Horticultural Systems and Practices to Facilitate Mechanization in Apples and Pears

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WSU-TFREC, Wenatchee, WA
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Orchard issues:

• cultivars and habitus,
• rootstocks,
• vigor,
• orchard design,
• fruit quality, color and homogeneity of the fruit distribution,
• mechanization
Different apple need

GOLDEN DELICIOUS

RED DELICIOUS

GALA (bicolor)

GRANNY SMITH

Apple habitus

Lespinasse, 1980
Pear cultivars

- Type 2a – Doyenné du Comice. 2-year-old branch with brindles
- Type 1 – Bartlett. 2-year-old branch with brindilla and spurs
- Type 2b – Abbé Fétel. 2-year-old branch with spurs
- Type 3 – Conference. 2-year-old branch with spurs
- Type IV – Beurré Bosc. 2-year-old branch with spur and short brindilla
- Type V – Passe Crassane. 4-year-old branch with spur

Pear fruit-bud models
Orchard issues:

- cultivars and habitus,
- rootstocks,
- vigor,
- orchard design,
- fruit quality, color and homogeneity in the fruit distribution in the canopy,
- mechanization

Main Apple Rootstocks

New rootstocks are under evaluation in Europe. M9 337 is the most important rootstock utilized.
Geneva® Apple Rootstocks by Tree Size

M.9 (Small)  
M.9 (Large) Pajam 2, EMLA Nic29
M.26
M.7 MM106

Mark B.9  
T337

15-30%  
30-35%  
35-40%  
40-50%

G.11  
G.41*
G.16  
G.210*  
G.214*  
G.222  
G.30  
G.202  
G.890*  
G.969  
G.935

Fire blight resistant
Replant tolerant
* Wooly apple aphid resistant

Modified for Washington State conditions after Terence Robinson, Cornell-Geneva; Gennaro Fazio, USDA-ARS Geneva

MAIN PEAR ROOTSTOCKS

<table>
<thead>
<tr>
<th>VIGOUR</th>
<th>SPECIES</th>
<th>CLONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwarfing</td>
<td>Cydonia oblonga</td>
<td>EM C, Adams, MH and Sydo</td>
</tr>
<tr>
<td>Medium vigour</td>
<td>Cydonia oblonga</td>
<td>Cts 212, MA and BA29</td>
</tr>
<tr>
<td>Vigorous (Seedling)</td>
<td>Pyrus communis</td>
<td>BP1, Fox 9 and Fox11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BP2, BP3 Farold 40, 69, 87</td>
</tr>
</tbody>
</table>

Modified for Washington State conditions after Terence Robinson, Cornell-Geneva; Gennaro Fazio, USDA-ARS Geneva
Orchard issues:

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- vigor,
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Effect of root pruning on tree vigour

- less uptake of water
- less uptake of nutrients
- changing the hormonal balance less cytokinines
- reduced shoot growth
- flower buds induction
Root pruning: lateral pruning in winter (February)

Root pruning: vertical pruning in winter
Orchard issues:

- cultivars and habitus,
- rootstocks,
- vigor,
- orchard design,
- fruit quality, color and homogeneity of the fruit distribution,
- mechanization
Ferree (1980) collected more productive efficiency with Palmette (1,121 tree/ha) than Slender Spindle (2,151 tree/ha), mini central leader (795 tree/ha) and pyramid (425 tree/ha).
# Pear training system and planting distance (2013)

