Horticultural Development Council

# Desk study report

TF 151

To draw up proposals for the specification of a 'Concept Orchard' aimed at reducing labour inputs by 30%

Final report

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Horticultural Development Council
Stable Block
Bradbourne House
East Malling
Kent
ME19 6DZ

Tel: 01732 848 383
Fax: 01732 848 498



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# 1 Introduction

This project aims to provide some ideas and concepts for a novel orchard system specifically aimed at reducing labour costs by 30%.

# 2 Background

The acreage of top fruit has declined by 9118 hectares (43%) over the past 10 years (Defra Basic Horticultural Statistics for the UK 1993/94 – 2003/4) as many growers were unable to make economic returns due largely to an oversupplied market and weak prices. During the last 3 years supply and demand have been more in balance and net returns have improved. There has been a corresponding improvement in grower confidence and increased levels of orchard replanting with some moderate expansion by some growers. However the growing systems being used are largely similar to those of 15-20 years ago and do not specifically address the issues the industry must face in the next 15-20 years.

The 2003 and 2004 seasons have once again illustrated the large variations that are possible in fruit quality between two years. This variability not only causes the industry technical and quality control problems but can lead to loss of confidence in the product. The Concept Orchard seeks to introduce ideas that will help secure a greater consistency both in yield and quality from year to year.

**The issues currently being faced by the industry include**

- Critical skills shortage
- General labour shortage
- Variability between quality of individual fruits
- Variability between quality in different seasons
- Variability in yield from year to year
- Improvements in productivity and corresponding reductions in unit costs.

Against this background the APRC Crop Husbandry Committee initiated a debate around these issues, particularly in the area of orchard practices and systems that will reduce labour inputs by a target of 30%. As a result the following projects were commissioned.

| | |
|---|---|
| TF136 Labour Reduction in apple & pear production desk study | Completed April 2002 |
| TF154 Root Pruning | Due for completion November 2006 |
| TF153 Reduction of labour inputs | Due for completion December 2005 |
| TF151 Concept Orchard | Due for completion December 2004 |

## 3 Principles of orchard design

Total yield is directly related to the proportion of light falling on the orchard area that is intercepted by the trees, and fruit quality is affected by the evenness of light distribution through the tree canopy. Orchard design must therefore take into account the crucial importance of these two factors of light interception and distribution. Due to the high latitude of fruit growing regions in the UK, light is a key limiting factor making the influence of light on yield and quality far more critical than in some other fruit producing areas.


*The tree on the left has good light distribution within the canopy but the percentage light interception is not being maximised. Unused light is falling on bare ground, and yields could be improved by planting closer. In the orchard on the right the light distribution is poor but interception is high*

It is generally considered that orchards should intercept between 70-80% of the available light. The cost of intercepting more than 80% is not recovered in the marginal extra yield and higher light interception levels generally mean a reduction in light distribution. Achieving this level of light interception as quickly as possible after planting increases early production and improves returns of young orchards.

The closer that planting systems approach a square plant, the more the light interception increases and the more even the light distribution within the tree canopy. This is due to a reduction in the amount of “wasted” light falling on the orchard floor. In single row orchards minimising this wasted light and utilising it to produce fruit is a major challenge. A reduction in tree height in order to perform all manual operations from the ground without a corresponding reduction of alleyway width has resulted in many dwarf-tree orchards not performing as well as expected in single row orchards.

Terence L Robinson, Cornell University, considers the ratio of tree height to row spacing should be about 0.8. i.e. 3.5m alley width and trees 2.8m tall (Compact Fruit Tree 36 p17).

Bruce Barritt, Washington State University considers that optimal light interception and light distribution often occur in orchard systems when tree height is equal to approximately two times the clear alley width. Therefore if the clear alley width (for bin movement, spraying, mowing etc) is 1.5m the trees can be allowed to grow to 3m tall. (Compact Fruit Tree 36 p7).

Taller trees have higher light interception than small trees but have poorer light distribution in the lower parts of the canopy.

**Pear orchard – Holland**

*Dense shadow cast from tall trees in a solid hedge*

Bruce Barritt (personal communication) stated that these calculations did not apply to fruit grown at 52° in the UK. A different relationship must be determined and in all areas individual conical trees must be maintained rather than letting a solid hedgerow develop.

