Selecting an Orchard System for Apples

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> *The effectiveness of each component of an orchard system, e.g., tree density, rootstock, tree training, etc., can be measured by its influence on light interception and light distribution.*

An orchard system is a comprehensive program (a strategy) for the establishment and management of an orchard. There are seven components that must be considered when selecting or designing all orchard systems: 1) rootstock, 2) tree density, 3) tree quality, 4) tree arrangement, 5) support systems, 6) tree training by limb positioning and 7) tree training through pruning. This article will 1) compare the performance of a number of orchard systems, 2) select the factors (components of orchard systems) which contribute to good performance of some orchard systems and 3) combine components into a successful system.

COMPARING SYSTEMS

Many orchard systems have developed over the years to meet special climate, equipment, labor and market needs at specific locations. Orchard systems developed in fruit districts around the world include the freestanding central leader, vertical axis, slender spindle, super spindle, slender pyramid, Solaxe, Tatura trellis, V-spindle and HYTEC.

As mentioned above, each of these systems is made up of seven building blocks (components). These are the seven pieces of the orchard system puzzle that must be integrated to achieve a successful orchard. Each orchard system is a unique combination of these factors. For example, the freestanding central leader system is a non-supported medium-density system of pyramid-shaped trees planted in single rows on a semi-vigorous rootstock with a central leader trained vertically up to a height of 4 to 5 m (13 to 16 ft). In contrast, the slender spindle system, also a pyramid tree form, is planted at much higher densities, often in multi-row arrangements, uses a dwarfing rootstock, is supported and is trained to a height of approximately 2 m (6.5 ft).

It is often assumed that tree training techniques (pruning and limb positioning) are the major factors contributing to superior performance of one system over another. For example, it has been suggested that positioning limbs below the horizontal (Solaxe) or training the leader at an angle (Tatura trellis, 'V'-spindle) contributes to improved productivity. As we will see below, tree training may not be as important in terms of orchard productivity as factors such as tree density or rootstock.

There have been a number of studies in different countries that have compared the productivity of various orchard systems. In most studies there have been differences in productivity between orchard systems. However, it generally has not been possible to conclude which of the major factors (components) contributed to improved productivity. It was not possible, for example, to determine if tree density, rootstock or tree training were the critical factors. The goals of this article are to first help decide which of the orchard systems components makes significant contributions to performance and, second, to select orchard systems components that, when combined, result in an efficient and highly productive orchard system.

It has been a common conclusion with orchard systems trials that the most productive systems, on a per-hectare basis, were the systems planted at the highest tree density and that the least productive systems had the lowest tree density. This is illustrated with cumulative yield data from a Braeburn trial in Washington (Fig. 1). A trial with Gala, also in Washington, shows that the sustained annual production (years 5-9) for slender spindle/M.9 was greater than 50 MT/ha (MT/ha is equivalent to bins/acre) (Fig. 2). The vertical axis systems on M.7 and M.26 averaged about 40 MT/ha, and central leader trees on M.26 and M.7 averaged just 30 MT/ha. In these trials, because the systems were planted at different densities and with different rootstocks, it was not possible to determine the separate influence of rootstock, tree density or tree training system on productivity.

A trial planted in 1990 with Fuji and Braeburn was in part designed to compare orchard systems which used the same rootstock. With both Fuji and Braeburn on M.26, vertical axis trees, at 1502 trees/ha (608 trees/acre), were compared with central leader trees at 1111 trees/ha (450 trees/acre) (Table 1). With both varieties, the vertical axis system had substantially higher production than the central leader system. The relative yields of the vertical axis and central leader systems were in proportion to their respective tree densities. The yield for the lower density central leader system was very similar to the yield that would be expected based on the fact that it was planted at a lower tree density (Table 1). Therefore, the yield difference between the two orchard systems can be attributed primarily to differences in tree density.

In the same trial with Fuji and Braeburn, slender spindle trees on M.9 at 2460 trees/ha (996 trees/acre) were compared with vertical axis trees at 1502 trees/ha (608 trees/acre), also on M.9 (Table 2). With Fuji, the mean yield per hectare for slender spindle and vertical axis systems in years 7 through 10 was similar. The relative yields of the two systems were not in proportion to their tree densities. The expected yield per hectare for the vertical axis system based on its lower density was substantially lower than the actual yield obtained for both Fuji and for Braeburn (Table 2). The higher than expected yield for the vertical axis system, that is higher than would be expected on the basis of its lower tree density, can be attributed to differences in tree training. The canopy volume/ha for the slender spindle and vertical axis trees with Fuji was similar (Table 2). This suggests that the training of individual vertical axis trees to a taller height and greater width (than the slender spindle) contributed to the greater total canopy volume/ha and, in fact, resulted in both systems having similar canopy volume/ha and similar yields. With Braeburn, a weaker growing cultivar, the trend was similar with the vertical axis system having higher production than would be expected based on its lower tree density. However, with Braeburn the vertical axis trees did not achieve production/ha as high as the slender spindle system.