<table>
<thead>
<tr>
<th>Training system</th>
<th>Spacing (m)</th>
<th>Density (tree/ha)</th>
<th>Density (tree/A)</th>
<th>Cultivar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Palmetta</td>
<td>3.6 x 1.5</td>
<td>1,850</td>
<td>749</td>
<td>Main</td>
</tr>
<tr>
<td></td>
<td>4.0 x 2.0</td>
<td>1,250</td>
<td>506</td>
<td></td>
</tr>
<tr>
<td>Slender spindle</td>
<td>3.5 x 1.0</td>
<td>2,850</td>
<td>1,153</td>
<td>Main</td>
</tr>
<tr>
<td></td>
<td>4.0 x 1.5</td>
<td>1,660</td>
<td>672</td>
<td></td>
</tr>
<tr>
<td>Vertical axes</td>
<td>3.5 x 0.7</td>
<td>4,080</td>
<td>1,651</td>
<td>Abbé Fétel/ Conference/ Doyenné du Comice/Bosc</td>
</tr>
<tr>
<td>Y tatura</td>
<td>4.0 x 0.8</td>
<td>3,125</td>
<td>1,265</td>
<td>Main</td>
</tr>
<tr>
<td></td>
<td>4.5 x 1.2</td>
<td>1,850</td>
<td>749</td>
<td></td>
</tr>
<tr>
<td>Y longitudinal Bibaum®</td>
<td>3.3 x 1.0</td>
<td>3,030</td>
<td>1,226</td>
<td>Main</td>
</tr>
<tr>
<td>V system</td>
<td>3.5 x 0.7</td>
<td>4,081</td>
<td>1,652</td>
<td>Abbé Fétel/ Conference/ Doyenné. Bosc</td>
</tr>
</tbody>
</table>

## Very high density

<table>
<thead>
<tr>
<th>V system intensive</th>
<th>Spacing (m)</th>
<th>Density (tree/ha)</th>
<th>Density (tree/A)</th>
<th>Cultivar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.5 x 0.50</td>
<td>6,000</td>
<td>2,429</td>
<td>Abbé Fétel/ Conference/ Doyenné du Comice/ Bosc</td>
</tr>
<tr>
<td>Vertical axis</td>
<td>3.0 x 0.30</td>
<td>11,000</td>
<td>4,453</td>
<td>Abbé Fétel</td>
</tr>
<tr>
<td></td>
<td>2.5 x 0.31</td>
<td>13,000</td>
<td>5,263</td>
<td></td>
</tr>
</tbody>
</table>

Source: Rielaborated from Sansavini e Musacchi 2000
Fruit distribution in the canopy. Harvest is done by zone due to the different fruit distribution.

Yield: 50.3 t/ha (20.36 tonne /A)
### Abbé Fétel - Top (2006)
- **Fruit weight**: 308
- **Firmness**: 3.95
- **Brix**: 15.1
- **Acidity (ml NaOH/10)**: 5.07
- **pH**: 4.03

### Abbé Fétel – Middle (2006)
- **Fruit weight**: 288
- **Firmness**: 3.74
- **Brix**: 14.1
- **Acidity (ml NaOH/10)**: 5.11
- **pH**: 3.78

### Abbé Fétel – bottom (2006)
- **Fruit weight**: 241
- **Firmness**: 3.90
- **Brix**: 14.4
- **Acidity (ml NaOH/10)**: 4.77
- **pH**: 4.04

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**Main Training systems actually used:**

- Slender spindle
- Solaxe- Centrifuge
- Bi-axis
Cripps Pink/M9 - Ferrara Planting Year 2003. Year 2007

Cripps Pink: Comparison Between Solaxe (Centrifuge) and Slender Spindle in the Po Valley (Ferrara)
Cripps Pink: effect of fruit position in the canopy

SpindleFuji/M9 2nd leaf 3.3 x 0.9 m (10.8' x 2.95')

FUJI/PAJAM2 – SPINDLE 2nd leaf 3.3 x 0.9 m (10.8' x 2.95')
Cripps Pink/M9 2nd year

BI-AXIS

Spacing 3.3 x 1 m - Density 3,030 trees/ha
(10.8’ x 3.3’) (1226 trees/A)
New ideas regarding tree shape include plants with 2 or 3 axis so as to divide the vigor over more branches.

Advantages and Drawbacks of Bi-axis

- High productivity
- Fruit distribution in the canopy is homogeneous
- Low pruning cost. Only few branches have to be bended
- Better vigor control esp. in the Po valley
- High level of mechanization: pruning and thinning

- Difficult to produce good tree in the nursery.
- Sometime the two axes present a different vigor.