Tree training systems that intercept maximum light and maintain good distribution have been developed. They depend on rigid training to a V-framework (eg Tatura trellis). Whilst production can be improved capital costs have limited the commercial exploitation.

For orchard design theory to dictate practice, growers need the cost of both trees and support systems to fall significantly and also to have access to a much wider range of specialist machinery than exists currently.

# 4 Current limiting factors to UK orchard productivity

Despite a resurgence of orchard planting in the 1980's, much of it at fairly high intensities, a large proportion of the UK acreage base is not performing at optimum levels of yield or quality.

The major limiting factor is poor orchard design and tree management that result in sub-optimal levels of light interception and distribution. Problems occur when trees outgrow their allotted space and the pruning techniques employed to maintain the tree shape and volume are inappropriate and unsuccessful.

The majority of orchards have too high a rate of vegetative growth that, apart from increasing the competition for resources with the fruit, also leads to reduced light distribution within trees and between trees.

This excess vigour reduces yields, increases yield variability from year to year, and reduces fruit quality, both visual and organoleptic. The increased cost to the industry is significant in terms of reliance on growth regulators and increased pruning.

Labour cost and availability is a major limiting factor, particularly for supervisory and managerial roles. The workforce is aging and recruiting staff with the necessary husbandry skills is proving increasingly difficult. The costs of thinning, harvesting and pruning are major factors in the overall cost of production and new orchard designs must address these issues by simplifying all manual procedures as much as possible.

The UK grower is also at a major disadvantage to his overseas competitors in not having a range of chemical thinning agents available.

Pest and disease factors are outside the scope of this project but advances in breeding for resistance to scab will gradually impact on the industry as varieties become more commercially acceptable. Improved techniques of controlling mildew and canker are urgently required.

The costs of orchard establishment, particularly for trees and stakes, are a significant deterrent to growers replanting at all and especially to them investing in orchards at higher tree densities for optimum cropping. Post and wire systems can reduce the cost compared to staking every tree. Developing trees from cuttings or seed that require little or no support seems unlikely within the foreseeable future.

# 5 Methods of reducing the limiting factors

- **Vegetative vigour**

**Ø Rootstocks**

Currently nearly all new apple orchards are planted on M9 rootstock and new pear orchards on Quince C rootstock. Both these rootstocks produce trees of excessive vigour on some soils and even on the weaker soils in replant situations the vigour can be strong enough to require the use of a growth regulator to optimise cropping and reduce pruning costs. Despite the availability of M27 it has not been taken up commercially due to problems achieving adequate fruit size with diploid varieties. A few growers have been successful with Bramley on M27 and have achieved significant reductions in tree management costs due to simpler pruning and reduced costs of growth regulator inputs. Yields and fruit size have generally been good and consistent with this variety.

Commercial experience with M27 has highlighted the problems of

- Being able to accurately predict the tree growth habit prior to planting so that the correct spacing could be chosen
- Not having sufficient trials data on practical areas such as depth of planting, crop load, pruning etc.
- Interactions between crop load and fruit size, which are much more critical with small trees on M27.

It is increasingly obvious that the industry would benefit from a range of rootstocks with vigour from sub M27 to M9. The aim of these rootstocks would be to modify tree vigour so that at any chosen spacing trees with a narrow conical form just fill their allotted space and do not grow beyond it. This would significantly reduce pruning, growth regulator and tree management costs and lead to improvements in cropping and consistency.

Ideally a new rootstock would also be well anchored and self-supporting so that staking costs could be reduced or eliminated.

**Ø Growth regulators**

Currently the industry relies on one plant growth regulator for vigour reduction. This puts it in a vulnerable position and alternative strategies must be developed, as well as new materials brought forward for registration. The imminent approval of a second active offers some potential but it may take some time to determine the best ways to use it.

**Ø Pruning**

New simplified pruning techniques need to be developed and introduced to reduce vigour and labour costs. Currently growers are experimenting with mechanical pruning but have no research support as to optimum timings and strategies.