FIGURE 1

Cumulative yield of six orchard training system/rootstock treatments through year 9 in a trial with Braeburn in Washington (SS, slender spindle training at 2460 trees/ha; VA, vertical axis training at 1502 trees/ha; CL central leader training at 1111 trees/ha).

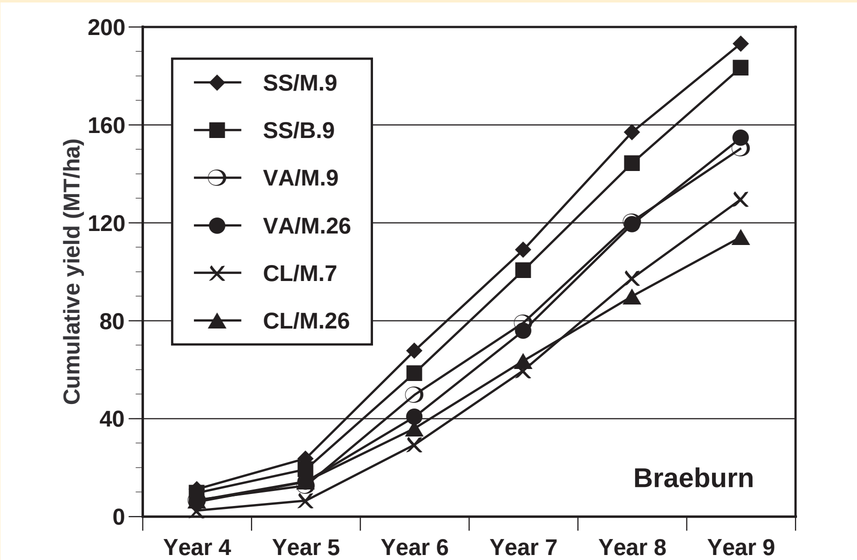
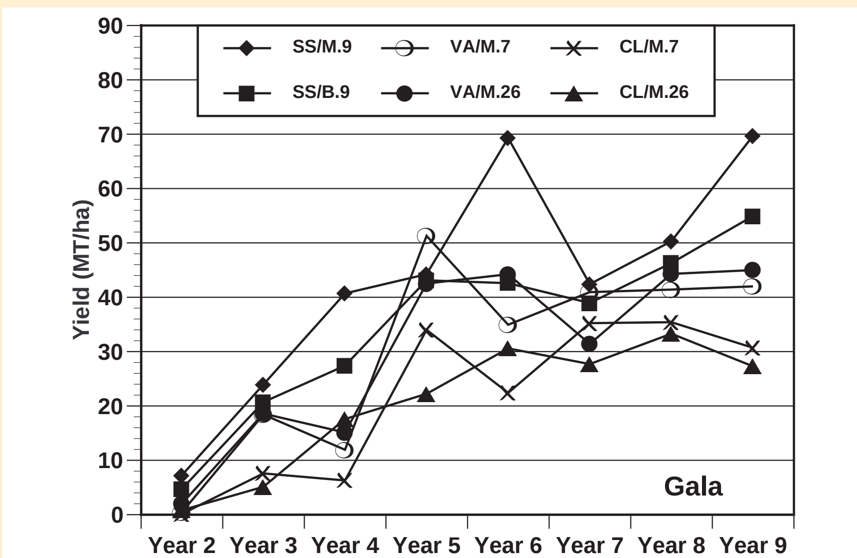


FIGURE 2

Annual yield of six orchard training system/rootstock treatments through year 9 in a trial with Gala in Washington (SS, slender spindle training at 1905 trees/ha; VA, vertical axis training at 1270 trees/ha; CL central leader training at 800 trees/ha).



From the 1990 trial comparing orchard systems on the same rootstock, it can be seen that in some situations differences in productivity are based on differences in tree density, but in other situations the differences in productivity can be attributed to differences in tree training. One result of differences in tree training, particularly changing tree height and spread, can be to affect canopy volume/ha.

A study was established in 1992 to compare the influence of tree training when orchard systems were planted at the same tree density and with the same rootstock. The training systems in the trial were Tatura trellis, V-spindle (Güttinger 'V') and double-row, all planted at 2500 trees/ha (1000 trees/acre). These three training systems were compared to the HYTEC system at 1667 trees/ha (675 trees/acre).

