Productivity and Profitability of Growing Packham Pears

B. van den Ende, et al

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Project aims:
The aim of this project was to:

- get Packham trees in early production using 2 training systems, 2 tree densities, different chemical and mechanical methods to promote branching, 3 sizes of nursery trees and different pruning methods.
- give orchardists the option of establishing a high density pear planting with or without a support system.
- show costs and returns of establishing and operating 2 orchard systems for Packham trees for the first 6 years.

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CONTENTS

INDUSTRY SUMMARY ................................................................. 2

TECHNICAL SUMMARY ............................................................. 3

INTRODUCTION ........................................................................... 4

THE PROJECT ............................................................................. 15

MAIN EXPERIMENT 1
The effect of chemical and mechanical treatments on branching
of trees planted on Open Tatura and Central Leader ......................... 18

MAIN EXPERIMENT 2
The effect of nursery tree size at planting on early production ............ 19

MAIN EXPERIMENT 3
The effect of training system on early production .............................. 25

SUPPLEMENTARY EXPERIMENT 1
The effect of distance of polliniser trees on misshapenness, size
And number of seeds of Packham pears ........................................ 33

SUPPLEMENTARY EXPERIMENT 2
The effect of reduced bud load on fruit set and yield of Packham ........ 36

SUPPLEMENTARY EXPERIMENT 3
The influence of bourse shoots on fruit set of Packham ...................... 38

SUPPLEMENTARY EXPERIMENT 4
The effect of cincturing on yield and fruit size .................................. 39

PROFITABILITY STUDY ............................................................ 41

DISCUSSION AND CONCLUSION ............................................. 42

TECHNOLOGY TRANSFER ......................................................... 44

REFERENCES ............................................................................. 47

APPENDIX 1 – Soil analysis .......................................................... 52
INDUSTRY SUMMARY

In 1997 a 2.7 ha demonstration orchard was established near Shepparton, Victoria, with Packham trees on Open Tatura and Central Leader. The aim of the 6-year-project was to:

- get Packham trees in early production using 2 training systems, 2 tree densities, different chemical and mechanical methods to promote branching, 3 sizes of nursery trees and different pruning methods.
- give orchardists the option of establishing a high density pear planting with or without a support system.
- show costs and returns of establishing and operating 2 orchard systems for Packham trees for the first 6 years.

Chemical agents and mechanical methods did not promote branching of Packham trees in the first year of planting due to transplant shock.

Planting large nursery trees as compared with planting small nursery trees improved yields of 6-year-old Packham trees on Open Tatura and Central Leader by 13 and 44 per cent respectively.

Early production of 6-year-old Packham trees on Open Tatura and Central Leader was more dependent on tree density than on training system. Open Tatura trees at 2222 trees per hectare and Central Leader trees at 1111 trees per hectare produced a total of 62 and 33 tonnes of fruit per hectare respectively from 5 harvests.

Limb-rub and misshapen fruit were the 2 major fruit quality factors, which contributed to poor packouts.

Pollination and pruning were crucial in maximising fruit set and packouts. Josephine trees were not reliable pollinisers and yield-wise benefited more from the Packham trees than visa versa. Detailed pruning and positioning of fruiting wood and spurs more than doubled fruit set and markedly reduced the incidence of limb-rub compared with 'normal' pruning practised in the Goulburn Valley. The distance of the Packham trees from the Josephine trees also had a marked effect on fruit set and misshapen fruit. Packham trees close to the Josephine trees had more fruit per tree and less misshapen fruit than trees further away from the polliniser trees. These measurements were made despite having placed in the orchard double the recommended amount of beehives per hectare.

Although profitability of a high and medium density planting with Packham cannot be based on the performance of the trees in the first 6 years, it nevertheless points to the fact that high returns must be generated early to repay the high investment. Fruit of high quality translates into high packouts and profitable returns to the orchardist. Average packouts of 50 per cent (12 cartons/bin) returned $221 per tonne resulted in a marked negative gross margin after 6 years, especially for the Open Tatura system. High density Packham plantings are a good investment if high fruit quality can be guaranteed.
TECHNICAL SUMMARY

Many pear growers are dissatisfied with their returns for Packhams, mainly because of poor packouts. Limb-rub, misshapenness, russet and small fruit are mostly responsible for the low packouts.

Most Packhams are grown on large trees that are expensive to prune and harvest. Josephine is commonly used as polliniser in the Goulburn Valley, because it has good market value.

A demonstration orchard was set up to show orchardists alternative ways of growing Packhams with the aim of getting early yields of fruit of high quality.

Production in the early years of a Packham orchard mostly depended on how many trees were planted per hectare and not the training system. Six-year-old Packham trees on Pyrus calleryana D6 rootstock on Open Tatura with 2222 trees per hectare yielded 62 tonnes per hectare and Central Leader with 1111 trees per hectare yielded 33 tonnes per hectare from 5 harvests.

Planting large nursery trees as compared with planting small nursery trees increased total yield of 6-year-old Packham trees on Open Tatura and Central Leader by 13 and 44 per cent respectively.

Branching of newly-planted Packham trees was not improved with chemical agents such as Waiken™, Dormex™ or winter oil, nor with mechanical treatments such as looping, scoring or plucking. Transplant shock was most likely responsible for lack of responses to these treatments.

The supplementary experiments have clearly shown, that yield, fruit size and fruit quality can be markedly improved by:

a) placing polliniser trees closer to the Packham trees for better cross-pollination,

b) prune trees to detail by positioning fruiting wood and spurs to avoid limb-rub,

c) using different polliniser varieties, or Josephine with another polliniser variety.

Costs and returns of 6-year-old Packham trees were not a reliable indication of the profitability of Open Tatura vs Central Leader. However, this study showed that 50 per cent packouts (12 cartons per bin) could not possibly lead to profitable growing of Packhams. High density systems must produce fruit of high quality and packouts of at least 75 % (18 cartons per bin). Orchardists should not attempt to plant a high density Packham orchard, unless he or she is prepared to put the work into it to produce fruit of high quality.

To remain competitive, orchardist must change the way they have grown Packhams and embrace the new techniques of managing a high density pear orchard.

INTRODUCTION
Australia's pear industry has an annual production of approximately 162,000 tonnes of which 85 per cent is sourced from the Goulburn Valley and Murray Valley irrigation areas of northern Victoria. Main varieties are Packham's Triumph (hereafter called Packham), Williams' Bon Chretien (WBC) and Buerre Bosc. Major pear growing areas in northern Victoria are around Shepparton, Kyabram, Ardmona and Cobram. Figures from Apple and Pear Australia Limited (APAL) indicate that there are about 400 pear growers in northern Victoria, with 3,000 hectares of pear orchards. The Goulburn Valley and Murray Valley grow 90 per cent of Australia's deciduous canned fruit, which includes WBC pears. The fruit industry employs around 3,000 permanent staff and close to 20,000 seasonal workers - including pickers and cannery staff. Approximately 80,000 tonnes of canned fruit is exported mainly to Europe and Asia by the SPC Ardmona cannery.

Figures from the Australian Bureau of Statistics indicate, that pear plantings have not increased at the level of apple plantings primarily because of a) poor packouts, b) high cost of production, and c) the lengthy non-bearing period after trees have been planted.

The majority of pears including Packhams, the main export variety, have for years been planted as low density free-standing orchards. Some of the original pear orchards planted almost a century ago are still producing.

The pear industry, unlike the apple industry, has not undergone major changes. New apple varieties have replaced some old varieties, and the availability of precocious size-controlling rootstocks allowed more apple trees to be planted per hectare with the advantage of early returns.

The interest in high density planting of apple and stone fruit has led to the development of efficient tree training systems for early and high yields, high fruit quality, and ease of tree management and harvesting. In Australia, most of the high density work with pear trees started at the Tatura Research Institute some 40 years ago, and intensified 30 years ago when the Tatura Trellis was developed and fruit crops such as WBC, were trialed on this system (van den Ende and Chalmers, 1983). However, Packham trees on Tatura Trellis were not properly evaluated. The problem of a lengthy non-bearing period for Packham has never really been addressed in Australia, because rootstocks, which induced precocity, were not available.

The pear industry recognised the need to extend orchard efficiencies as developed in other fruit crops, to Packham. An anticipated skilled labour shortage to prune and harvest large trees, and the doubtful benefits of removing old widely spaced big trees were further incentives to evaluate a high density approach to Packham trees on the existing seedling rootstock. It is not simply a matter of transferring existing techniques from apples to pears. A pear tree does not behave the same as an apple tree and there is no proven system to control size of trees, which contrasts with apple trees where size-controlling rootstocks are quite efficient. In Australia, the choice for pear is limited to the seedling rootstock Pyrus calleryana D6. It is unlikely that this situation will change in the foreseeable future, since no research work on pear rootstocks in Australia has...
been undertaken since 1969 (Selimi and Keatly, 1970). To improve profitability of growing Packham pears, other avenues needed to be explored.

The goal when establishing a new orchard, or upgrading to a new orchard system, is essentially the same for any type of fruit crop. To be profitable, significant production is required in the 3rd year and fruit should be of high quality. This is achieved by increasing the percentage light interception and light distribution to all parts of the canopy (Flores, 1997). To do this in Packham pears requires adapting existing high density tree training systems with some modifications. The training systems chosen for this project require relatively high initial costs and labour inputs, but this is expected to drop once the orchard is established, as pruning and harvesting will be cost-effective. High density systems such as Open Tatura are known to be very appealing to workers, and worker productivity in such systems has been known to increase by at least 20 per cent (Ing, 1989). Minimising labour costs and efficient targeting of sprays per unit of land are other considerations. Profitability of the Packham pear industry was seen as the key aspect that prompted this project, because without sustained profitability, pear orchards will not exist much longer in their current form.

The Packham industry in Australia remains committed to the production of high quality pears for the export and domestic markets. In recent years, the national industry has spent considerable effort in identifying how to be more competitive in the world market. A benchmarking study conducted in 1995 highlighted the need for growers to adopt new technologies in tree training and management in order to induce early bearing (precocity), improve quality of fruit, and obtain a high pack out per bin (Pullar, 1995). Under a Federal Government funding initiative, the industry has established Quality Network Discussion groups and these groups have identified 'improvement in the tree management techniques' as a key aspect of a quality management system for their orchards.

Pear exports are focussed on the premium markets of the United Kingdom and Europe, and markets in South East Asia. Compared with other pear producing countries, Australia produces only 1.4 per cent of the world pear production (Horticulture Australia Ltd, 2001, HAL for short). Fresh pear exports, principally Packhams accounted for about 14 per cent of the overall season's production in 1997. Exports in 1998 plummeted to 8 per cent (13,688 tonnes), but bounced back in the following year to 10 per cent (16,000 tonnes) (HAL, 2001). Fresh domestic sales of all pear varieties accounted for a further 45 per cent, and 41 per cent for processing (HAL, 2001). More recently, the demand for premium quality pears by South East Asian markets has required a re-think in the way pears are grown to maximise early yields of fruit of high quality. This has paved the way towards more modern training systems for pears, something previously reserved for export varieties of apples and stone fruit.