**Ø Root pruning**

Root pruning is being practiced by many pear growers in Holland and Belgium and offers growers in the UK an alternative means of achieving growth control. However the degree of pruning required each year or during the year is still largely determined subjectively and until recently little development work has been done in the UK. Studies have indicated that there is a very fine line between a pruning treatment that produces little benefit and one that is too severe, resulting in reductions to crop load and/or fruit size.

**Ø Ridging**

Growing trees on ridges with or without undercutting can also restrict root volume leading to a reduction in vigour of approximately 10%. The ridge becomes warmer in spring and summer and colder in winter. The ridge also dries out more quickly and the trees require trickle irrigation.

**Ø Partial root zone drying and regulated deficit irrigation**

Methods of manipulating and controlling plant vigour by managing the water supply have been proven and are being introduced into commercial practice in a range of crops across the world. There is potential for achieving improved growth control with no loss of crop volume or quality. Partial root drying relies on two trickle lines per row of trees. One side of the tree is deliberately kept dry and the stress response of the tree results in reduced growth. To prevent damage to the root system the dry side is then wetted and the other side is allowed to dry out. Regulated deficit irrigation relies on just providing enough water for the crop's requirements whilst restricting the amount sufficiently to reduce vegetative growth.

- **Poor light interception and distribution**

Once planted, it is impossible to correct fundamental flaws in the orchard design but by providing the industry with better training in the basic principles of pruning and developing simple pruning methods to correct poor tree shape, then better light distribution should be achievable.

The use of reflective mulches can also improve the light levels, especially in the lower parts of the canopy, and has been proven to increase fruit yield, size and quality in both apples and pears.

- **Labour issues**

These are important and need to be addressed in the following areas:

- Better education and training
- Better recruitment
- Simplification of key tasks eg pruning and harvesting
- Improved chemical/mechanical alternatives
- Increased robotics and remote sensing

# 6 Developing a 'Concept Orchard'

**Existing orchards**

The majority of new orchards are planted in either intensive single row configurations or multi row bed systems at densities of between 2000 and 3250 trees/ha.

The single row systems at the lower densities are tall conical trees allowed to grow to between 2.0 and 3m in order to maximise light interception whereas in the more intensive bed systems the tree height is maintained at 2m to prevent between-tree shading in the bed.

The multi-row bed system is therefore ideally suited to the weaker soils where tree height can be maintained at 2m without resorting to major pruning which stimulates the lateral spread of the tree. This system makes better use of the land and can improve the efficiency of harvest as bins do not need to be moved as much. Spraying time is also reduced as the length of alleyway per orchard area is significantly less. However bed systems do not allow any potential developments in mechanical pruning or root pruning to be adopted. They are also not easily adapted to ridging and partial root drying techniques.

Orchard Design

Holland and Belgium

Orchard Design

Italy and Poland

Intensive single-row systems are now the most widely planted system worldwide and are largely standard throughout Europe. The problems they raise are due to the increased tractor movements per orchard area and the risk of poor light distribution in the lower part of the tree canopy due to the increased tree height. The tree height has also meant that mobile platforms are required for pruning, training and harvesting the top third of the tree.

**Orchard design - Italy**

Single rows are ideally suited to root pruning; mechanical thinning and pruning; ridging; partial root drying etc.

## A UK 'Concept Orchard'

The objectives of all new orchards should include the following:

- To have a tree size at planting and orchard design that fills the allotted space as quickly as possible, creating early high yields.
- To create a uniform and controlled distribution of leaves and fruit in order to improve light interception and photosynthetic efficiency leading to consistency of fruit size and quality.
- To arrange the branches in such a way to minimise light competition within and between trees.
- To reduce vigour so that the trees naturally fill their allotted space and inter-tree shade is minimised.

**For the near future**

Taking into account that mechanisation will play an increasing role in orchard management in the lifetime of new orchards (15-20 years) the concept orchard should be a single row configuration.

As there is little experience with trellis systems in the UK and due to the high cost of establishment associated with them the tree should be a narrow conical shape. This will be achieved by planting a well-feathered 'knip-boom' tree and allowing the centre leader to develop as a super spindle.

## Comparison of trained and untrained orchard - Kent

Because there is a need for all parts of the canopy to receive a similar amount of light so that fruit size, colour and internal quality is as consistent as possible, the concept orchard should be trained to a post and wire support. This will allow every branch to be placed in the optimum position (height and angle) for light interception and distribution.