Trial:
Location: Migliaro (Ferrara)
Graft combination: Rosy Glow/M9T337
Training system: Bi-axes and Spindle
Year of planting: 2006
Planting distance and density:
Spindle: 3.3 x 0.8 m (3,788 trees/ha)
10.8’ x 2.6’ (1,534 trees/A)
Bi-axis: 3.3 x 0.8 m (3,788 trees/ha)
10.8’ x 2.6’ (1,534 trees/A)
### Second Trial: Rosy Glow/M9 T337 – Medelana (FERRARA) Planting year 2006. Productive and vegetative traits 2007

<table>
<thead>
<tr>
<th>Training system</th>
<th>Planting density (trees/ha)</th>
<th>Planting density (trees/A)</th>
<th>Fruit number</th>
<th>kg/tree</th>
<th>Avr. fruit weight (g)</th>
<th>TCSA (cm²)</th>
<th>Yield effic. (kg/cm²)</th>
<th>Calc. Yield (t/ha)</th>
<th>Calc. Yield (tonne/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bi-axis</td>
<td>3,788</td>
<td>1,533</td>
<td>21.2</td>
<td>5.02</td>
<td>238</td>
<td>a</td>
<td>5.34</td>
<td>0.97</td>
<td>19.0</td>
</tr>
<tr>
<td>Spindle</td>
<td>3,788</td>
<td>1,533</td>
<td>23.2</td>
<td>5.18</td>
<td>226</td>
<td>b</td>
<td>4.27</td>
<td>1.24</td>
<td>19.6</td>
</tr>
</tbody>
</table>

**Significance**
- Bi-axis: ns
- Spindle: * ns
- Large branch: * ns
- Small branch: * ns
- **Calc. Yield (%)**
  - Large branch: 41.2
  - Small branch: 58.8

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### Cumulated yield and the average fruit weight

- **yr 2009**
  - Bibaum®: 14.8
  - Spindle: 13.8
- **yr 2010**
  - Bibaum®: 34.6
  - Spindle: 22.8
- **Fruit weight**
  - Bibaum®: 19.8 b
  - Spindle: 13.8

- **Cumulated yield**
  - Bibaum®: 194.0
  - Spindle: 171.0
Cumulated yield and the average fruit weight in the canopy

Fruit size distribution (%) (yrs 2009-2010)
Pear cv Abbé Fétel:
2 training systems and 4 quince rootstocks:

Location: Ferrara

Year of planting: 2006

- Bi-axis (Bibaum®)
- Spindle
- Quince MC with Butirra Hardy interstem
- Quince BA29
- Quince MH
- Quince Sydo
Comparison between 2 training systems and 4 quince rootstocks: cumulated yield (kg/tree – t/ha): 2°-6° year (2007-2011)

Fruit size distribution (%) (6° year - 2011)
Yield distribution on tree canopy: cumulated yield from 3° to 6° year (2008-2011)

<table>
<thead>
<tr>
<th>Clone</th>
<th>Site</th>
<th>Planting year</th>
<th>Fruit weight</th>
<th>Plant. dist. &amp; tree density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiku 8</td>
<td>Lugo (Ra)</td>
<td>2003</td>
<td>55.6%</td>
<td>15.2 b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10.7 a</td>
<td>201</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15.1 b</td>
<td>310</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14.6 b</td>
<td>317</td>
</tr>
</tbody>
</table>

Fuji: Other experience on Bi-axis tree

- **Clone**: Kiku 8
- **Site**: Lugo (Ra)
- **Year**: 2003
- **Fruit weight**: 55.6%
- **Plant. dist. & tree density**:
  - Bi-axis: 3.6 m x 1.2 m (2,315 trees/ha)
  - Bi-axis: 11.8” x 3.9” (937 trees/A)
  - Spindle: 3.6 m x 1.0 m (2,778 trees/ha)
  - Spindle: 11.8” x 3.3” (1,127 trees/A)
Fuji (Ravenna):
different overcolor in the bottom part of the tree – Year 4