Figure 1. Tree numbers of popular fruit varieties grown in the Goulburn Valley

Source Northern Victoria Fruitgrowers' Association Ltd (NVFA).
The Australian pear industry is about 1/3 the size of the apple industry. The majority of Australia's pear production occurs in the Goulburn Valley of Victoria where 76 per cent of the tree numbers are planted (Figure 1).

Commercial production centres on WBC, an early season pear used mainly for processing, and Packhams (Baxter, 1997). Packhams are the main fresh market pear and was a selection from the breeding program of C.H. Packham of Molong, New South Wales in the early 1900s.

Australian pear plantings are not limited to Packham, WBC or Buerre Bosc. Other varieties such as Josephine de Malines (hereafter called Josephine), Howell and Corella are gaining popularity. However, the Packham pear remains the preferred export variety and this variety is recognised internationally for its flavour and long storability.

The lengthy non-bearing period between planting and the first commercial harvest, and low pack out of high quality fruit have been disincentives to grow Packhams. It was important therefore that research be conducted on a commercial site under Australian conditions to see if these problems could be overcome. Training systems used for apples and stone fruit were one area of investigation to see if the same benefits could be applied to Packham pears.

Many Packham pear orchards in the Goulburn Valley are older than 40 years and use the conventionally widely spaced free-standing system with approximately 300 trees/ha. These trees are large and costly to maintain and a new initiative was required to replace the conventional method with a modern design that uses tighter spacings, combined with less pruning and more tree training during the first 3 years to show that Packham trees can produce fruit early in the life of the orchard. If this could be achieved, it would ensure that the Packham remains the major fresh market pear for Australia and especially the Goulburn Valley.

This document reports experiments designed to investigate the effect of two training systems on early production of Packham on seedling rootstock, and the effect of size of nursery tree on precocity. It also reports an assessment of tree growth response using a range of chemical and mechanical treatments as a means of stimulating lateral branch development in newly planted nursery trees, as well as factors affecting pollination and fruit set and causing skin defects.

**CONCEPTS OF HIGH DENSITY PLANTING**

Although Packhams are only grown in the Southern Hemisphere, much of the research on the culture of pears has been carried out in the Northern Hemisphere. The introduction of size-controlling rootstocks provided the basis for controlled tree growth, indispensable for closer planting distances. In addition, size-controlling rootstocks induce early cropping which in turn is a growth-reducing factor. To achieve maximum yield per hectare, it is important for trees to intercept a high proportion of sunlight, and as quickly as possible in the life of the orchard (Barritt 1993, Lakso et al 1997). Training systems planted with large well-branched nursery trees at high densities,
intercept more sunlight in the early years than do low density orchard systems with unbranched trees and thus have higher early production per hectare (Barritt, 1992). Sunlight, which strikes the orchard floor is wasted, so the efficiency of a training system must be evaluated in terms of 'light use' (Robinson and Lakso, 1991), that is, the capacity of the tree to maximise the partitioning of carbohydrates into fruit (Chalmers, 1989). Training systems must be used that can intercept at least 70 per cent of sunlight and distribute its energy efficiently (Forshey and McKee 1970; Jackson 1978 and 1980; Palmer 1989a; Robinson et al 1993).

The main impetus for a worldwide interest in new training systems has come from the need to improve orchard production efficiency and profitability. This has led to a number of experiments over the last 35 years to compare different training systems, predominantly for apples. These comparisons have shown that no one system is optimal for all scion/rootstock combinations, economic situations, or climates (Barritt 1987, Robinson 1993). However, work on this topic has produced 3 important concepts regarding productivity and profitability of training systems.

First Concept - Total dry matter production and potential crop yield are a function of total light interception (Agha and Buckley 1986; Hunter and Proctor 1986; Monteith 1977; Palmer 1976, 1989; Palmer and Jackson 1974). Free-standing widely spaced trees have discontinuous canopies. Total light interception and, thus potential yield, are controlled by tree spacing and canopy characteristics (height, width, shape, and leaf density) (Corelli and Sansavini, 1989). A major objective in orchard design is to arrange the trees so that the canopy intercepts a high proportion of the incoming sunlight as quickly as possible. Robinson et al, (1991; Palmer et al, 1992) concluded that high yield per hectare requires high total light interception of around 70 per cent. To obtain the yield benefits of high light interception requires high tree efficiency (efficient rootstocks, tree forms, and pruning practices). The best way to obtain high early light interception and thus, high early yields, is to plant trees closely. When light interception exceeds about 70 per cent, flower bud formation, yield and fruit quality may be reduced (Cain, 1971; Palmer et al., 1992). This is because a high proportion of the tree canopy is shaded.

Second Concept - Although maximum fruit yields are ultimately limited by light interception, economic fruit yields and quality are a function of how efficiently light is being utilised and distributed within the canopy (Jackson, 1980). Tree design is therefore important so that fruiting sites within the canopy receive adequate exposure to localised light. Tree designs, which maximise exposure within the canopy, are generally more efficient at converting light energy to fruit than canopy designs that are subject to heavy internal shading.

A more fundamental estimate of tree efficiency is the ability of the tree to convert light energy into fruit. This allows a uniform comparison between tree forms and spacings (Robinson, 1993). It can then be determined which training system is more efficient at converting light energy captured by the orchard trees. The portion that is not captured by the trees is lost to the ground and this light is wasted. Robinson et al (1991) found that light interception was highest with the 'Y trellis,' which also accounted for a large portion of increased yield. The increased light interception was due to the tree architecture, which caused the tree canopy to grow partially over the row, allowing less
light to fall on the ground. However, of the sunlight that was intercepted, only a portion will be used for fruit growth, and some will be used for tree growth.

Another index of tree efficiency is the partitioning index. This is the amount of fruit produced in relation to amount of vegetative growth produced, expressed as kilograms of fruit per square centimetre of trunk cross-sectional area (TCA). TCA has proved to be a useful basis on which to express yield per tree size. This indicates how well the tree partitions its photosynthetic resources into fruit. Robinson et al, (1991) found that the Y trellis performed well in the partitioning index.

The efficiency of converting light energy into fruit is a measure of the efficiency of the training system to produce carbohydrates from intercepted sunlight and convert a large proportion of these carbohydrates into fruit (Robinson, 1993). In the long term, this conversion efficiency would include the effects of sunlight on return bloom, fruit set, fruit size, skin colour, and photosynthetic efficiency. In the study by Robinson et al (1991), the highest conversion efficiency was attributed to the Y trellis system.

Interestingly, the Y trellis is synonymous with the Tatura Trellis, which is the forerunner of the Open Tatura used for the work reported later in this study. The Open Tatura was selected given that pear trees generally require more light (by up to 20 per cent) (Dirix, 1995) than apples for the same conversion efficiency of light into fruit.

**Third Concept** - Early yields during the first 5 to 7 years of an orchard’s life have a large impact on the return to investment of a new orchard. With longer time between planting and full production (normally 7 to 10 years), and the high level of investment required for a new high density orchard, yields in the early years have an unusually large impact on the lifetime profitability of the orchard. Robinson (1993), Jackson and Palmer (1989), van den Ende (2001) found that tree density is the single most important factor affecting early yields. High density training systems studied in several comparative long-term field trials by Robinson et al (1991), showed that cumulative yields of apples have been higher for all of the high density systems. There was a linear relationship between yield and tree density over the first 10 years of the orchard’s life for the high density systems, indicating that cumulative yield can be increased by increasing tree density. This has been the principal reason for the worldwide effort to increase tree densities. As tree densities increase, so do establishment costs due to the large number of trees and associated support systems. This makes early yield essential to the cost-recovery and success of high density orchards.

It can be concluded from these concepts, that a modern training system should integrate high light interception, good light distribution within the canopy, and high tree density for early production (Jackson 1980, 1985). If these concepts could be applied to Packham, growing Packham pears may become profitable.

The goals when establishing a new orchard, or changing to a new training system are to obtain high yields per hectare, high packouts, minimise labour costs, and obtain efficient targeting of sprays. Flores (1997) points out that high density planting can keep trees lower and thinner and so the use of spray material will be considerably lower, since fewer pesticides are used per unit of land area. Labour requirements and therefore costs will drop and pruning and harvest will be simplified once the orchard is
established. By planting at higher density, higher production per unit of land area is possible.

However, increasing tree density for early production must be tempered by the high cost of nursery trees and the need to manage the orchard when the trees are mature (van den Ende, 2000). Yield can in itself be taken too far at the expense of fruit quality and cropping consistency. The aim is to achieve a balance between tree growth and production of quality fruit that maximises profit. Only a balanced tree can then give balanced cropping.

**GROWTH AND FRUITING HABITS**

This chapter provides a basis for understanding how a Packham pear grows and how it responded to the factors that were investigated.

The growth of a pear can be divided into two stages: the cell division stage and cell enlargement stage. Both stages influence fruit size at harvest. For about 50 days after full bloom cells in fruit flesh increase rapidly. After these 50 days, the cells start to fill up with water and sugars (Faust, 1989). The growth curve of the pear is sigmoidal, when fruit volume or weight is plotted as a function of time (Figure 2). The complete sigmoidal curve does not occur with the pear, because the fruit is picked immature and ripened off the tree. If left on the tree to ripen, growth would level off and be sigmoidal.

![Figure 2. Seasonal growth curve for pear has a typical S-shaped curve.](Source Westwood, M.N. (1993))

Strydom (1997) uses a number of examples to describe the growth and fruiting habits of the pear. The pear displays strong apical dominance and is not willing to form lateral branches. It is a challenge to subdue this apical dominance and develop trees that are strong in the base and become progressively 'softer' (weaker) towards the top. Pears are less responsive to bio-regulators to force shoot development.
Newly planted nursery trees suffer from a phenomenon called transplant shock. Water movement from the soil to the atmosphere through a tree is a continuum. This continuum is broken when nursery trees are lifted from the nursery and must be re-established when trees are planted. For re-establishment of the continuum, good root-soil contact is necessary especially since the root surface area has been reduced during lifting (Strydom, 1997). When good root-soil contact is re-established, pear trees on *Pyrus* calleryana D6 can tolerate wet soils.

Relative to other fruit crops (except for stone fruit), the availability of size-controlling rootstocks that have good compatibility characteristics, remain a limiting factor for pears. In Australia Packham trees on *Pyrus* calleryana D6 turned into large vigorous trees. A worldwide search for an M.9 equivalent rootstock for pear has so far failed. Quince rootstocks have been used for growing pears in Europe. One of the first was Quince A (or Angers), which originated in France and is widely used as a rootstock throughout Europe. However, most pear varieties in Australia, particularly Packham and WBC need a compatible interstock with quince (Campbell, 2000). Pear trees on quince do not perform well in countries with long hot summers.

Severe pruning of young trees, which created many limbs and forks, often exacerbated vigour of Packham trees. While the search for the elusive size-controlling rootstock is going on, the issue of pollination and fruit set also present challenges. Compared to other fruit crops, pear flowers and those of Packhams in particular, are relatively unattractive to bees. Pears do not have a definite ‘king bloom’, so that the flower, which opens first, does not necessarily give rise to the largest fruit. Collectively, the peculiarity in growth and fruiting habit and the higher sunlight requirement of the pear tree tends to exacerbate the problem of attaining high yields. However, once in full production, the plateau yield of a high density Packham orchard can be 30 to 40 percent higher than the plateau yield of apple, but early yields are lower for reasons mentioned previously.

