High density planting systems: principles and pitfalls

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Reasons for adoption of intensive systems

- Improvement of fruit quality
- Reduction of production costs
- Improvement of precocity
- Reduction of spray drift
These are the main reasons why HDP systems have been adopted in many parts of the world; the importance of each of the four reasons may vary depending on local circumstance.

I suspect that all four are current pressures on Australian growers.
Key drivers in the uptake of HDP

• A demonstrated advantage over existing methods

• Availability of dwarfing rootstocks

• Economic pressures

• New cultivars

• Skill base
Successful systems must display economic benefit

This is determined at the income side by:

• Precocity

• High yield

• Excellent fruit quality
Economic analyses have usually reached the following conclusions: higher tree densities give improved returns when:

fruit prices are high
trees are cheap
land is expensive
interest rates are low

The optimum tree density depends upon economics, environment and biology.
Reasons for slow adoption of HDP

- Adequate performance of existing trees
- Lack of dwarfing rootstocks in quantity
- General poor quality of nursery tree
- Concerns over - woolly apple aphid
  - sunburn
- Lack of experience
- Lack of an innovative culture
Apple trees are very adaptable to manipulation and can be grown in all manner of systems, as the following eight slides illustrate.
1 row, 2 row and 3 row systems, East Malling
6 row bed system on M.27 c. 6666 trees/ha, East Malling
20,000 trees/ha 1.25 x 0.4 m, Wilhelminadorp
5,000 trees/ha bed system on slope

S. Tyrol
3,000 trees/ha  3.15 x 1.05m, Guttinger V, Wilhelminadorp
Royal Gala/MM.106

5 x 3 m

666 trees/ha
The genetic variation in tree form has to date, not really been commercially exploited in apples.

An example is the Wijcik mutation.
Principles of successful systems

Two key concepts:

- light interception
- light distribution

*The use and the misuse of light*
Light interception

- Over the last 30 years, work in a number of countries has shown that yield of apples is linearly related to light interception.

- One of the difficulties of working with row crops such as apples is that there are a large number of variables e.g. rootstock, spacing, tree height, pruning system. Light interception integrates all these factors.
Relationship between intercepted solar radiation and dry matter production, redrawn from Monteith (1976)
Major determinants of light interception

- Direct sunlight
- Scattered light
- Tree dimensions
- Leaf area (LAI)
- Row spacing
- Row direction
Measuring light interception using a Ceptometer
Measuring light interception using quantum sensors and data logger
Measuring light interception using a Whirligig
Measuring light interception using a mobile logging system
Relationship between LAI and light interception
Relationship between harvested fruit yield and mid-season light interception from different cultivars, systems and locations.

Lakso, 1994
Relationship between yield and light interception in apple, NZ data

![Graph showing the relationship between light interception and fruit yield for Royal Gala, Braeburn, and Fuji apples. The graph includes data points and trend lines for each variety.]
Seasonal light interception
Mean of four spacings for each cultivar

Time from October 1 (days)

Light interception (%)

- ▲ Braeburn
- ● Royal Gala
- ▼ Fuji
Relationship between seasonal light interception and total dry matter production for apple

![Graph showing the relationship between light interception and total dry matter production for different apple varieties.]

- Royal Gala
- Braeburn
- Fuji
- UK data

Light interception (MJ m\(^{-2}\) PAR) vs. Total dry matter production (t ha\(^{-1}\))
Light interception

High yields cannot be achieved without high light interception

Light interception can be increased by closer planting, taller trees, closer row spacings

Use the light you have to your best advantage
Light distribution

Apple orchards are more than light harvesting systems.

We are producers of fruit, ideally high quality fruit, that will attract a high price in the market.

The light distribution within our trees has a major influence on the quantity and quality of fruit we produce.

*Shady business has no place in the orchard.*
Effect of light on leaf mass per unit leaf area
Generalised effects of shade on apple leaf characteristics

Decrease

- leaf photosynthesis
- leaf thickness
- leaf cupping
- leaf mass per unit area
## Effects of shade on apple fruit quality, flowering and fruit set (compilation from the literature)

<table>
<thead>
<tr>
<th>Decrease</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit weight</td>
<td>Shrivel</td>
</tr>
<tr>
<td>Fruit red colour</td>
<td>Fruit firmness</td>
</tr>
<tr>
<td>Soluble solids concentration</td>
<td></td>
</tr>
<tr>
<td>Bitter pit incidence and severity</td>
<td></td>
</tr>
<tr>
<td>Sunburn</td>
<td></td>
</tr>
<tr>
<td>Flower bud numbers</td>
<td></td>
</tr>
<tr>
<td>Skin russet</td>
<td></td>
</tr>
<tr>
<td>Fruit set</td>
<td></td>
</tr>
</tbody>
</table>
3 row North Holland spindle system, East Malling
Lifting shaded branches reveals poorly coloured fruit even in an intensive system.
The use and the misuse of light

High light interception is essential for high yield per hectare.

Good light distribution is essential for high quality fruit.

A successful system is one that combines both of these.