Spindle

Bi-axis

Fuji: Year 4 (Ravenna) - Data 2006 –
Shoots number at various tree heights

0-1.2
1.2-1.8
1.8-2.4
>2.4

(m)

Tree height (m, cm)

Shoot number

P<0.01

Bi-axis

Spindle

(Source: Dorigoni, 2008; Dorigoni et al., in press)
Orchard issues:

- cultivars and habitus,
- rootstocks,
- vigor,
- orchard design,
- fruit quality, color and homogeneity of the fruit distribution,
- mechanization

(Source: Dorigoni, 2008; Dorigoni et al., in press)
Example of fruit distribution in the tree canopy on the basis of the different training systems:

Abbé Fetel/NI - Training system: Spindle. Density: 12,121 tree/ha. Planting distance: 2.75 x 0.30 m.

Abbé Fetel/Sydo - Training system: 4 axes. Density: 1,666 tree/ha. Planting distance: 4.0 x 1.5 m (Ferrara, 2005).

Abbé Fetel/Sydo - Training system: Spindle. Density: 3,571 tree/ha. Planting distance: 3.50 x 0.80 m.


Fruit distribution in the canopy. Spindle 60-70 % of the fruit are located in the bottom part.
**PROGETTO AGER INNOVAPERO**

Fruit distribution in DA classes at harvest

Harvest 2011 (30-31/8)

Harvest 2012 (10-11/9)

**MODI**

Yield (kg) per training systems per bearing wood 2011
“Column-system of apple trees” with up to 155 t / ha (62.8 tonne/A) (Geyzengeym Germany).

Narrow canopy tree in Washington
Orchard issues:

- cultivars and habitus,
- rootstocks,
- vigor,
- orchard design,
- fruit quality, color and homogeneity of the fruit distribution,
- mechanization

Flat canopy is the requirement for mechanical pruning
NEW ORCHARDS

Two-axis

Three-axis

Bi-axis tree
Fruit wall?  Concept of mechanization trimming

Pommier, le Mur fruitier, 2002 A. Masseron

MUR FRUITIER PRUNING

Fruit wall?  Concept of pruning

12 leaves pruning
Summer 2-3 h/ha

Winter manual pruning
to integrate the mechanical

Pommier, le Mur fruitier,
2002 A. Masseron
Pruning basis AOC - Winter pruning by hand

- A = Affaisses = Sagging
- O = Oublies = Forget
- C = Concurrents = Competitor

Pommier, le Mur fruitier, 2002 A. Masseron

Fruit wall - Filling surface
13,000 to 17,000 m² of surface per ha (25 fruits/m²) 400,000 fruits/ha (161,900 fruits/acre)
Pruning machine suitable for high density orchard. Vertical bar, up to 280 cm long with knife “SCH”, can be matched upper and lower top with tilting and hydraulic return. The max cutting diameter is 3cm.


Saw with bar and windows (different levels of cutting)
Examples of mechanical pruning in apple – Summer pruning 12 leaves

Effect of mechanical pruning on flower bud formation
Mattawa: Apple Mechanical pruning

PINK LADY/M9-337

YEAR OF PLANTING: 2012

PLANTING DISTANCES = 3 ft X 10 ft

overall row length: 1,200 ft

<table>
<thead>
<tr>
<th>row (avr. 3 reps)</th>
<th>avr. cut leaves kg/tree</th>
<th>avr. cut wood kg/tree</th>
<th>tot material removed kg/tree</th>
<th>avr. num cut fruit /tree</th>
<th>mechanical pruning time sec/tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical summer pruning row (2 June 2014)</td>
<td>0.20</td>
<td>0.12</td>
<td>0.32</td>
<td>9</td>
<td>1.78</td>
</tr>
</tbody>
</table>
Pink Lady 2014 harvest