**PRODUCTION AND COST RECOVERY**

It is still generally accepted in the Goulburn Valley, that it takes about 7 years for conventionally planted Packham trees to produce a commercial crop. The orchard may finally return a profit when 10 or 12 years old. Delaying production only postpones the return on investment and delays profitability. With rising costs and the market uncertainty facing the industry, any production delay can accelerate or even cause permanent investment loss.

The goal for any orchard planting is to make a profit. Once the orchard is planted, the grower cannot simply reverse this process. Careful planning is essential and must precede any decision, so mistakes are avoided or at least minimised. After planting, the management practices adopted must therefore promote early production of marketable fruit and should be used to maximise production in a cost-effective manner throughout the life of the orchard (Myers and Savelle, 1996). A number of factors influence early production and thereby reduce the risk of investment loss. However, these factors are
based on certain principles and practices of training and pruning that are common to any orchard system.

**APICAL DOMINANCE AND GROWTH**

The phenomenon of apical dominance refers to the tendency for a tree to exhibit active growth in the terminal regions of shoots and branches. This growth dominates and thereby influences the number lateral shoots formed, the length of lateral shoots, and the angle at which shoots develop relative to the limb (Stebbins, 1980). The intensity of apical dominance varies between fruit tree species and varieties. Pear trees tend to exhibit strong apical dominance and growth is strong in the top of the tree and weak in the base. Lateral branches of pear trees have narrow crotch angles, which make the trees upright. Strong apical dominance tends to favour vegetative growth at the expense of flower bud production (Myers and Savelle, 1996). This should be considered when new pear orchards are established so that appropriate training and pruning techniques are used to influence the degree of apical dominance. The aim is to achieve a balance between vegetative growth and flower bud formation.

Apical dominance results from the interaction of a number of endogenous plant hormones. These include cytokinin and auxin. Cytokinins are produced in the root tips in spring and move up through the xylum to the tips of shoots. This causes the apical buds to break dormancy. Cytokinins are also involved in cell division and the transport of carbohydrates and nutrients to developing tissues. Next, the hormone auxin is produced in quantity by these active buds, stimulating vascular connections and thus developing preferential accumulation of stored nutrients, bio-regulators and carbohydrates. Auxins produced in these active apical buds and newly expanded leaves move down the shoots by gravity through the phloem and inhibit buds from developing into shoots. As buds become more and more distant from the growing apex, or if the flow of auxin is temporarily stopped by way of scorning or notching, buds are released from the auxin influence and may develop as lateral shoots.

Pear trees in conventional orchards are free-standing and vase-shaped. Pruning is most commonly used to alter apical dominance and is carried out in winter. Lateral branches and upright shoots are indiscriminately headed. In spring the trees respond with strong vegetative regrowth from buds immediately below the heading cuts. The regrowth is in direct proportion to the severity of pruning (Forshey, 1986). Dormant heading cuts delay when trees come into production.

Barden et al., (1989) found that in apple trees, the number and length of lateral shoots that develop after pruning are relative to time and severity of pruning, and age of wood. As pruning severity increases, shoot number decreases and average shoot length increases. This is due to the decrease in the total number of growing points, the removal of apical buds that produce auxin, and the temporary loss of apical dominance. The opportunity to see if this growth pattern applies to Packham pear trees grown on modern high density training systems has not been investigated.

**POLLINATION AND FRUIT SET**
Pollination is the transfer of pollen grains carrying the male genetic material from the polliniser, to the female part of the flower by the pollinator (the bee) (Lombard, 1982). Since Packham flowers are self-sterile (Wauchope, 1968), flowers will not produce fruit without the transfer of pollen from another variety (cross-pollination). Inadequate provision for cross-pollination and/or no introduction of bees during flowering often resulted in poor fruit set and misshapen fruit (van Heek, 1984). Pear flowers also have a short effective pollination period, especially on vigorous rootstocks (Strydom, 1993).

Inadequate cross-pollination is further exacerbated when pear flowers must compete with other flowering species that are more attractive to bees. Plants such as cape weed and apple are more preferred by bees than pear blossoms are. Pear nectar only contains 7 per cent sugar, while apple nectar has 23 per cent sugar.

**FACTORS INFLUENCING EARLY PRODUCTION**

**Branch positioning.**
Tree training can play a major role in affecting early production. In apples, the technique of bending branches to flatter angles has been shown to improve flowering, fruit set, and yield (Mielke, 1993). Some growers who have tried to manipulate pear shoots felt that production had been increased, but the degree of increase was uncertain and the limited data available for pears meant that evidence is anecdotal at best. To generate some hard data, Mielke conducted an experiment on d’Anjou pears trained to an intensive Central Leader system and used a range of tree training techniques. Production was achieved in the third year and this was attributed to the positioning of lateral branches at flatter angles.

Positioning branches at flatter angles is one method that helps to achieve the general objective of orchard management to maximise fruit production while minimising growth of unproductive wood (Myers and Savelle, 1996).

**Tree size at planting.**
The cost-effectiveness of a high density orchard is determined by the number of years it takes to get trees into production for a quick return from fruit. Rapid tree growth is essential in the early stages at least until trees fill their allotted space, after which low vigour and high fruitfulness must be induced and maintained (Jerie et al, 1989). Knowing the effect of nursery tree size on early production would help growers decide whether the higher purchase cost of a large nursery tree is offset by a larger canopy surface area and an increase in yield.

The initial physical characteristics, e.g. size and number of lateral branches of nursery trees, are factors that affect growth of young trees. Substantial production in year 2 will depend very much on tree quality as well as a high standard of management during the establishment phase (Lawes et al, 1997). Research with apples has shown that:

- More trees produced side branches when they were worked on rootstocks of large size.
- Increased numbers of feathers (branches) resulted in higher yield.
• Early yield was positively correlated with thickness of the trunk of the nursery tree.
• Care with planting nursery trees improved tree growth and precocity.
• The effects of nursery tree quality on growth and yield could persist for many years.

The same should also be true for pears (Lawes et al., 1997). Trees available from nurseries may vary in a number of ways. There is a choice between 1- or 2-year old trees. Thus tree size will differ, and this may correlate with growth rate in the orchard. There may be a risk with planting trees lifted 2 years after budding, as transplant shock from the nursery to planting in the orchard can be severe and can limit tree establishment (Strydom, 1997). This is more likely where the transplanted tree has a small root mass that is not in balance with the large top - a situation that demands a high standard of early tree care (Lawes et al., 1997; Strydom, 1997). Nursery trees of good quality were found to be of great importance in achieving the ideal orchard tree – based on its size, complexity, form and precocity. Van den Ende and Strydom (1998) described nursery apple trees of good quality as possessing the following characteristics:

• Trees are uniform in size and structure,
• Leaves have not been artificially removed in the autumn,
• Trees are free of pests and diseases,
• Trees have not been dug until fully dormant,
• Trees have 6 or more feathers between 500-800 mm from the ground,
• Feathers are 300-500 mm long and obey the 3-to-1 rule,
• Roots have grown evenly around the shank with many fine roots,
• Trees are about 1.5 – 1.8 m tall.

**TRAINING SYSTEMS FOR PEARS**

Compared with apples, there has been little research in Australia on the use of high density training systems and tree management techniques to induce early bearing to improve pear production. The majority of pear growers persist with orchards that have large widely spaced trees. Many are reluctant to adopt high density training systems and the associated management techniques, even though the benefits of high density planting for apples and stone fruit are recognised. Wertheim and Wagemakers (1994), proponents of high density planting, say it is sensible to perform density trials with important pear cultivars in the various pear growing areas to evaluate the production and economic benefits of a high density training system before advice is given to growers. Mielke (1993) points out that in apples high density systems can play a major role in affecting early production. In apples, manipulative tree training techniques, such as bending branches to flatter angles, improve flowering, fruit set, and yield. Additional techniques (chemical or mechanical treatments) have shown to stimulate buds to break and form lateral shoots. While this has been shown many times with apples, there was no hard data available for pears.

As with apples, it is expected that intensive pear production will be looked at favourably, if evidence is available that supports the use of manipulative techniques in a high density planting.
The manipulative techniques described earlier have not been practical and cost effective on conventionally planted pear trees. Manipulative techniques may however be possible and practicable on trees in high density training systems. If this proves to be effective, it will offer Packham growers an alternative method of pear production.

With most fruit crops, yield is almost entirely derived from the fixation of carbon by way of photosynthesis. When water and nutrients are not limiting, the photosynthetic potential of the tree is determined by the ability of the tree to intercept and distribute the available solar energy and to maximise its use in photosynthesis. Several factors can determine the tree’s potential for high yields. Training systems (i.e. Tatura Trellis) and tree management (i.e. tying and spreading of branches) influence the interception and distribution of sunlight, and therefore yield. Other components such as pest and disease control, irrigation and soil management, size and quality of nursery tree, rootstock, flowering, pollination and fruit set are also important for achieving high yields of pear.

In young apple trees, early and sustained production is possible by incorporating a number of manipulative techniques to help trees fill their allotted spaces quickly. These include chemical methods using sprays of bio-regulators and mechanical methods such as scoring and notching of the leader (trunk), plucking the terminal part of the leader, and looping the leader. These methods help stimulate branch development by forcing dormant buds to break in spring. By stimulating lateral branching, more new wood is developed in the first year helping trees fill their allotted space quickly. This method tends to induce early bearing and increase the prospect for early yields and quick returns on investment. Although such work was done with apple trees (Miller, 1986), little is known about such practices with Packham trees.

THE PROJECT

The objective of this project was to establish and operate a demonstration orchard for 6 years using 2 training systems. The project covers 3 main experiments and 4 supplementary experiments and a profitability study.

Conducting experimental work on a commercial orchard presented certain limitations. While grower cooperation and support has been most generous and accommodating, the economic reality meant, that compromises had to be made in order to satisfy the commercial interest and the objectives of this project. For these reasons, the standard experimental design was not followed and a statistical analysis of results was not possible.

Soil description and preparation
The soil type of the demonstration orchard consisted of Goulburn clay loam, which had been under perennial pasture for some years. Goulburn clay loam, a grey-brown earth, is widely distributed in the Shepparton Irrigation Area (Skene and Poutsma, 1962). The soil was deep-ripped with 3 passes using 3 tines and then 1 tine was used from the alternate end of the block to ensure the entire area was deep-ripped. Soil analysis
results did not recommend adding gypsum or lime. Hilling up of the rows prior to planting was done using a plough and Merrigum grader.

Size of planting and duration of the project
The size of the demonstration orchard was 2.7 hectare, of which half was planted to Open Tatura and the other half to Central Leader (for more details see Training Systems in this section).

The project began in 1997 when Packham trees on Pyrus calleryana D6 rootstock were planted in the orchard of J.H. & J.M. Pottenger, Shepparton East. The project was completed in 2003. The first 3 years (1997 to 2000) were the formative years when the tree canopies were developed. The next 3 years (2001 to 2003) were the productive years, when trees were expected to settle down and produce commercial crops.