*Maximum use with minimum misuse*
The control of tree growth is therefore essential in any successful system

Too little growth and we do not fill the space and yield is limited by low light interception

Too much growth and we have problems with excessive shading and poor quality fruit
Ideal apple tree characteristics

• Good light penetration
  - conical shape
  - planar canopy

• Control of tree vigour

• Ease of access for man, machines and spray
The orchard systems puzzle (With thanks to Bruce Barritt)
The early years

Where shading is not a problem, particularly in the first few years of the orchard’s life, yield of high quality fruit is a linear function of light interception.

Light interception is primarily driven by how rapidly the orchard fills its space.

That in turn is driven by tree density and by tree quality at planting.
The orchard begins in the nursery

Rootstock choice

Tree quality, especially feathers
Well feathered trees

Braeburn/M.9

Comice/QC
Effect of tree quality, tree density and site on yield of Royal Gala/M.9 in year two

![Graph showing the relationship between tree density and total yield for feathered and unfeathered trees across different sites.](image)
Effect of tree quality on early cropping of Royal Gala and Fuji on M.9 rootstock

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Orchard year</th>
<th>Fruit no. per tree</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Feathered</td>
<td>Non-feathered</td>
<td></td>
</tr>
<tr>
<td>Royal Gala</td>
<td>2</td>
<td>42</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Fuji</td>
<td>2</td>
<td>22</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Royal Gala</td>
<td>3</td>
<td>139</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Fuji</td>
<td>3</td>
<td>152</td>
<td>61</td>
<td></td>
</tr>
</tbody>
</table>
Build up of annual yield of Royal Gala/M.9 in relation to tree density at two sites

Yield (tonne ha$^{-1}$) vs Tree density (trees ha$^{-1}$) for Year 2, Year 3, Year 4, and Year 5.
Mean yield per tree and average fruit weight of Royal Gala/M.9 over four seasons at two sites

<table>
<thead>
<tr>
<th>Year</th>
<th>Grower 1</th>
<th></th>
<th>Grower 2</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Yield (kg)</td>
<td>Mean wt. (g)</td>
<td>Yield (kg)</td>
<td>Mean wt. (g)</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>198</td>
<td>3</td>
<td>208</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>191</td>
<td>16</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>185</td>
<td>26</td>
<td>147</td>
</tr>
<tr>
<td>5</td>
<td>34</td>
<td>180</td>
<td>38</td>
<td>189</td>
</tr>
</tbody>
</table>
The secret of balancing light interception and light distribution is found in controlling and manipulating growth.
Methods of growth control

- Rootstocks
- Pruning and tree training
- Growth regulators
- Root pruning
- Girdling
- Root restriction
- Water/nutrition & understorey mgt
Apple clonal rootstocks

Offer advantages of:

- vegetative propagation
- tree uniformity
- tree size control
- precocity
- tree habit
- soil borne pest and disease resistance
- improved fruit quality
Growth control by rootstocks
Sources of apple rootstocks

- UK – Malling, Malling Merton and AR series
- USA – Mark, CG series
- Canada – Ottawa, Vineland series
- Poland – P series
- Russia – Budagovsky series
- Japan – JM series
Apple rootstock range available in NZ

M.27
M.9
Mark
M.26
MM.106
M.793

Increasing vigour
Apple rootstocks in the M.9 size range

B.9
T337
Mark
EMLA 9
NZ9
Pajam 1 (Lancep)
Brugmar 719
Ncoli 29
Pajam 2 (Cepiland)
Apple rootstocks in the M.26 size range

M.26
EMLA 26
CG210
CG202
Interstem trees using dwarfing rootstocks as an interstem piece on more vigorous rootstocks

Usually M.9 on MM.106 or M.793

- Offer advantages of dwarfing with a root system resistant to woolly apple aphid
- Degree of dwarfing related to the length of interstem
- Generally tree size in M.26 range or larger
Currently in the world, the most widely planted apple rootstock for intensive systems is M.9 (and its clones).

It offers the best combination of tree growth control, precocity and fruit quality.

Alternatives are needed in situations of:
- high vigour and low vigour
- areas of high temperature with fireblight
- areas of low winter temperatures.
Tree training aids (1)

- String
- Spreaders
  - pegs
  - tooth picks
  - wood
- Weighted pegs
- Posts and wires
- Tucking
- Pruning
Tree training aids (2)

Tree training should begin in the nursery with a well feathered tree.

Feathers should be at the right height (80+cm), with good horizontal crotch angles, with at least 8-10 good feathers per tree.
Tree training aids (3)

Dissipate growth on the central leader with many growing points.

Upright growth leads to vigour.

Tying branches below the horizontal devigorates.

Weak shoots beget weak shoots
Strong shoots beget strong shoots.
Summary
Light interception

High yields cannot be achieved without high light interception.

Light interception can be increased by closer planting, taller trees, closer row spacings.

Use the light you have to your best advantage.
Light distribution

High quality fruit cannot be achieved without good light penetration to the fruit.

Excessive tree shading results in: smaller fruit size, less fruit colour, lower soluble solids, delayed maturity, fewer flower buds.
The discussions and controversies between orchard management specialists and between growers about planting distances and tree training systems for a given fruit species undoubtedly began with the first orchard; they will last as long as fruit trees are planted.

Hugard, 1980
Thank you for your attention

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