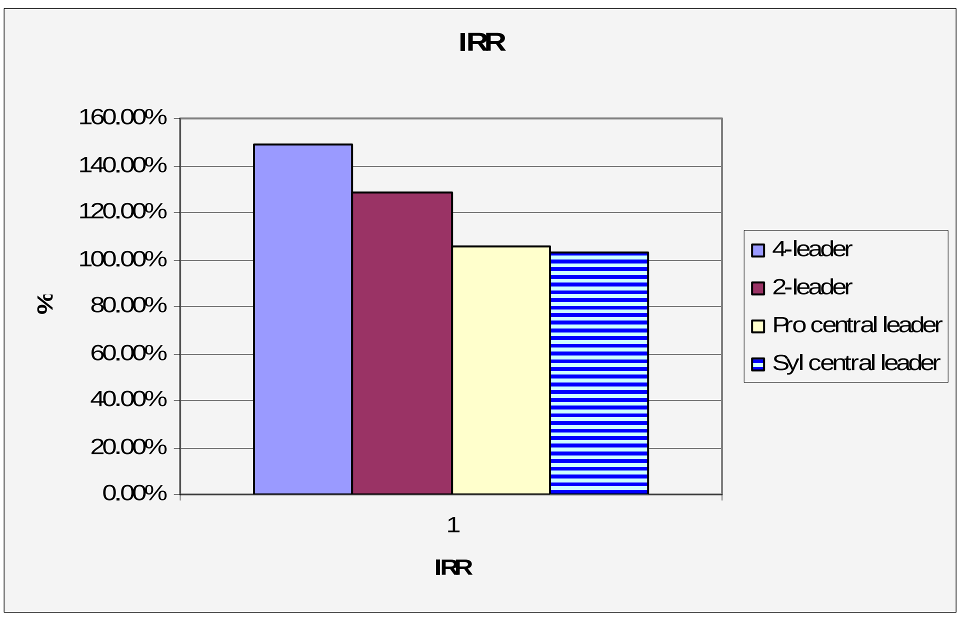

Figure 5.8: Internal rate of return of an 'Alpine' orchard at Lushof farm near Ceres trained to four different training systems from year 0 to year 12.

ADDENDUM B

Table 5.1: Gross production value and specified cost for the 'Alpine' orchard planted at Lushof farm in Ceres trained to a four-leader system from year 0 (establishment) to year 12

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Gross production (t/ha)	0.00	0.00	0.53	11.52	17.43	20.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Gross production value (R/ha)													
Export	0.00	0.00	2709.12	58650.00	88882.80	102000.00	127500.00	127500.00	127500.00	127500.00	127500.00	127500.00	127500.00
Local	0.00	0.00	722.43	15640.00	23702.08	27200.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00
Other	0.00	0.00	39.84	863.93	1307.10	1500.00	1875.00	1875.00	1875.00	1875.00	1875.00	1875.00	1875.00
Total	0.00	0.00	3471.39	75153.93	113891.98	130700.00	163375.00	163375.00	163375.00	163375.00	163375.00	163375.00	163375.00
Specified cost (R/ha)													
Establishment cost													
Plant material	10005.00												
Contract labour													
Planting	588.00												
Pruning	0.00	87.49	87.49	716.09	686.69	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
Thinning	0.00	0.00	27.02	568.155	423.86	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
Picking	0.00	0.00	21.59	468.23	932.19	2400.00	3600.00	3600.00	3600.00	3600.00	3600.00	3600.00	3600.00
Total	10593.00	87.49	136.10	1752.48	2042.74	7900.00	9100.00	9100.00	9100.00	9100.00	9100.00	9100.00	9100.00
Margin above specified cost (R/ha)	-10593.00	-87.49	3335.29	73401.45	111849.24	122800.00	154275.00	154275.00	154275.00	154275.00	154275.00	154275.00	154275.00
Cumulative margin above specified cost (R/ha)	-10593.00	-10680.49	-7345.20	66056.25	177905.49	300705.49	454980.49	609255.49	763530.49	917805.49	1072080.49	1226355.49	1380630.49

NPV @ 5%	943439.61
NPV @ 10%	666233.85
IRR	149%

Table 5.2: Gross production value and specified cost for the 'Alpine' orchard planted at Lushof farm in Ceres trained to a two-leader system from year 0 (establishment) to year 12