Trees for pollination
This project used the Josephine variety as polliniser, because a) its flowering coincides with that of Packham, b) it is widely used for that purpose in the Goulburn Valley, and c) Josephine pears have good commercial value.

In each row, Josephine trees were planted as pollinisers. The concentration of polliniser trees was 12 per cent and 8 per cent for Open Tatura and Central Leader respectively. The decision to use more polliniser trees in the Open Tatura is because this system has a greater bearing surface area and higher concentration of flowers than the Central Leader trees.

Trunk guards and weed growth
Immediately after planting, trunk guards were placed around young nursery trees to protect them against damage from herbicide sprays and hares. Pieces of plastic were wrapped around the trunk and stapled. Herbicide sprays for weed control were used in spring and summer each year consisting of pre-emergent, contact and residual herbicides.

Fertiliser application
Fertiliser and water requirements were formulated to maximise growth of the young trees in both training systems. Soil and leaf samples were taken on 2 occasions and analysed to check soil pH and the nutrient status of the trees. A number of different fertilisers were applied from spring 1998 onwards. Major nutrients such as nitrogen and calcium in the form of calcium ammonium nitrate and superphosphate were broadcasted under the trees, while trace elements such as zinc, boron and magnesium were applied as foliar sprays. In the last two years of the experiments, liquid nitrogen fertiliser (Green N™) was applied through the irrigation system.

Irrigation
Snapjet™ microjet sprinklers with a delivery rate of 25 L/hour were used. Tensiometers and a small soil auger were used to check soil moisture. Seven weeks before anticipated harvest the soil was kept wet to maximise fruit growth.
The aim of planting intensively is to speed up and increase returns (van den Ende and Strydom, 1998). Present trends in the Goulburn Valley are focussed on 2 training systems namely Open Tatura and Central Leader. Open Tatura is a system that evolved from the Tatura Trellis developed in 1973 (Chalmers and van den Ende, 1976). The Open Tatura differs from the Tatura Trellis because in each row there are 2 lines of trees that alternate left and right and there is 1 leader per tree, and the angle of the ‘V’ is 45°. It is open, because a narrow strip of 300 mm wide separated the lines of trees within each row. This allowed more sunlight into the lower part of the canopy. The Central Leader system used a single vertical extension of the trunk from which all scaffold and fruiting branches originated. Although both systems offer similar tree physiological benefits, they differed vastly in tree architecture and tree density. Central Leader trees were pyramidal and did not require support, while Open Tatura needed a well-constructed trellis to train and support the trees during their entire life.

Rows in both systems were orientated north-south.

In addition to using 2 different training systems, it was important to evaluate the effect of size of nursery tree on early production in both systems.

Open Tatura
Tree density of the Open Tatura was 2222 trees/ha (4.50 x 1.00 m). Trees were supported by a posts and wire trellis. The angle of each post was 22.5° to the vertical.

One month after planting, trees were trained to form the initial tree structure. Feathers (branches) were trained to flatter angles by tying them to the trellis wires with Klipon™ ties. The flatter a branch was positioned, the more readily it developed flowers and set fruit, hence earlier production (Mielke, 1993a). To further promote branching, a rest-breaking agent was applied on 28th August 1997 at the rate of 3 litres of winter oil per 100 litres of water at ‘green tip’ to force buds to break and form lateral shoots.

The leader and feathers were plucked and the leader was also scored at ‘green’ tip 900 mm from the ground. Plucking refers the removal buds from the terminal part of a leader or shoot when the buds have burst and new growth emerged. It is done to get breaks and avoid the development of blind wood. Scoring is a circular incision through the bark only, and was done to temporarily stop the flow of auxin to the lower buds which gives the buds time to break and form shoots (van den Ende and Strydom, 1998). In addition, buds were notched, by making small horizontal cuts above individual buds, to temporarily stem the flow of auxin. New shoots were fastened to wires using a Max Tapener™.

Central Leader
Rows were 4.50 m wide and trees were planted 2.00 m apart (1111 trees/ha). When the trees were planted, the leaders were singulated by removing competing shoots. To promote branching, a rest-breaking agent was applied at the rate of 3 litres of winter oil per 100 litres of water at green tip to force breaks. The leaders were scored at green tip 900 mm from the ground to promote lateral shoots. In the first 12 months, scaffold branches that developed were spread at 45° to the vertical using wooden or plastic spreaders.
MAIN EXPERIMENT 1.

THE EFFECT OF CHEMICAL AND MECHANICAL TREATMENTS ON BRANCHING OF TREES PLANTED ON OPEN TATURA AND CENTRAL LEADER

Methods and Materials

One month after planting, an experiment was set up to evaluate the effect of different chemical and mechanical treatments on stimulation of lateral branch development in newly-planted pear trees. Leader length, total branch length and number of laterals of 105 large Open Tatura nursery trees and 45 large Central Leader trees were measured on 26th August 1997.

Between 22nd September and 13th October 1997, 21 treatments (11 chemical, 9 mechanical, 1 control) were applied to 105 large Open Tatura trees (21 treatments x 5 trees).
The chemical treatments were:

1. 4% Waiken™ at budswell
2. 8% Waiken™ at budswell
3. 3% winter oil at budswell
4. 5% winter oil at budswell
5. 5% winter oil at budswell and 3% winter oil one week later
6. 3% winter oil +1% Dormex™ at budswell
7. 4% Dormex™ at budswell
8. 3:1 water : Cytolin™ + 0.1% Tween 20 at budswell
9. 3:1 water : Cylex™ + 0.1% Tween 20 at budswell
10. 3% DC Tron Plus™ oil at budswell
11. 3% DC Tron Plus™ oil + 1% Dormex™ at budswell

The mechanical treatments were:

12. After the trees were planted leaders were headed to a height of 1.50 m and feathers were cut back to 100 mm. Leaders were headed again at green tip (double heading) by removing the terminal 3 buds (approximately 50 mm).
13. After the trees were planted feathers were cut back to 100 mm and leaders were headed at 'green tip' (delay-headed).
14. Feathers and leaders were not headed but plucked in spring at 'green tip'.
15. Leaders were looped at 'green tip' for 2 weeks.
16. Leaders were looped at 'green tip' for 2 weeks then scored at 900 mm from the ground.
17. Leaders were looped at 'green tip' for 2 weeks then plucked.
18. Leaders were scored in spring.
19. Leaders were scored then plucked in spring
20. Plastic sleeves were placed over each leader at budswell.
21. Control – nothing was done to the nursery trees.

Nine treatments (8 mechanical, 1 control) were applied to 45 Central Leader trees (9 treatments x 5 single tree) between 22\textsuperscript{nd} September and 27\textsuperscript{th} October 1997.

Length of leader, total length of branches and total number of laterals of the Open Tatura and Central Leader trees were measured after the treatments were applied and measured again in August 1998.

Result

After 2 years of growth, there were no significant differences in the length of leader, total length of branches and total number of laterals between control trees and any of the chemical or mechanical treatments in Open Tatura and Central Leader. This is most likely due to transplant shock having suppressed any responses to the treatments.
Transplant shock is a severe problem of pear trees – much more so than with apple trees.

**MAIN EXPERIMENT 2.**

**THE EFFECT OF NURSERY TREE SIZE AT PLANTING ON EARLY PRODUCTION**

The success of any orchard begins in the nursery and the selection of strong, uniform trees with a good root system does become a critical factor to set the orchard off to a good start. The effect of nursery tree size on early production was believed to be an important factor that needed investigation. This would demonstrate if the size of nursery tree affected precocity of pear trees.

**Methods and Materials**

**Separation of trees into size categories**
The nursery trees ranged in size (height) from large to small. Before the nursery trees were planted, they were separated into 3 size categories: large, medium and small. A local nursery was engaged to grow 2-year-old feathered Packham trees on *Pyrus calleryana D6* seedling rootstocks. A total of 4550 nursery trees were grown. In July 1997, the nursery trees were delivered to the orchard and separated into 3 size groups – large, medium and small based on tree height. Tree height related closely with the circumference of the trunks. There were more medium trees than large or small trees. The planted area for each tree size was kept the same for the 2 training systems.

**Size grouping in the Open Tatura**
The 1.35 hectare Open Tatura block consisted of 23 rows. Each row had 116 Packham trees and 14 Josephine trees. There were 7 rows of large Packham trees (812 trees), 11 rows of medium trees (1276 trees), and 5 rows of small trees (580 trees). In total, the Open Tatura block consisted of 2990 trees made up of 2668 Packham trees and 322 Josephine trees.

In August 1997 (one month after planting), the average size of large, medium and small trees was determined by measuring the butt circumference and length of leader of 57 trees in a randomly selected row of large, medium, and small trees. The circumference of each tree was measured at a pre-determined spot indicated by a ring of white paint.

The measurements confirmed the initial arbitrary groupings by size (Figures 3 and 4). Culver and Till (1967) found that the circumference of the trunk was a reliable measure of tree size. Butt circumference measurements were converted to trunk cross-sectional area (TCA cm$^2$) to conform to an international measurement of trunk size (Figures 5 and 6).
Size grouping in the Central Leader
The 1.35 hectare Central Leader block consisted of 23 rows of trees. Each row had 60 Packham trees and 5 Josephine trees. There were 7 rows of large Packham trees (420 trees), 11 rows of medium trees (660 trees), and 5 rows of small trees (300 trees). In total, the Central Leader block consisted of 1495 trees, made up of 1380 Packham trees and 115 Josephine trees.

In August 1997 (one month after planting) the average size of large, medium and small trees was determined by measuring the butt circumference and length of leader of 57 trees in a randomly selected row of large, medium, and small trees. The circumference of each tree was measured at a pre-determined spot indicated by a ring of white paint. Although size groups were arbitrary selected at time of planting, the size measurements carried out one month after planting confirmed the initial arbitrary grouping by butt size (Figures 4 and 6). However, the length of leader did not turn out as expected which for medium size trees was on average 24.8 mm longer than large trees (Figures 4).

Yield determination.
Weight of harvested fruit was determined by counting the number of wooden bins that were filled or partially filled by the pickers in each section of large, medium and small nursery tree of Open Tatura and Central Leader. Initially we had established the weight of different portions of fruit in a standard wooden bin with 4 boards. These weights were as follows:

- Full bin = 520 kg
- ¼ bin = 390 kg
- ½ bin = 260 kg
- 1 board = 130 kg
- ½ board = 65 kg
- ¼ board = 33 kg

If a bin had different sizes of boards, we calculated the weight of fruit in a bin as a portion of the standard height of the bin, i.e. 630 mm.
Figure 3. Mean leader length at planting of each size group of Open Tatura.

Figure 4. Mean leader length at planting of each size group of Central leader
Figure 5. Mean butt size at planting in each size group of Open Tatura

Figure 6. Mean butt size at planting in each size group of Central Leader.
Results

Effect of nursery tree size on yield.

Table 1 shows the total yield of 6-year-old Packham trees when they were planted as large, medium and small nursery trees on Open Tatura and Central Leader.