<table>
<thead>
<tr>
<th>trt</th>
<th>num fruit/tree</th>
<th>net weight fruit (kg/tree)</th>
<th>TCSA (cm²)</th>
<th>avr. fruit weight (g)</th>
<th>yield efficiency (kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>42 a</td>
<td>10.4 a</td>
<td>11.9 b</td>
<td>248</td>
<td>0.89 a</td>
</tr>
<tr>
<td>summer pruning</td>
<td>44 a</td>
<td>10.9 a</td>
<td>13.7 a</td>
<td>251</td>
<td>0.82 ab</td>
</tr>
<tr>
<td>winter pruning</td>
<td>34 b</td>
<td>9.0 b</td>
<td>12.4 b</td>
<td>261</td>
<td>0.74 b</td>
</tr>
</tbody>
</table>

Significance:
- *** p < 0.001
- ** p < 0.01
- * p < 0.05
- ns = not significant

Pink Lady 2014:
fruit size distribution at harvest
(9 trees per trt)
Effects of mechanical pruning on fruit maturity/ripeness

Fruit DA distribution according to pruning

DA meter: non-destructive measure of absorbance related to chlorophyll levels

<table>
<thead>
<tr>
<th>Season</th>
<th>DA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>5.3</td>
</tr>
<tr>
<td>Control</td>
<td>5.8</td>
</tr>
<tr>
<td>Summer</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Effects of mechanical pruning on fruit ripeness/maturity

<table>
<thead>
<tr>
<th>Starch index</th>
<th>Winter</th>
<th>Control</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.3</td>
<td>5.8</td>
<td>6.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Brix</th>
<th>Control</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13</td>
<td>15</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Titratable acidity</th>
<th>Control</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.68</td>
<td>0.88</td>
<td>0.86</td>
</tr>
</tbody>
</table>
Effects of mechanical pruning on fruit quality: color measurements

Hue angle on reddest side of fruit

Chroma on reddest side of fruit

Orchards mechanizations

THINNING
### DARWIN 300

- apparatus positioned in the front - right side of the tractor
- constituted by a rotating spindle on which are inserted numerous plastic whips (2 ft long).
- a hydraulic motor rotates the spindle.
- the action of whipping whips makes flower buds drop.
- Darwin manages to thin a vegetative wall tall 9 ft with a working capacity of 3 h / 5 acres.

### Apple mechanical thinning

- intervention date: 15/04/2010
- corymb retracted 50-60% open flowers
- rotation: 240 rpm/min
- Speed: 6-7 km/h
Effect of mechanical thinning over the cluster

Effect of mechanical thinning over the cluster
### Gala: mechanical thinning

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N°fruit</th>
<th>Stat.</th>
<th>Weight (Kg/tree)</th>
<th>Fruit average (g)</th>
<th>Stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATS</td>
<td>151.9</td>
<td>ab</td>
<td>21.4 a</td>
<td>142.6 ab</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>174.1</td>
<td>a</td>
<td>22 a</td>
<td>127.1 b</td>
<td></td>
</tr>
<tr>
<td>Mechanical thinning + BA</td>
<td>98.9</td>
<td>b</td>
<td>16.7 a</td>
<td>171.8 a</td>
<td></td>
</tr>
<tr>
<td>Mechanical thinning</td>
<td>122.4</td>
<td>ab</td>
<td>17.6 a</td>
<td>148 ab</td>
<td></td>
</tr>
</tbody>
</table>

Source: Fondazione Navarra

<table>
<thead>
<tr>
<th>Frt number</th>
<th>Kg/tree</th>
<th>Avr. Frt wt (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATS</td>
<td>151.9</td>
<td>142.6</td>
</tr>
<tr>
<td>Control</td>
<td>174.1</td>
<td>127.1</td>
</tr>
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<tr>
<td>Mechanical thinning</td>
<td>122.4</td>
<td>148</td>
</tr>
</tbody>
</table>

Source: Fondazione Navarra

### Orchards mechanizations

**Harvest**
Source: http://www.nblosi.com/it/prodotti/bintro.php
Mechanization

Mechanization of pear harvesting with specialized machinery.

Apples and pears in crates ready for transport.

Washington State University
World Class. Face to Face.

12/2/2014
Harvest

THANK YOU!!!