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Gross production (t/ha)	0	0	2.522	17.997	20.13	20	25	25	25	25	25	25	25
Gross production value (R/ha)													
Export	0	0.00	12862.20	91800.00	102663.00	102000.00	127500.00	127500.00	127500.00	127500.00	127500.00	127500.00	127500.00
Local	0	0.00	3429.92	24480.00	27376.80	27200.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00
Other	0	0.00	189.15	1349.78	1509.75	1500.00	1875.00	1875.00	1875.00	1875.00	1875.00	1875.00	1875.00
Total	0	0.00	16481.27	117629.78	131549.55	130700.00	163375.00	163375.00	163375.00	163375.00	163375.00	163375.00	163375.00
Specified cost													
Establishment cost													
Plant material	19995.00												
Contract labour													
Planting	1213.03												
Pruning	0	65.43	65.43	1042.36	952.08	3000	2800	2800	2800	2800	2800	2800	2800
Thinning	0	0.00	190.65	1360.485	565.15	2700	2900	2900	2900	2900	2900	2900	2900
Picking	0	0.00	114.57	817.60	1286.95	2500	3700	3700	3700	3700	3700	3700	3700
Total	21208.03	65.43	370.65	3220.45	2804.18	8200.00	9400.00	9400.00	9400.00	9400.00	9400.00	9400.00	9400.00
Margin above specified cost (R/ha)	-21208.03	-65.43	16110.62	114409.33	128745.37	122500.00	153975.00	153975.00	153975.00	153975.00	153975.00	153975.00	153975.00
Cumulative margin above specified cost (R/ha)	-21208.03	-21273.46	-5162.83	109246.50	237991.87	360491.87	514466.87	668441.87	822416.87	976391.87	1130366.87	1284341.87	1438316.87

NPV @ 5%	992162.64
NPV @ 10%	658392.79
IRR	129%

Table 5.3: Gross production value and specified cost for the 'Alpine' orchard planted at Lushof farm

in Ceres, proleptically trained to a central leader system from year 0 (establishment) to year 12

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Gross production (t/ha)	0.00	0.00	3.09	17.02	20.40	20.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Gross production value (R/ha)													
Export	0.00	0.00	15764.61	86751.00	104040.00	102000.00	127500.00	127500.00	127500.00	127500.00	127500.00	127500.00	127500.00
Local	0.00	0.00	4203.90	23133.60	27744.00	27200.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00
Other	0.00	0.00	231.83	1276.43	1529.85	1500.00	1875.00	1875.00	1875.00	1875.00	1875.00	1875.00	1875.00
Total	0.00	0.00	20200.34	111161.03	133313.85	130700.00	163375.00	163375.00	163375.00	163375.00	163375.00	163375.00	163375.00
Specified cost (R/ha)													
Establishment cost													
Plant material	30000.00												
Contract labour													
Planting	1820.00												
Pruning	0.00	95.81	95.81	1191.73	1028.10	3100.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00
Thinning	0.00	0.00	177.99	980.00	628.89	2800.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
Picking	0.00	0.00	154.35	849.80	1312.85	3000.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00
Total	31820.00	95.81	428.14	3021.53	2969.84	8900.00	9550.00	9550.00	9550.00	9550.00	9550.00	9550.00	9550.00
Margin above specified cost (R/ha)	-31820.00	-95.81	19772.20	108139.50	130344.01	121800.00	153825.00	153825.00	153825.00	153825.00	153825.00	153825.00	153825.00
Cumulative margin above specified cost (R/ha)	-31820.00	-31915.81	-12143.61	95995.89	226339.90	348139.90	501964.90	655789.90	809614.90	963439.90	1117264.90	1271089.90	1424914.90

NPV @ 5%	979513.45
NPV @ 10%	695333.67
IRR	105%

Table 5.4: Gross production value and specified cost for the 'Alpine' orchard planted at Lushof farm in Ceres, sylleptically trained to a central leader system from year 0 (establishment) to year 12