Table 1. The effect of size of nursery tree on total yield of 6-year-old Packham pear trees on Open Tatura and Central Leader.

<table>
<thead>
<tr>
<th>Training system</th>
<th>Large trees</th>
<th>Medium trees</th>
<th>Small trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Tatura</td>
<td>62.8</td>
<td>58.1</td>
<td>55.8</td>
</tr>
<tr>
<td>Central Leader</td>
<td>38.5</td>
<td>32.4</td>
<td>26.8</td>
</tr>
</tbody>
</table>

It is an advantage to plant large nursery trees. Planting large nursery trees as compared to small nursery trees increased the yield of 6-year-old Packham trees by 15 and 49 per cent for Open Tatura and Central Leader respectively.

Tree Growth

Large size nursery trees planted on Open Tatura had proportionally the highest TCA increase (Table 2), while in the Central Leader, medium size nursery trees overtook large trees in TCA increase (Table 3).

As production increased in Open Tatura, the amount of carbohydrate being partitioned to vegetative growth in all tree sizes was reduced. In Central Leader trees the crop had not yet slowed down tree vigour as indicated by TCA increases.

It was not expected that Packham trees on seedling rootstock would settle down within 6 years. The results only indicate that, after 6 years, the TCA of large, medium and small Open Tatura trees were less than those of Central Leader trees. This may be due to the start of a root competition effect in Open Tatura, since total length of roots is closely related with the size of the trunk (Mikhail and Walbran 1974). Reduced root growth in Open Tatura resulted in less vegetative growth of the top, and higher yield efficiency than Central Leader (Table 6).
Table 2. Mean TCA (cm$^2$) and TCA increase (cm$^2$) from 1997 to 2002 in large, medium and small trees on Open Tatura.

<table>
<thead>
<tr>
<th>Year</th>
<th>Large trees</th>
<th>Medium trees</th>
<th>Small trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>2.2</td>
<td>1.9</td>
<td>0.7</td>
</tr>
<tr>
<td>1998</td>
<td>8.0</td>
<td>6.5</td>
<td>3.7</td>
</tr>
<tr>
<td>1999</td>
<td>22.0</td>
<td>18.5</td>
<td>13.7</td>
</tr>
<tr>
<td>2000</td>
<td>35.3</td>
<td>30.6</td>
<td>24.4</td>
</tr>
<tr>
<td>2001</td>
<td>44.9</td>
<td>39.5</td>
<td>33.4</td>
</tr>
<tr>
<td>2002</td>
<td>56.4</td>
<td>50.0</td>
<td>42.0</td>
</tr>
</tbody>
</table>

TCA increase 1997-2002 54.2 48.1 41.3

Table 3. Mean TCA (cm$^2$) and TCA increase (cm$^2$) from 1997 to 2002 in large, medium and small trees on Central Leader.

<table>
<thead>
<tr>
<th>Year</th>
<th>Large trees</th>
<th>Medium trees</th>
<th>Small trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>2.4</td>
<td>1.6</td>
<td>0.8</td>
</tr>
<tr>
<td>1998</td>
<td>6.4</td>
<td>7.5</td>
<td>5.5</td>
</tr>
<tr>
<td>1999</td>
<td>18.8</td>
<td>24.6</td>
<td>18.8</td>
</tr>
<tr>
<td>2000</td>
<td>35.0</td>
<td>43.0</td>
<td>33.5</td>
</tr>
<tr>
<td>2001</td>
<td>49.1</td>
<td>61.1</td>
<td>50.6</td>
</tr>
<tr>
<td>2002</td>
<td>67.2</td>
<td>79.0</td>
<td>64.4</td>
</tr>
</tbody>
</table>

TCA increase 1997-2001 63.8 77.4 63.6
MAIN EXPERIMENT 3

THE EFFECT OF TRAINING SYSTEM ON EARLY PRODUCTION

Open Tatura and Central Leader were chosen because these 2 systems allow maximum light interception and optimise light distribution in the tree canopy. The object of this experiment was to determine the effect of training system on early production.

The aim of high density planting is to get trees in production quickly, and maximise yields per hectare with high packouts. We regarded the first 3 years of this project to be the establishment phase, where the trees filled their allotted space both in height and width. Cropping the trees in years 2 and 3 was partly done to contain tree vigour, so that a balance between tree growth and fruiting could be achieved in year 4, 5 and 6, the productive phase.

Indicators of productivity have evolved in an attempt to provide a consistent basis for comparing orchard productivity. The most common of these are kilograms of fruit per square centimetre of trunk cross-sectional area (TCA). TCA has proven to be a useful basis on which to express yield per tree size. This expression is based on the correlation of TCA with tree weight (Westwood and Roberts, 1970), which relates to potential bearing sites and to leaf area (Holland, 1968) and which, in turn, relates to light interception and carbohydrate production. Robinson and Lakso (1991) working with 4 different training systems for apple found, that light interception was strongly correlated with TCA per hectare and the relationship was the same for all systems. However, this relationship is only relevant for young orchards, because TCA per hectare continues to increase but per cent light interception levels off once the trees have filled their allotted space. Therefore, this simple measure should be a useful method of estimating light interception in the early years. Robinson et al, (1991) have shown that TCA per hectare is highly correlated with yield in the first 10 years of an orchard’s life.

Yield has also been correlated with canopy volume, but is not as reliable as TCA per hectare is, and canopy volume is difficult to determine accurately. Within the range of natural-form, and when trees have been lightly pruned, the canopy volume can be correlated with tree size and light interception. It is obvious, though, that leaf area density and number of fruiting sites within the volume, especially in restricted canopies, can affect these relationships.

The efficiency of converting light energy into fruit is an integrated measure of efficiency of the training system to produce assimilates (carbohydrates) from intercepted sunlight (assimilation efficiency) and to partition assimilates into fruit (partitioning index) (Robinson, 1992). The ratio of yield to the increase in TCA is an estimate of partitioning between fruit and vegetative growth, and indicates how well the tree partitions its carbohydrate resources into fruit. Thus, besides differences in light interception, training systems can also differ in how the trees use the products of the intercepted sunlight.
It is difficult and onerous to measure directly the annual amount of vegetative growth; but the annual increase in TCA is a reliable measure of tree growth (Robinson, 1992). Thus, between 1997 and 2002, the trunk circumference of 57 trees from each of the large, medium and small Open Tatura and Central Leader trees were measured for growth.

Methods and Materials

The 2 training systems were the Open Tatura and Central Leader. The trellis for the Open Tatura was erected in April 1997. The Central Leader did not require a support system. This experiment was designed to investigate the effect of 2 high density training systems on early production of Packham trees and sustained production of fruit of high quality.

Two-year old Packham trees on Pyrus calleryana D6 rootstock were planted on an orchard block of 2.7 hectares (6.75 acres) in July 1997. The block was divided into 2 sections of 1.35 hectares. One section accommodated the Open Tatura and the other section Central Leader. Arrangements were made with the nursery to grow trees specifically for the 2 training systems. A total of 4550 trees comprising 4108 Packham trees and 442 Josephine trees (for cross pollination) were purchased.

Open Tatura

Open Tatura has a V-shape canopy (Figure 7 and Plate 1). It is open, because trees within each row are separated by a narrow strip of 300 mm wide. This system evolved from the Tatura Trellis, which was developed at the Tatura Research Institute in the Goulburn Valley of Victoria in 1973 (Chalmers and van den Ende, 1976; Chalmers et al, 1978). The Open Tatura allows the orchard to intercept a high percentage of sunlight and have a good distribution of sunlight throughout the canopy.

Space between the V gave orchard workers easy access to both sides of the canopy. The angle of the canopy was 22½° to the vertical. The Open Tatura had the following features:

- High tree density for early production. Density was 2222 trees per hectare.
- The thin canopy allowed trees to capture a high percentage of sunlight to produce maximum yields.
- The thin canopy allowed good distribution of sunlight to produce fruit of high quality.
- The angle of the tree canopy and arrangement of the tree structure facilitated pruning and harvesting.
- Width of row from centre to centre was 4.5 metres.
- Each row consisted of 2 lines of trees that are separated by a 0.30 m wide strip a) to optimise distribution of sunlight throughout the canopy, and b) to have easy access for summer pruning.
- Trees alternated left and right, in a diamond shape. Roots were 1.0 m apart but the trees on each side were 2.0 m apart. This unique arrangement effectively crowded the roots for control of vigour, but not the trees.
- Josephine was used as polliniser trees spaced at a ratio of 1:11 Josephine to Packham in each row.
• The Open Tatura allowed existing orchard equipment to be used. A total of 2990 trees were planted in the 1.35 hectare Open Tatura block comprising of 2668 Packham and 322 Josephine pear trees. The block consisted of 23 rows. Each row had 116 Packham trees and 14 Josephine trees planted near each trellis frame along the length of the row.

**Materials for trellis assembly**
The trellis was erected before the trees were planted. Pine poles, which were treated with copper, chromium, arsenate (CCA) were used. The poles for the end frames had a diameter of 100-125 mm, and 75-100 mm diameter for frames in the rows. Poles were 3.6 m long and were driven into the ground with a pole driver. Within each row, frames were placed 15.0 metres apart. Screw anchors of 2.1 m long were used. Four high-tensile wires of 2.65 mm diameter were used on each side of the trellis (total of 8 trellis wires).

**Central Leader**
The Central Leader trees had a single vertical trunk from which all scaffold and fruiting branches originated (Figure 8 and Plate 2). The trunk is referred to as the leader. When reference is made to the training system, it is written as the Central Leader system. Central Leader for pears is different from apples in that no distinct lower tier of scaffolds was developed. Scaffolds were arranged around the leader and became progressively weaker towards the top. No support system was used.

Weight of harvested fruit was determined by counting the number of wooden bins that were filled or partially filled by the pickers in Open Tatura and Central Leader. Initially we had established the weight of different portions of fruit in a standard wooden bin that was 630 mm high and had 4 boards (see page 20).

**Fruit size, fruit quality and fruit maturity assessments.**
A sample of 200 fruit was taken from each of the large, medium and small tree sections in the Open Tatura and Central Leader to determine average fruit size, skin defects and undersized fruit according to the Recommended Export Pear Standards Chart. Each fruit was carefully examined and the following criteria applied based on the chart:

- Russet
- Limb-rub
- Sunburn
- Misshapenness
- Light Brown Apple Moth damage
- Codling Moth damage
- Black Spot damage
- Undersize (< 56 mm diameter)
- Mechanical Injury
- Acceptable as marketable fruit

A sub-sample of 15 fruit was randomly taken from the above samples to determine fruit maturity based on firmness and total soluble solids (TSS) in °Brix. A McCormack pressure tester (penetrometer) fitted with an 8.0 mm diameter plunger. The tester was mounted on a modified drill press stand to give better control over the force applied.
The test was based on the method described by Little and Holmes (2000) for firmness testing of apples and pears. A strip of skin was removed with a vegetable peeler (to give a uniform thickness of skin removed) on opposite sides of each fruit.

Fruit was rested on the drill stand’s firm surface and the plunger tip lowered and pressed into the fruit flesh. Firmness was read to the nearest 0.25 kg force. The mean firmness was calculated from the 30 readings.