The concept orchard should be planted at a spacing of between 0.6 and 1.0m depending on the variety/rootstock/site characteristics. The tree height will be limited to 2.25m and the alley way spacing will be 3.5m maximum. This could be reduced to 3.0m if tractors etc allow.

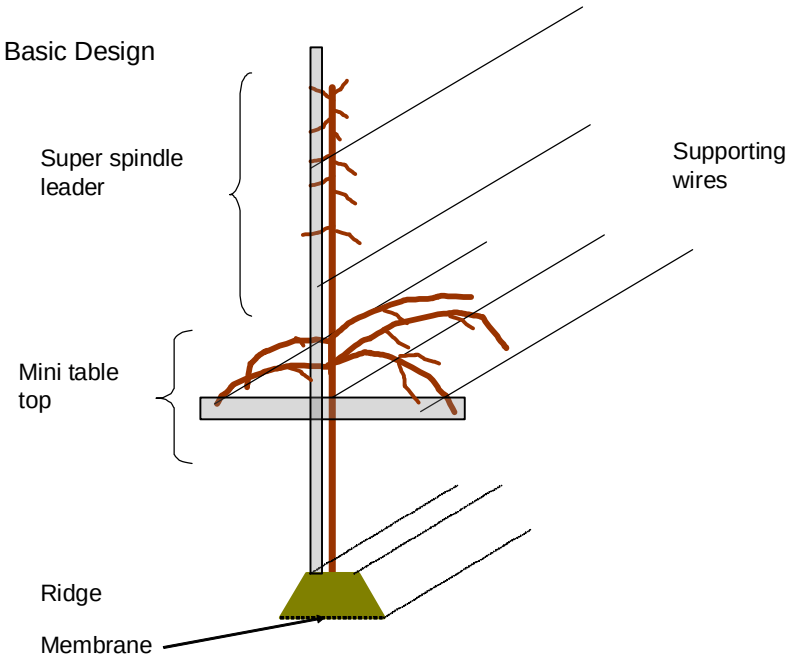
The tree will be supported on wires at 90cm, 120cm and 200cm. At the 90cm height two further wires supported by a cross piece will be placed at 60cm from the centre line to form a narrow 'table top' to train the branches below this mini table top. This will create a convenient working height for picking. All branches below the table top will be removed and branches headed back to the correct tree diameter in the May of the planting year.

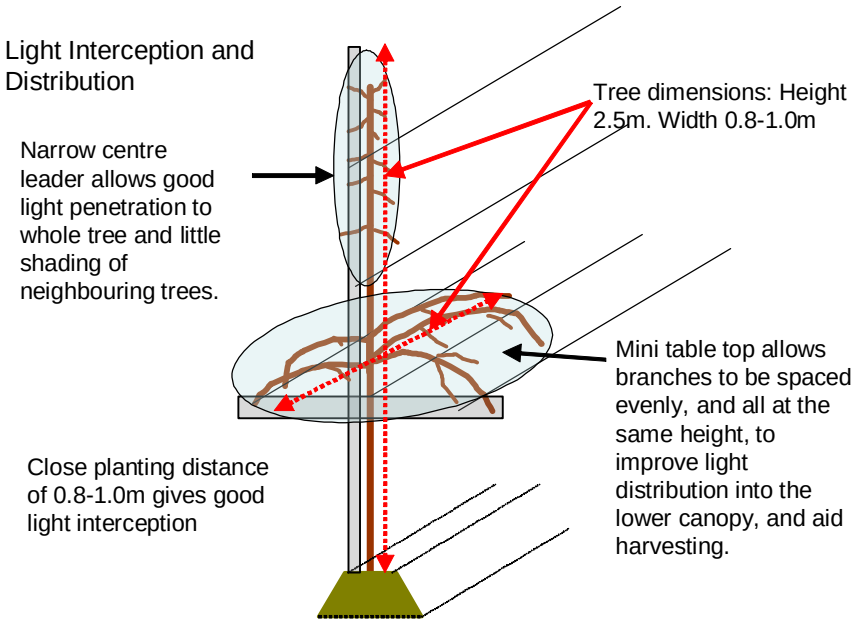
 

The tree vigour will be controlled using a rootstock of vigour between M9 and M27, growing on a ridge and utilising partial root drying techniques. To further restrict root volume, root pruning will be employed or a root membrane will be placed under the tree at planting.