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Gross production value (t/ha)	0.00	0.00	2.61	16.93	18.85	20.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Gross production value (R/ha)													
Export	0.00	0.00	13300.80	86190.00	96390.00	102000.00	127500.00	127500.00	127500.00	127500.00	127500.00	127500.00	127500.00
Local	0.00	0.00	3546.88	22984.00	25704.00	27200.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00
Other	0.00	0.00	195.60	1269.45	1413.83	1500.00	1875.00	1875.00	1875.00	1875.00	1875.00	1875.00	1875.00
Total	0.00	0.00	17043.28	110443.45	123507.83	130700.00	163375.00	163375.00	163375.00	163375.00	163375.00	163375.00	163375.00
Specified cost (R/ha)													
Establishment cost													
Plant material	30000.00												
Contract labour													
Planting	1820.00												
Pruning	0.00	96.95	96.95	1085.72	1050.27	3100.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00
Thinning	0.00	0.00	172.83	1121.72	534.94	2800.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
Picking	0.00	0.00	126.15	818.72	1247.26	3000.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00
Total	31820.00	96.95	395.93	3026.16	2832.47	8900.00	9550.00	9550.00	9550.00	9550.00	9550.00	9550.00	9550.00
Margin above specified cost (R/ha)	-31820.00	-96.95	16647.35	107417.30	120675.35	121800.00	153825.00	153825.00	153825.00	153825.00	153825.00	153825.00	153825.00
Cumulative margin above specified cost (R/ha)	-31820.00	-31916.95	-15269.60	92147.69	212823.05	334623.05	488448.05	642273.05	796098.05	949923.05	1103748.05	1257573.05	1411398.05

NPV @ 5%	968099.73
NPV @ 10%	685603.68
IRR	103%

CHAPTER VI

CONCLUTIONS

The results from Chapter III showed that rootstock only played a significant role when it came to fruit weight. Trees on SAPO 778 rootstocks induced better fruit size than trees on Kakamas seedling rootstocks. This means that trees on SAPO 778 rootstocks can produce a better packout percentage in terms of first class fruit, which makes is the preferred rootstock. SAPO 778 also seems less susceptible to root-knot nematodes than GF 677 and Kakamas seedling, because no visual symptoms were found on either root or vegetative growth in trees planted on SAPO 778 rootstocks. This can also contribute to better fruit size on SAPO 778.

It was found that the four-leader system produced a lower cumulative yield than the other systems during the first three years of production because of the lower planting density. However, there was no significant difference found in production between the different training systems in the third year of production, when all the systems have filled their allocated spaces. The four-leader system had the lowest annual labour input of all the training systems. The two-leader system had the highest cumulative labour input during the first four years. Very little difference was found between the proleptically trained central leader and the sylleptically trained central leader.

Different problem areas in terms of light penetration were found for each of the training systems. Poor light penetration in the four-leader system occurred in the upper and outer parts of the canopy, directly under the main scaffold branches. This will especially become a huge problem when the gap between tree rows is not kept open. The inside of the ‘V’ of the four-leader should also be kept open. The central leader systems had better light penetration because of the narrower pyramidal canopy shape. However, the sylleptically trained central leader had poor light penetration in the lower and inner parts of the tree canopy because of strong growth in the basal part of the tree. The two-leader system also has a pyramidal canopy shape with a broad base and a narrower top, which means better light penetration. Light penetration was however poor in the upper parts of the ‘V’ of the two-leader system because the ‘V’ was not kept open properly during summer pruning. Because the two-leader system consists of two ‘central leaders’ on one trunk, it can enjoy the benefit of better light interception together with the advantage of better light penetration because of the pyramidal shape of the two ‘central leaders’.

A conflict in rankings was found according the internal rate of return (IRR) and net present value (NPV) calculations of the different training systems, hence conclusions was made according to the NPV calculations. The two-leader systems had the highest NPV at a discount rate of 5%. The proleptically trained central leader had the highest NPV at a discount rate of 10%. This implies that if the opportunity cost of capital is low, the two-leader system should be preferred. If the opportunity cost of capital is high, the proleptically trained central leader should be preferred, because with this system, relative high returns on the initial investment are generated early during the first years of production.

Finally, the low density planted system (four-leader) took longer to fill the allocated space and therefore was slower to produce high yields during the first three years. As soon as the trees have filled its space, it produced yields equal to that of the higher density systems. The high density planted (central leaders) system was early to produce high yields because the tree could fill its allocated space quickly. However, with the higher density came higher establishment cost, as well as higher labour requirement. The two-leader system has advantages of both the high and low density systems, because it produces high yields during the first three years of production and establishment cost is lower than the central leader system because of the lower planting density.