The same 15 fruit were then prepared to determine TSS. A segment was cut from the top half of each pear and placed into a household garlic press. Enough juice was extracted to cover the Atago ATC-1E refractometer prism surface. The TSS in °Brix was read to nearest 0.2, and the mean calculated of the 15 readings.

The fruit was taken to Geoffrey Thompson Packing Company Pty. Ltd., Shepparton, where it was graded and stored.

**Trunk cross-sectional area (TCA) and yield efficiency**

Butt circumferences of 57 large trees, 57 medium trees and 57 small trees in Open Tatura and Central Leader were measured in 5 consecutive winters (1997 to 2002). The measurements were made on the same trees at about 200 mm above the ground. A ring of white paint was used to mark the spot where the circumference of each tree was measured. Trunk circumferences were then converted to trunk cross-sectional area using the conversion table of Westwood (1993).

## Results

**Effect of training system on yield.**

The results in Table 4 show, that the total accumulated yield of 6-year-old Packham trees on Open Tatura was almost double than the total accumulated yield of Central Leader Since tree density of Open Tatura was double the tree density of Central leader (2222 vs. 1111 trees/ha), the results indicate that, in the early years, the tree training system is less important than the tree density. The same observations were reported for apple trees (van den Ende, 2001).

Total yield of the Josephine polliniser trees shows a similar trend as for Packhams (Table 5). Yields of Josephine exceeded those of the Packham trees.
Figure 7. Open Tatura.

Plate 1. - Open Tatura planted in 1997 showing tree with feathers (lateral branches)

Figure 8. Central Leader.

Plate 2. Central Leader planted in 1997
Table 4. The effect of training system on early production of Packham.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Tatura</td>
</tr>
<tr>
<td>1999 (2\textsuperscript{nd} year)</td>
<td>1.9</td>
</tr>
<tr>
<td>2000 (3\textsuperscript{rd} year)</td>
<td>2.6</td>
</tr>
<tr>
<td>2001 (4\textsuperscript{th} year)</td>
<td>33.4</td>
</tr>
<tr>
<td>2002 (5\textsuperscript{th} year)</td>
<td>8.7</td>
</tr>
<tr>
<td>2003 (6\textsuperscript{th} year)</td>
<td>15.3</td>
</tr>
<tr>
<td><strong>Total yield</strong></td>
<td><strong>61.9</strong></td>
</tr>
</tbody>
</table>

Table 5. The effect of training system on early production of Josephine (polliniser).

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Tatura</td>
</tr>
<tr>
<td>1999 (2\textsuperscript{nd} year)</td>
<td>0</td>
</tr>
<tr>
<td>2000 (3\textsuperscript{rd} year)</td>
<td>0.5</td>
</tr>
<tr>
<td>2001 (4\textsuperscript{th} year)</td>
<td>43.1</td>
</tr>
<tr>
<td>2002 (5\textsuperscript{th} year)</td>
<td>17.9</td>
</tr>
<tr>
<td>2003 (6\textsuperscript{th} year)</td>
<td>20.4</td>
</tr>
<tr>
<td><strong>Total yield</strong></td>
<td><strong>81.9</strong></td>
</tr>
</tbody>
</table>
Effect of training system on yield efficiency.
Yield efficiency of Packham trees on Open Tatura was slightly better than Central Leader (Table 6). This is most likely a direct result of close planting. After 6 years of growth, closely planted Open Tatura trees had smaller trunks than Central Leader trees as a result of restricted root growth (Mikhail and Walbran 1974). Restricting growth of roots caused a decrease in overall vegetative growth, as determined by the size of the trunk, and an increase in fruitfulness (yield). Central Leader trees had more soil space, which resulted in a larger root system and a larger, more vigorous tree that was less fruitful and therefore less efficient in producing fruit than Open Tatura.

Table 6. The effect of training system on yield efficiency of 6-year-old Packham trees.

<table>
<thead>
<tr>
<th>Training system</th>
<th>TCA/tree (cm²)</th>
<th>Yield kg/tree</th>
<th>Yield Efficiency (kg/cm² TCA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Tatura</td>
<td>49.5</td>
<td>27.8</td>
<td>0.561</td>
</tr>
<tr>
<td>Central Leader</td>
<td>70.2</td>
<td>30.0</td>
<td>0.427</td>
</tr>
</tbody>
</table>

Fruit quality and packouts
The packouts as shown in Table 7 were disappointing. Limb-rub and misshapenness were the major causes of the low packouts. Most of the limb-rub occurred in the tops of the trees, especially in Central Leader. This problem may be rectified in a few years when the leaders and fruiting wood in the tops become more rigid, and detailed pruning is carried out to prevent limb-rub (Figure 9).

The unacceptable high percentage of misshapen fruit must be contributed to Josephine being a poor polliniser for Packham. In fact, the yield figures indicate that Packham has been a good polliniser for Josephine. Six-year-old Josephine trees outperformed Packham despite having introduced twice the recommended number of beehives per hectare, and Josephine was a smaller pear (152 g) than Packham (169 g).

According to the Apple and Pear Maturity Assessment (Revised Edition 1995) by Colin R. Little, fruit has been harvested according to the recommended firmness of > 6.0 kg (Table 8).
Table 7. Percentage export grade fruit, fruit with skin defects and undersized fruit of Packham on Open Tatura (OT) and Central Leader (CL), 4<sup>th</sup> (2001), 5<sup>th</sup> (2002), and 6<sup>th</sup> (2003) harvest.

<table>
<thead>
<tr>
<th></th>
<th>4&lt;sup&gt;th&lt;/sup&gt; harvest</th>
<th>5&lt;sup&gt;th&lt;/sup&gt; harvest</th>
<th>6&lt;sup&gt;th&lt;/sup&gt; harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OT*</td>
<td>CL*</td>
<td>OT</td>
</tr>
<tr>
<td>Export grade</td>
<td>53</td>
<td>48</td>
<td>58</td>
</tr>
<tr>
<td>Russet</td>
<td>14</td>
<td>31</td>
<td>3</td>
</tr>
<tr>
<td>Limb-rub</td>
<td>10</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Sunburn</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Misshapenness</td>
<td>13</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Undersize</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>LBAM*</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Codling moth</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cuts and stem punctures</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

* Light Brown Apple Moth

Table 8. Firmness and TSS of Packham on Open Tatura (OT) and Central Leader (CL), 4<sup>th</sup> (2001), 5<sup>th</sup> (2002), and 6<sup>th</sup> (2003) harvest

<table>
<thead>
<tr>
<th></th>
<th>4&lt;sup&gt;th&lt;/sup&gt; harvest</th>
<th>5&lt;sup&gt;th&lt;/sup&gt; harvest</th>
<th>6&lt;sup&gt;th&lt;/sup&gt; harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OT</td>
<td>CL</td>
<td>OT</td>
</tr>
<tr>
<td>Firmness (kg force)</td>
<td>6.4</td>
<td>6.6</td>
<td>6.1</td>
</tr>
<tr>
<td>TSS (°Brix)</td>
<td>13.1</td>
<td>13.2</td>
<td>13.9</td>
</tr>
</tbody>
</table>

SUPPLEMENTARY EXPERIMENT 1.
THE EFFECT OF DISTANCE OF POLLINISER TREES ON MISSHAPENNESS, SIZE AND NUMBER OF SEEDS OF PACKHAM Pears.

Orchardists in the Goulburn Valley prefer Josephine as polliniser for Packham, because Josephine has good market value. However, Josephine may not be the most reliable polliniser, and has often been planted at the incorrect ratio.

Previous studies on pollination and fruit set of Packham have determined that this variety is self-sterile but can set fruit parthenocarpically. Parthenocarpic fruit had 3 times more misshapen fruit than did fruit with seed. Also, fruit weight and number of misshapen fruit increased the further away the Packham trees were from the Josephine polliniser trees. The more seeds the better the shape (van den Ende 2002). Packham had more flowers and more pollen per flower than did Josephine. Bees preferred to work Packham rather than Josephine flowers (Jackson and Sharifani, 1997).

In this experiment we wanted to determine a) if Josephine has been a reliable polliniser for Packham, b) if the ratio of Packham trees to Josephine trees has been adequate for cross-pollination in Open Tatura, and c) the importance of having fruit with seeds.

Method

A few days before the anticipated harvest in 2000 and 2002, we counted the number of fruit on each tree in 2 rows of Open Tatura (total of 232 trees), noting down the positions of the Josephine trees. We also counted the misshapen fruit.

In 2000 we sampled at random 100 harvested fruit from Packham and Josephine on Open Tatura. We measured the diameter before we cut each fruit and counted the number of seed.

Results

Figure 10 clearly shows that the Packham trees next to a Josephine tree had the highest number of fruit, and Packham trees furthest away from a Josephine tree had few fruit. The effect of distance of polliniser tree on fruit set of Packham was even more pronounced in the middle of the row where we had not planted a Josephine tree and the distance was 30 m instead of 16 m between Josephine trees. It appeared that even 16 m between Josephine trees was too far for adequate cross-pollination in Open Tatura.

If Figure 11 is compared with Figure 10, it becomes obvious, that inadequate cross-pollination resulted in a high percentage of misshapen fruit. Packham trees close to Josephine trees had less misshapen fruit than trees further away.
Figure 9. The effect of pruning on packout of Packham.

Figure 12. The effect of number of seeds on size and shape of Packham pears.
Figure 10. The effect of distance of polliniser (red bar) on fruit set of Packham.

Figure 11. The effect of distance of polliniser (red bar) on shape of Packham.
The importance of having adequate seeds in fruit is shown in Figure 12. Packham pears with more than 4 seeds had good size and good shape. Fruit shape and size became worse as seed number decreased.

Josephine had an average of 6.0 seeds per fruit and Packham 3.8 seeds per fruit, indicating that Josephine benefited more from Packham than visa versa.

**SUPPLEMENTARY EXPERIMENT 2.**

**THE EFFECT OF REDUCED BUD LOAD ON FRUIT SET AND YIELD OF PACKHAM.**

Young Packham trees flower profusely, but fruit set is often poor. Competition between fruitlets for stored carbohydrates and nutrients is severe. We wanted to see, if we could improve fruit set by removing about 50 per cent of the fruit buds or flower trusses.

With detailed pruning a large proportion of flower buds is removed when spurs are trimmed and fruiting wood is renewed. Detailed pruning is expensive, but can lead to strong buds, large fruit and minimal skin blemishes, especially limb-rub.

**Methods**

Experiments were carried out in 2001 and 2003 on Packham flowers, which were pollinated by Josephine pollen. Trees were on Open Tatura and close to a Josephine tree. We made sure that the trees were also near a beehive. Bees were introduced when 5 per cent of the flowers had opened.

In the spring of 2001 we broke off about 50 per cent of the trusses at ‘5-finger’ stage, leaving the vegetative basal parts of the trusses in tact on 3 trees. No trusses were removed on the 3 control trees.