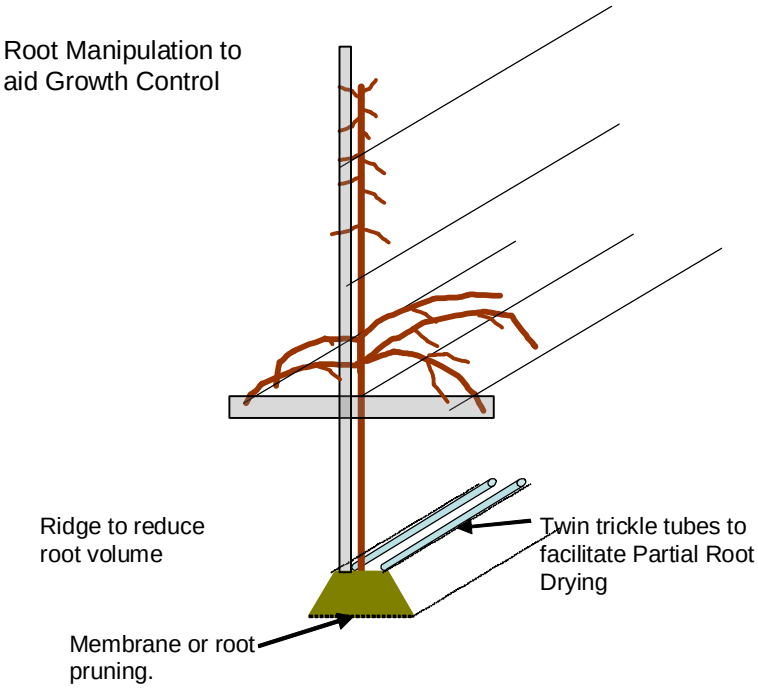
This tree type is suitable for all desert apple orchards and would also suit pears grafted onto Quince C rootstock. The only difference would be that the branches of apples will be trained horizontally onto the table top whereas the pears will be trained at 45° onto the table top.

## New Pear Orchard - Wisbech







***An illustration of the concept orchard ideas showing hail net, overhead sprinklers, ridge planting and root restricting membrane to limit tree growth.***

**'Future Concept'**

One tree type that could potentially deliver many of the requirements for the industry is the columnar apple.

***New varieties in the breeding programme at Geisenheim***

**Advantages**

- Minimal pruning
- Self supporting
- Narrow conical shape
- Spur type habit

**Disadvantages**

- Commercially acceptable varieties are not yet available
- The dense spur habit can cause shade within the tree
- Over production of fruit bud can lead to a need for thinning every year
- Slow growing – long period to fill height if growing on dwarfing rootstocks. Using M26 or MM106 could over comes this.
- May be sensitive to canker (*Nectria*)

Breeding programmes are leading to improvements in eating quality and the introduction of some scab resistance characteristics. These programmes are also producing intermediate types that may also deliver greater benefits than the true columnar types.

**Scarletsentinel**

**Goldsentinel**

*Recent columnar types from the Summerland Breeding Programme.*

The tree type lends itself to developing narrow multi-row bed systems with good light distribution through the bed. Tree arrangements closer to the optimum square plant would be possible leading to a maximisation of production potential. Alternatively the regular tree form lends itself to developing mechanisation techniques for harvesting and thinning. Theoretical yields of over 110 tons/ha have been calculated by Helmut Jacob of the Research Institute at Geisenheim, Germany.

Another interesting development is the use of the columnar type as an interstem on a MM106 rootstock to create a self-supporting dwarfing tree for planting at conventional distances ie 1.0m between trees.

# 7 Research and development requirements

### Commercial evaluation of recent rootstock introductions.

Following trials at EMR commercial evaluations of the most promising rootstocks should be undertaken on growers' farms. The trials should be of sufficiently sized blocks to allow comparison of several spacings and variety combinations. Suggested rootstocks for trees should be chosen from the programmes below in consultation with staff at EMR.