The Tatura trellis trees were planted in a single row with one tree angled (65˚ above horizontal) to the right and the next tree to the left and the limbs were trained in a thin plane along the wires as an angled palmette system. The V-spindle trees were also planted in a single row with one tree angled (70˚ above horizontal) to the right and the next tree to the left, but the individual trees were cone-shaped spindle trees with the leader trained at the 70˚ angle (an angled spindle system). This trial included two variety/rootstock combinations, Fuji/M.9 and Braeburn/M.26. In addition, half the trees in the trial were allowed to grow to a 3 m (10 ft) height while the other half were contained to a 2 m (7 ft) tree height.

Mean annual production (years 5 to 8) for the three orchard systems at a density of 2500 trees/ha was very similar with both Fuji and Braeburn (Table 3). The HYTEC system, with lower tree density, had significantly lower production/hectare than the other three systems with both Braeburn and

Fuji. The reduction in yield for the HYTEC system (70% of the other systems) was proportional to its reduced tree density (67% of the other systems). It is apparent from these data that the tree training system had a relatively small influence on production when each system was planted at the same tree density and with the same rootstock. The 3 m (10 ft) tall trees had significantly greater annual production (about 15% greater) than the 2 m tall trees with both Braeburn and Fuji (Table 3).

THE SUNLIGHT FACTOR

An explanation for why some tree training systems may be more productive than others can be considered in terms of both light interception by orchard canopies and light distribution within individual trees. Orchard systems which intercept approximately the same amount of sunlight can be expected to have similar productivity per hectare.

Many studies have shown that, as light interception increases, productivity increases. On the other hand, light distribution within the tree canopy influences fruit quality. Many studies have shown that in areas of the tree canopy with poor light distribution (shaded zones) fruit of inferior quality is produced, particularly fruit of small size, poor color and low soluble solids.

The effectiveness of each component of an orchard system, e.g., tree density, rootstock, tree training, etc., can be measured by its influence on light interception and light distribution. Given a common tree form (e.g., cone shape) and tree density, taller trees have higher light interception than short trees. However, very tall trees tend to have poor light distribution in the lower parts of their canopy. Trees planted at high densities tend to have high light interception but often have problems with tree-to-tree shading, resulting in poor light distribution within the canopies.

Rootstocks that produce relatively large trees, e.g., M.7, MM.106, MM.111 and M.793, often have high light interception but unfortunately usually also have relatively poor light distribution throughout the canopy. On the other hand, trees with dwarfing rootstocks can have low light interception unless they are planted at sufficiently high tree densities and are trained to a reasonable height (e.g., 3 m). However, trees on dwarfing rootstocks generally have excellent light distribution due to weak shoot growth and openness of the canopy.

Optimal light interception and light distribution often occur in orchard systems when tree height is equal to approximately two times the clear alley width. The clear alley width is the width required for equipment and bin movement down the row within the orchard. If a clear alley width of 1.5 m (5 ft) is required for the tractor and bin, then a tree height of approximately 3 m (10 ft) would be appropriate. It is also interesting to note that trees which are approximately 3 m (10 ft) tall, when compared to 2 m (7 ft) tall trees with the same basal diameter, have approximately 60% greater canopy volume per tree. It is therefore prudent to train trees to a height of at least 3 m to capitalize on the increased canopy volume and improved light interception. Data presented above indicated a 15% improvement in productivity for trees trained to a height of 3 m (10 ft) vs 2 m (7 ft) in the trial with Braeburn and Fuji.

TABLE 1

A comparison of vertical axis and central leader training systems at different tree densities with Fuji and Braeburn on M.26 rootstock.

System/rootstock	Tree density (no./ha)	Yield, mean of years 7-10 (MT/ha)	Canopy volume/ha, mean of years 7-9 (m^3/ha)
Fuji			
Vertical axis/M.26	1,502	31.4	11,471
Central leader/M.26	1,111	22.4 (23.2)*	9,088 (8,489)*
Braeburn			
Vertical axis/M.26	1,502	35.1	5,514
Central leader/M.26	1,111	24.9 (22.8)*	3,149 (4,080)*

*In brackets, the expected value for central leader system compared with the vertical axis system based on reduced tree density (.74 times vertical axis).

TABLE 2

A comparison of slender spindle and vertical axis training system at different tree densities with Fuji and Braeburn on M.9 rootstocks.

System/rootstock	Tree density (no./ha)	Yield, mean of years 7-10 (MT/ha)	Canopy volume/ha, mean of years 7-9 (m^3/ha)
Fuji			
Slender spindle/M.9	2,460	31.1	8,033
Vertical axis/M.9	1,502	32.3 (18.9)*	8,789 (4,900)*
Braeburn			
Slender spindle/M.9	2,460	42.4	4,499
Vertical axis/M.9	1,502	34.4 (25.9)*	3,301 (2,744)*

*In brackets, the expected value for the vertical axis system compared with the slender spindle system based on reduced tree density (.61 times slender spindle).