In the winter of 2003, we pruned 6 trees according to the 1,2,3 rule of renewal pruning (van den Ende 2002), and spur wood was pruned to a single upright fruit bud. Another 6 trees were selected nearby which were pruned by staff of the orchardist. These pruners followed the 1,2,3 rule, but did not do detailed spur pruning.

**Results**

37
Results in Table 9 show that when half the flower trusses were removed, percentage fruit set almost doubled as compared with trees which were not thinned. However, yield and fruit size were not affected. This phenomenon is known as the compensatory effect, and occurs with apple trees when a significant number of flowers are removed by detailed spur and renewal pruning.

Table 9. The effect of removing about 50 per cent of trusses on fruit set, yield and weight of fruit of Packham (2001).

<table>
<thead>
<tr>
<th></th>
<th>Number of trusses per tree</th>
<th>Number of flowers per truss</th>
<th>Number of flowers per tree</th>
<th>Per cent fruit set</th>
<th>Fruit per tree</th>
<th>Weight per fruit (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trusses removed</td>
<td>159</td>
<td>5.9</td>
<td>938</td>
<td>7.2</td>
<td>68</td>
<td>197</td>
</tr>
<tr>
<td>(3 trees)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trusses not removed</td>
<td>300</td>
<td>5.8</td>
<td>1740</td>
<td>3.8</td>
<td>66</td>
<td>184</td>
</tr>
<tr>
<td>(3 trees)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Detailed pruning left fewer flowers on the tree than trees that were not detailed pruned. Detailed pruning increased fruit set and yield per tree, and trees had less limb-rubbed fruit than trees that were not detailed pruned. Pruning treatments appeared to have had no effect on fruit size (Table 10).

Table 10. The effect of detailed pruning on fruit set, the incidence of limb-rub
and fruit size.

<table>
<thead>
<tr>
<th></th>
<th>Trees were Detailed pruned</th>
<th>Trees were not detailed pruned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trusses/tree</td>
<td>163</td>
<td>224</td>
</tr>
<tr>
<td>Number of flowers/tree</td>
<td>954</td>
<td>1310</td>
</tr>
<tr>
<td>Number of fruit/tree</td>
<td>77</td>
<td>38</td>
</tr>
<tr>
<td>Per cent fruit set</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Per cent fruit with limb rub</td>
<td>10.4</td>
<td>19.1</td>
</tr>
<tr>
<td>Average weight of fruit (g)</td>
<td>157</td>
<td>141</td>
</tr>
</tbody>
</table>

SUPPLEMENTARY EXPERIMENT 3.

THE INFLUENCE OF BOURSE SHOOTS ON FRUIT SET OF PACKHAM

Earlier studies on flowering and fruit set of Packham suggested, that the third drop of fruitlets is the result of competition between fruitlets in the same truss or between fruitlets and bourse shoots in the same truss (Wauchope 1968).

Pear trees suffer more from shoot-to-fruit competition than apples do. This often results in poor fruit set despite sufficient flowers. Shoot-to-fruit competition is especially evident when seedling rootstocks are used (Strydom, 1993). With Packham, some fruit buds had trusses of flowers without bourse shoots, others had 1 or 2 bourse shoots. We wanted to see if we could improve fruit set of Packham by manipulating the shoot-to-fruit competition.

Method

Seventeen days after full bloom we selected 24 trusses without bourse shoots and 48 trusses with 1 or 2 bourse shoots. Of the 48 trusses with bourse shoots, we selected 24 and removed the bourse shoots with a pair of fine-pointed secateurs. The remaining 24 trusses with bourse shoots were our control trusses.

The trees where this study was carried out were all close to polliniser trees and a beehive. Seventeen days after full bloom we were able to recognise the 3 types of trusses and establish how many flowers each truss had and count the number of spur leaves at the base of each truss.

At harvest time, we examined each truss and counted and weight the fruit.
Results

Results in Table 11 show, that when we removed the bourse shoot(s), it markedly improved fruit set and fruit size. It confirmed the strong competitive effect between bourse shoots and fruitlets. Fruit set did not appear to have been improved on trusses that had no bourse shoots, which is most likely due to the strong initial competition between fruitlets on the same truss (Wauchope 1968).

Table 11. The effect of trusses with or without bourse shoots on fruit set and fruit size of Packham.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Truss without bourse shoot(s)</th>
<th>Bourse shoot(s) removed</th>
<th>Bourse shoot(s) not removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of flowers/truss</td>
<td>5.8</td>
<td>5.9</td>
<td>6.7</td>
</tr>
<tr>
<td>Number of spur leaves/truss</td>
<td>9</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Number of fruit/100 trusses</td>
<td>25</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>Per cent fruit set</td>
<td>4.3</td>
<td>8.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Average weight of fruit (g)</td>
<td>168</td>
<td>200</td>
<td>152</td>
</tr>
</tbody>
</table>

SUPPLIMENTARY EXPERIMENT 4.

THE EFFECT OF CINCTURING ON YIELD AND FRUIT SIZE

In spring competition for nutrients and carbohydrates between new shoots and flowers makes good fruit set often difficult to achieve when trees are young and vigorous. Under these circumstances crop load cannot effectively control tree vigour. Furthermore, with the need to produce large fruit, it is risky to bring tree vigour under control through crop load.

Cincturing or bark ringing is a well-known method for apple trees to control vigour and increase fruitfulness through improved fruit set. This experiment was set up to see if we could improve fruit set of 3 year-old Packham trees.

Method
In the spring of 2000 at full bloom, we cinctured 20 Open Tatura trees (10 trees on the east side and 10 trees on the west side of 1 row), and 10 Central Leader trees. We also marked the same amount of trees in the same rows, which were not cinctured. All trees were in close proximity to polliniser trees and beehives.

Two horizontal half-circle rings 5 mm wide, were made around each trunk. The rings were made on opposite sides of the trunk and overlapped each other by a few millimetres. The rings were 500 mm apart. Cutting out a ring of bark (phloem tissue) temporarily interrupts the flow of assimilates from the aerial portion of the tree to the roots.

At harvest time, we weighed and counted the fruit on each cinctured and non-cinctured tree.

**Results**

When the cinctures were made, the average TCAs of the Open Tatura and Central Leader trees were 24.4 cm² and 33.5 cm². The results in Table 12 show that a 5mm wide cincture on 3-year-old Packham trees had no effect on fruit set and fruit size.

Recent experience with cincturing Packham trees indicate, that pear trees on seedling rootstock are insensitive to cincturing, unless it is done on 1-year-old trees at the start of the second year and is repeated in the third year. The average TCAs of the 1-year-old Open Tatura and Central Leader trees were 3.7 cm² and 5.5 cm² respectively. When we cinctured the trees, the TCAs had increased almost 7 fold in 2 years, and although just 3 years old, they already showed no response to a 5mm wide cincture. If we had cinctured the trees at the start of the second year, it would have most certainly affected tree growth but it would also have taken longer for the trees to fill their allotted spaces. It could also be argued, that a wider cincture at the start of the fourth year, would have been necessary to obtain a response.

**Table 12. The effect of trunk cincturing on yield and weight of fruit of 3-year-old Packham trees.**

<table>
<thead>
<tr>
<th>Training system</th>
<th>Treatment</th>
<th>Yield kg/tree</th>
<th>Fruit weight g/tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Tatura</td>
<td>Cinctured</td>
<td>10.8</td>
<td>48</td>
</tr>
<tr>
<td>Open Tatura</td>
<td>Not cinctured</td>
<td>11.6</td>
<td>53</td>
</tr>
<tr>
<td>Central Leader</td>
<td>Cinctured</td>
<td>16.6</td>
<td>71</td>
</tr>
<tr>
<td>Central Leader</td>
<td>Not cinctured</td>
<td>20.2</td>
<td>106</td>
</tr>
</tbody>
</table>
Many factors contribute to the profitability of an orchard. The 2 most important factors are marketable yield per hectare and the price received for the fruit. Early yields also have a big impact on profitability of a new orchard. In the early years of an orchard, tree density generally has a greater effect on yield than does the training system. However, as the orchard matures, yields can differ depending on the tree training system.

There has been considerable debate over whether high density planting systems offer any economic advantage over medium density planting systems for Packham. A key issue is whether the extra cost of more trees per hectare and their support are compensated for by additional revenue generated through high yields in the first few years of production.

In this study we have made a comparative analysis of costs and returns between a high density planting system and a medium density planting system for the first 6 years of the life of the orchard. The costs only included the most common and major expenses, and make no provision for items such as fuel, rates, phone, accountancy, insurance, irrigation water, etc. Returns were based on what was received per bin. Bins with fruit from the project were taken to Geoffrey Thompson’s Fruit Packing Co. Pty. Ltd. in Shepparton. Fruit was then graded and stored. Fruit was packed and sold up to 9 months later. Returns were calculated as $/bin. The average price received for the fruit from 5 harvest was $115/bin or $221/t. Prices ranged from $70/bin to $150/bin. Since the 2003 harvested fruit was in storage at the time of preparing this report, the company estimated a return to the grower of $150/bin.

Records of costs and returns were kept by the orchardist and are meant to be only an elementary guide. Since these records cover establishment costs and operational costs for the first 6 years of the life of the orchard, one cannot expect an economic analysis based on such a short period. Orchardists should do their own costs and returns, because there are many variables in establishing and managing a high density orchard.

It was never our intention to develop a budget or model based on 6 years of costs and returns. Estimating future performance of the 2 training systems would be fallible and could be misleading. We prefer, that the reader makes his or her own assumptions.

Results

Costs of establishing and operating an Open Tatura and Central Leader orchard for the first 6 years from 1997 to 2003 are stated in Table 13. The higher costs of establishing and operating 1 ha of Open Tatura for 6 years can be contributed to higher tree density and the trellis as compared with the free-standing, medium density Central Leader. The slight difference in the cost per tonne and the marked difference in gross margins between Open Tatura and Central Leader, suggests that the low returns ($221/t) have had a greater impact on Open Tatura than on Central Leader during the first 6 years.
High density systems, such as Open Tatura, need to generate high early returns by way of high yields of high quality fruit. The poor packouts impacted negatively on the Open Tatura system more than the Central Leader system by a gross margin difference of -$4396. If for example, packouts were 75 per cent (18 cartons/bin) and returned $330/t instead of 50 per cent (12 carton/bin) and $221/t, the Central Leader would have broken even after 6 years, leaving a difference in gross margin between Central Leader and Open Tatura of - $1069.

Table 13. Costs and returns for the first 6 years of a 1 ha demonstration orchard of Open Tatura and Central Leader with Packham trees in the Goulburn Valley, Victoria.