**Apples** The Polish series
The J-TE series from the Czech Republic
The AR, R, and B series from EMR
Reduced vigour clones of M9 eg Fleuren 56

**Pears** EMH

### Tree height

Work by Jackson & Palmer (1972) determined the light interception by model hedgerow orchards, however it is still difficult to find a definitive answer to what is the optimum tree height within different planting systems in the UK.

### Root volume

It would be valuable to determine what is the optimum root volume required by established apple and pear trees. This would help design the best ridge height and spread and root pruning depth for maintaining ideal tree vigour.

### Root sensing

The degree of root pruning required would be much easier to determine if the root depth and spread could be plotted remotely without disturbing the soil.

### Manipulating light wavelength

Professor Bill Davies, Lancaster University (personal communication) considers it possible to manipulate the wavelength of light by crop covers or reflective mulches to create growth retardant effects within the tree canopy.

### Partial root zone drying and regulated deficit irrigation

These techniques need to be demonstrated on a commercial scale for the benefit of UK growers.

## Pruning

Le Mur Fruitier (The Fruit Wall) developed by Alain Masseron (Ctifl) depends on extension growth being cut at a precise phenological stage (12 new leaves) in order to achieve the production of new spurs with a fruit bud and a short shoot. A similar trial programme in the UK on local varieties would help growers determine the best time to mechanically prune trees in the summer so that resulting regrowth produces fruit buds rather than just growing shoots.

## Columnar orchards

Ken Tobutt of EMR is breeding improved types that should have commercially acceptable characteristics. The first of these, SA544-28, is worthy of further trialling. The tree habit also has huge potential for cider and juice orchards, a fact now recognised by some cider producers. Experience at EMR suggests that on MM106 the columnar types can grow too tall, reaching 3-3.5m after 10 years, on M26 they naturally stop at about 2-2.5m, on M27 they are too weak stopping at 1.2-1.5m and on M9 they require good support. They appear to be self-supporting on MM106 and M26.

In order to reduce planting costs multi-stemmed trees may be induced in the nursery. Some clones are naturally more prone to branching and could be planted more extensively.

The potential for columnar apples to improve yields and dramatically reduce growing costs by virtually eliminating pruning and growth regulators should be recognised urgently. A development programme to address the following areas is necessary.

- Orchard systems
- Evaluation of top 10 current selections
- Evaluation of new selections
- Further breeding to improve disease resistance, fruit characteristics and tree habit.
- Closer collaboration with other breeding programmes and Institutes investigating columnar apple varieties and growing systems.

It is essential that this programme is a joint venture with professional growers and advisers as well as EMR staff.

# 8 Mechanisation potential

Potential for mechanisation falls into the following areas.

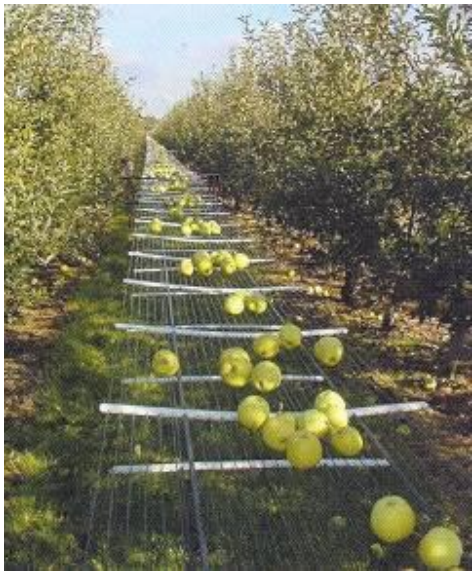
- Picking aids
- Pruning
- Root pruning
- Thinning

## Picking aids

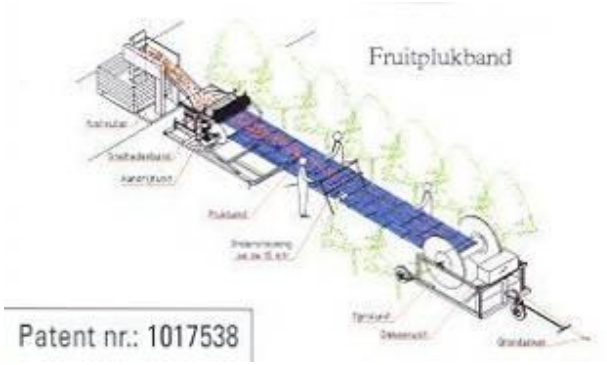
Within the concept orchard the most promising area to achieve labour reductions is in the use of picking aids. The mini table top is designed not only to improve light distribution and make better use of the land but also to provide a comfortable working height for pickers. With a standard picking height productivity will be improved and the development and introduction of picking aids will be simpler.