TABLE 3

A yield comparison of four orchard systems and two tree heights with Fuji and Braeburn.

Treatments	Yield, mean of years 5 to 8 (MT/ha)	
Orchard system	**Fuji/M.9**	**Braeburn/M.26**
Tatura trellis at 2500 trees/ha	45.3	42.7
'V' spindle at 2500 trees/ha	44.7	41.3
Double row at 2500 trees/ha	43.5	39.0
HYTEC at 1667 trees/ha	31.2 (70%)[z]	28.9 (70%)[z]
Tree height:		
2-meter	38.4	35.1
3-meter	43.9 (114%)	40.8 (116%)

[z]Yield for the HYTEC system is 70% of the mean yield of the other three systems.

COMBINING COMPONENTS INTO A "SYSTEM"

Based on data from orchard systems trials, it is possible to select the components of an orchard system to optimize light interception and distribution and therefore achieve high productivity with high fruit quality. The "system" would have the following features:

1. M.9 or similar size-controlling rootstock.
2. Large nursery trees with branches.
3. A planting density of 1750 to 2500 trees/ha (700 to 1000 trees/acre).
4. Trees arranged in single rows.
5. Trees supported vertically with a 3-wire trellis.
6. Tree training by positioning the central leader vertically (with or without a zigzag) with lateral branches either flat or up to 30˚ above the horizontal and by developing the tree in a cone shape to a height of 3 m (10 ft).
7. Tree training by pruning the tree minimally, thereby discouraging excess vigor but pruning enough by thinning to keep the canopy open and by shortening (3 to 5-year-old branches) to stiffen limbs, thereby providing sufficient weak shoot growth to protect fruit from sunburn.

This "system" is the HYTEC (Hybrid Tree Cone) orchard system. It has a combination of features of the slender spindle and vertical axis systems with modification to reduce fruit sunburn in districts with clear skies and high temperatures.

ADDITIONAL READING

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Barritt, B.H., M.A. Dilley and B.S. Konishi. 1997. Orchard potential depends on solving preplant jigsaw puzzle. Proc. Wash. Sta. Hort. Assoc. 92:113-116.

Barritt, B.H., B.S. Konishi and M.A. Dilley. 1997. Tree size, yield and biennial bearing relationships with 40 apple rootstocks and three scion cultivars. Acta Hort. 451:105-112.

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CONVERSION FACTORS ENGLISH VS. METRIC

To convert Column 1 into Column 2, multiply by:	Column 1	Column 2	To convert Column 2 into Column 1 multiply by:
	Length		
.621	kilometer, km	mile	1.609
1.094	meter, m	yard	.914
3.281	meter, m	foot, ft	.3048
39.4	meter, m	inch	.0254
.03281	centimeter, cm	foot, ft	30.47
.394	centimeter, cm	inch	2.54
.0394	millimeters, mm	inches	25.40

metric: 1 km = 1000 m; 1 meter = 100 cm; 1 meter = 1000 mm
English: 1 mile = 5280 ft; 1 mile = 1760 yards; 1 yard = 3 ft; 1 ft = 12 inches

	Area		
247.1	kilometers^2, km^2	acre	.004047
2.471	hectare, ha	acre	.4047
.4047	trees/hectare	trees/acre	2.471

metric: 1 ha = 10,000 m^2 = .01 km^2
English: 1 acre = 43,560 ft^2

	Volume		
1.057	liter	quart (US)	.946

English: 1 US gallon = 4 quarts

	Mass—Weight		
1.102	ton (metric), MT	ton (English)	.9072
2.205	kilogram (kg)	pound, lb	.454
52.5	ton (metric) of apples	apple packed box, *carton	.01905

metric: 1 metric ton = 1000 kg
English: 1 ton = 2000 lb; 1 packed box or carton* of apples = 42 lb

	Yield or Rate		
0.446	ton (metric)/hectare, MT/ha	ton (English)/acre	2.242
.892	kilogram/hectare, kg/ha	pound/acre	1.121
.991	ton (metric) of apples/hectare, MT/ha	bins* of apples/acre	1.009
.4047	trees/hectare	trees/acre	2.471
0.107	liter/hectare	gallon (US)/acre	9.354

metric: 1 metric ton = 1000 kg; 1 hectare = 10,000 m^2
English: 1 ton = 2000 lb; apple bin* = 900 lb; 1 acre = 43,560 ft^2

	Temperature		
1.8 C + 32	Celsius, C	Fahrenheit, F	.555 (F-32)

**Commercial cartons (packed boxes) of fruit and field/storage bins of fruit do not have universal weights. The weight of fruit in a packed box or carton varies around the world and with the type of fruit, but is here taken for apples as 42 lbs (19.05 kg); the weight of fruit in a bin also varies but is here taken for apples as 900 lbs (408.2 kg).*