<table>
<thead>
<tr>
<th>Items</th>
<th>Open Tatura 2222 trees/ha</th>
<th>Central Leader 1111 trees/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>COSTS*</td>
<td>$21032</td>
<td>$10317</td>
</tr>
<tr>
<td>Establishment costs (1997)</td>
<td>28092</td>
<td>10747</td>
</tr>
<tr>
<td>Operational costs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First year (1997-1998)</td>
<td>3796</td>
<td>1506</td>
</tr>
<tr>
<td>Second year (1998-1999)</td>
<td>2713</td>
<td>832</td>
</tr>
<tr>
<td>Third year (1999-2000)</td>
<td>4688</td>
<td>970</td>
</tr>
<tr>
<td>Fourth year (2000-2001)</td>
<td>4528</td>
<td>3236</td>
</tr>
<tr>
<td>Fifth year (2001-2002)</td>
<td>2328</td>
<td>1398</td>
</tr>
<tr>
<td>Sixth year (2002-2003)</td>
<td>2979</td>
<td>2375</td>
</tr>
<tr>
<td>Total operational costs</td>
<td>$21032</td>
<td>$10317</td>
</tr>
<tr>
<td>RETURNS @ $221/t</td>
<td>$13680</td>
<td>$7359</td>
</tr>
<tr>
<td>Operational costs/t</td>
<td>$340</td>
<td>$310</td>
</tr>
<tr>
<td>Gross margin**</td>
<td>- $7352</td>
<td>- $2956</td>
</tr>
</tbody>
</table>

* For more details of costs see Appendix 4.
** Gross margin is the gross income less the operational costs. It does not take into account the establishment costs.

**DISCUSSION AND CONCLUSION**

Six years of experimenting has revealed some of the mysteries of Packham production. Although the first 6 years in the life of a Packham orchard are too short to make reliable predictions on the productivity and profitability of growing Packhams in the 21st century, this demonstration orchard has provided valuable pointers.
Investing in a high density pear orchard requires a complete new thinking about the way Packham orchards used to be managed. High early yields and high packouts are the important ingredients of profitable pear growing. The emphasis must be on producing pears with few skin defects and good size and shape.

The project has demonstrated that this can be done by

- planting trees closely, since early yields are related to the number of trees planted on a hectare, and not the training system used.

- planting large Packham trees, usually offered as 2-year-old nursery trees

- adequate cross-pollination with the correct polliniser variety and introduce bees. Josephine was not a reliable polliniser when planted as single trees between Packham trees. Experience in the Goulburn Valley indicates that Winter Nelis, Chojuro, Hosui and Howell are more reliable pollinisers than Josephine.

- training Packham trees intensively during the first 3 years to fill their space and develop a balanced tree structure and fruiting wood.

- pruning trees in summer to remove unwanted growth and prune trees in winter to renew and position fruiting wood, and trim and position spurs. This detailed pruning is a combination of spur pruning and renewing fruiting wood according to the 1,2,3 rule.

Some orchardists in the Goulburn Valley and other areas in Victoria have used the above pointers and consistently obtain early and high yields with high packouts of Packham trees on *Pyrus* calleryana D6 seedling rootstock.

In this project, russet could not be classed as a major quality problem. Russet was a contributing factor to poor packouts only in 2001, when the entire Goulburn Valley Packham crop suffered from late fruit russet.

The high standard of fruit quality demanded by the domestic and export markets makes the correlation between per cent light interception and yield per hectare somewhat irrelevant. Yield may have to be sacrificed to obtain large fruit to make a profit. Under these circumstances, light interception and light distribution may have to be related to fruit size and fruit quality and ultimately to $$$ per hectare.

There is enough evidence to suggest, that growing Packham pears can give us both quality and quantity if we focus more on tree density, pollination, tree training and tree management. Large fruit of high internal and external qualities have become the benchmark of growing Packhams profitably in the 21st century.

**TECHNOLOGY TRANSFER**

44
FIELD DAYS

Dates and times of Field Days held, and the subjects that were discussed:

September 3, 1997 – 3 – 5.30 p.m. Introducing the new Open Tatura and Central Leader blocks; the contractor who erected the trellis was on hand to explain the procedures used and answer questions.

November 12, 1997 – 3.30 – 5.30 p.m. The effects of rest-breaking agents, scoring, plucking, delay-heading and the use of plastic sleeves on branching of newly-planted Packham trees.

April 7, 1998 – 3 – 6 p.m. 1997-1998 tree growth; cost of establishing and maintaining young Packham trees in the first year; demonstration of a simple herbicide applicator for Open Tatura; several varieties of pears not commonly grown in the Goulburn Valley were displayed and their future potential was discussed; several promising crossings from the pear breeding program at ISIA Tatura and IHD Knoxfield were displayed.

December 16, 1998 – 4 – 5 p.m. Pollination and fruit; summer pruning and tree training.

April 8, 1999 – 3 – 4.30 p.m. Yield and fruit quality; financial review.

September 25, 1999 – 8 – 9 a.m. Pollination and bee activity; beekeeper’s concerns, how to have a good relationship between orchardist and beekeeper.

December 14, 2000 – 4 – 5 p.m. Pollination and fruit set in 4th year; how the trees have been pruned in winter; how the trees are being pruned in summer (demonstration); how the trees have been cinctured to enhance fruit set and control vigour.

August 7, 2002 – 3.30 – 5.30 p.m. Financial benefits of growing high quality and large fruit; summer pruning demonstration.

POSTER PRESENTATION

SNACKFRUIT 2000 Conference Canberra.

MEDIA COVERAGE

45
The following articles appeared in horticultural journals and newspapers:


Country News, April 13, 1198 p.5. “Orchards of the future on show”.


Field Days

November 1997

April 1999.
Dominic Nardi explains yield results

September 1999.
Apiarist Craig Scott shows evidence of pollen collected by bees.

April 1999.
Bas van den Ende shows the effects of summer pruning of Central Leader trees.
REFERENCES


### APPENDIX 1

#### SOIL ANALYSIS

<table>
<thead>
<tr>
<th>Test</th>
<th>Test results 1997</th>
<th>Test results 2002</th>
</tr>
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<tbody>
<tr>
<td>Available P (Colwell)</td>
<td>47 ppm</td>
<td>36 ppm</td>
</tr>
<tr>
<td>Organic carbon</td>
<td>1.5%</td>
<td>1.5%</td>
</tr>
<tr>
<td>pH (calcium chloride)</td>
<td>5.8</td>
<td>5.1</td>
</tr>
<tr>
<td>pH (water)</td>
<td>6.4</td>
<td>6.0</td>
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<tr>
<td>Total cation exchange capacity</td>
<td>12.6 meq/100 g</td>
<td>12.2 meq/100 g</td>
</tr>
<tr>
<td>Exchangeable cations (meq/100 g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>8.7 69%</td>
<td>7.8 64%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2.7 21%</td>
<td>3.5 29%</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.9 7%</td>
<td>0.7 6%</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.3 2%</td>
<td>0.2 2%</td>
</tr>
<tr>
<td>Aluminium</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Calcium/Magnesium ratio</td>
<td>3.2</td>
<td>2.2</td>
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### APPENDIX 2

53
### LEAF ANALYSIS

<table>
<thead>
<tr>
<th>Test</th>
<th>2001</th>
<th></th>
<th>2003</th>
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<tbody>
<tr>
<td></td>
<td>OT*</td>
<td>CL</td>
<td>OT</td>
<td>CL</td>
</tr>
<tr>
<td>Nitrogen (%)</td>
<td>2.37</td>
<td>2.32</td>
<td>2.28</td>
<td>2.07</td>
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<tr>
<td>Phosphorus (%)</td>
<td>0.19</td>
<td>0.21</td>
<td>0.13</td>
<td>0.13</td>
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<tr>
<td>Potassium (%)</td>
<td>1.50</td>
<td>1.84</td>
<td>1.42</td>
<td>1.43</td>
</tr>
<tr>
<td>Calcium (%)</td>
<td>1.85</td>
<td>1.83</td>
<td>1.59</td>
<td>1.57</td>
</tr>
<tr>
<td>Magnesium (%)</td>
<td>0.23</td>
<td>0.21</td>
<td>0.31</td>
<td>0.27</td>
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<tr>
<td>Sodium (%)</td>
<td>0.016</td>
<td>0.018</td>
<td>0.080</td>
<td>0.080</td>
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<tr>
<td>Chloride (%)</td>
<td>0.03</td>
<td>0.04</td>
<td>-----</td>
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<tr>
<td>Manganese (mg/kg)</td>
<td>83</td>
<td>79</td>
<td>118</td>
<td>121</td>
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<tr>
<td>Copper (mg/kg)</td>
<td>16</td>
<td>16</td>
<td>18</td>
<td>11</td>
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<tr>
<td>Zinc (mg/kg)</td>
<td>29</td>
<td>32</td>
<td>28</td>
<td>29</td>
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<tr>
<td>Iron (mg/kg)</td>
<td>147</td>
<td>170</td>
<td>184</td>
<td>160</td>
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<td>Sulphur (%)</td>
<td>0.13</td>
<td>0.16</td>
<td>0.19</td>
<td>0.17</td>
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<tr>
<td>Boron (mg/kg)</td>
<td>31</td>
<td>37</td>
<td>26</td>
<td>25</td>
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* OT = Open Tatura; CL = Central Leader

### APPENDIX 3

Details of costs and returns
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<th>Items</th>
<th>Open Tatura</th>
<th>Central Leader</th>
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<tbody>
<tr>
<td></td>
<td>2222 trees/ha</td>
<td>1111 trees/ha</td>
</tr>
<tr>
<td></td>
<td>$/ha</td>
<td>$/ha</td>
</tr>
<tr>
<td><strong>Establishment costs (1997):</strong></td>
<td></td>
<td></td>
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<tr>
<td>Soil preparation (deep ripping, grading)</td>
<td>1033</td>
<td>1033</td>
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<tr>
<td>Microjet irrigation (materials and installation)</td>
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<td>Trees @ $5.65 each</td>
<td>12406</td>
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<tr>
<td>Trunk guards (incl. labour)</td>
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<tr>
<td>Trellis materials</td>
<td>4836</td>
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<tr>
<td>Trellis labour (marking and erecting)</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>28092</strong></td>
<td><strong>10747</strong></td>
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<tr>
<td><strong>First year operational costs (1997-1998):</strong></td>
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<tr>
<td>Tree training (materials and labour)</td>
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<td>1171</td>
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<td>Fertilisers</td>
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<td>Herbicides</td>
<td>479</td>
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<td>Staking some trees</td>
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<td>21</td>
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<td><strong>Total</strong></td>
<td><strong>3796</strong></td>
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<td><strong>Second year operational costs (1998-1999):</strong></td>
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<td>Tree training (materials and labour)</td>
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<td>32</td>
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<td>Harvest (labour)</td>
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<td><strong>Total</strong></td>
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<td><strong>Third year operational costs (1999-2000):</strong></td>
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<td>Irrigation maintenance</td>
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<td><strong>Total</strong></td>
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<td><strong>Fourth year operational costs (2000-2001):</strong></td>
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<td><strong>Fifth year operational costs (2001-2002):</strong></td>
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<td>Description</td>
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<td>2003</td>
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<td>Harvest (labour)</td>
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<td><strong>Total</strong></td>
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**Sixth year operational costs (2002-2003):**

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<td>37</td>
</tr>
<tr>
<td>Summer pruning</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Harvest (labour)</td>
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<td>Spreading branches</td>
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<tr>
<td><strong>Total</strong></td>
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<td><strong>2375</strong></td>
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**Grand total operational costs**  

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<th>2003</th>
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<td><strong>Grand total operational costs</strong></td>
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<td><strong>10317</strong></td>
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