The most promising of these include.

- **Picking conveyors**






**Dutch picking conveyor**

- **Bin filling aids**

**Italian picking aid**

- **Self propelled harvesting aids eg Pluck-o-truc**

- **Picking Train**


The picking train offers the most immediate method of reducing the labour inputs during harvesting. It eliminates the need to place bins in the orchard prior to picking and reduces bin handling at harvest. Picking teams can be more easily supervised and by working as a team productivity can be increased.

### Pruning

The super spindle top of the concept tree could lend itself to being developed as a mini-fruit wall and some mechanical pruning treatments developed. Similarly the table top could also receive some mechanical pruning.

# 9 Costings

## Near future post and wire system

### Trees

At a planting distance of 3.5m by 0.8m the Concept Orchard requires 3500 trees per hectare compared to 2285 in a conventional planting of 3.5m by 1.25m.

### Support system

The post and wire system in the concept orchard is based on a post approximately every 10m with a bamboo cane to every tree. The posts are around £4.75 and the canes £0.35 giving a cost per tree of £0.75. T-pieces, wires and clips will add a further £0.35 per tree, thus the total support cost is £1.10 compared to £1.15 for a tall stake to each tree in a conventional planting.

## Planting

Labour costs for installing the post and wire system are about 20% lower than for staking each individual tree. If the trees are planted on ridges where soil is earthed up over the roots mechanically planting costs are also reduced by about 30%. Using these guide figures, and including a cost of £0.50 per tree for trickle irrigation, the total cost per hectare is £17080 for the Concept Orchard and £14713 for the Conventional, an increase of £2367 per hectare (16%).

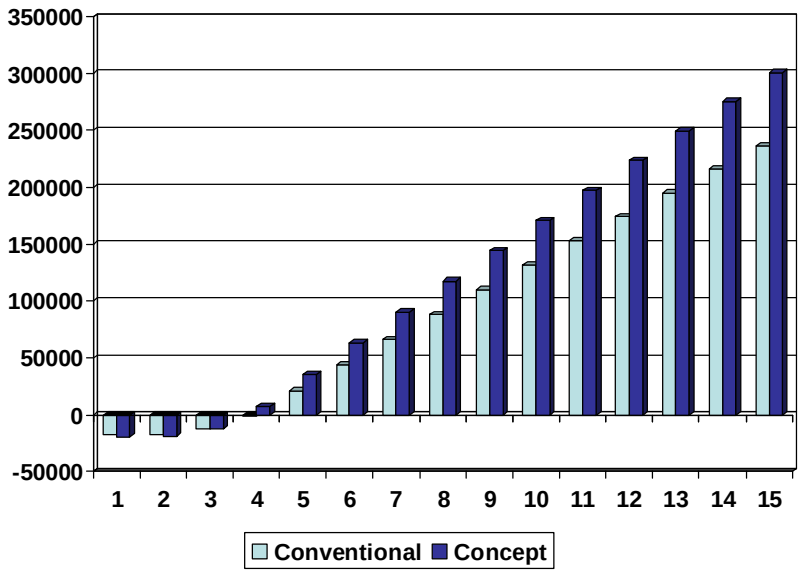
## Lifetime cconomic comparison

Based on the establishment costs above and making the following assumptions a comparison of the cumulative returns over a 15 year orchard life are shown in the graph below.

Assumptions

- Labour costs reduced by at least 20% in the Concept Orchard
- Average maximum yield in the Concept orchard is 60 tonnes/ha and in the conventional orchard is 50 tonnes/ha.
- The time taken to build up to maximum yield is 5 years from planting in both cases.

## Accumulative return/ha




The Graph above shows cumulative return per hectare over a 15-year period from planting.

*Data based on Orchard Costings Template developed by John Pelham of Andersons Farm Business Consultants and used with permission.*