What Tree Density and Training System Should NY Growers Use with New Apple Orchards?

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Our results show there are no large differences in yield, quality or profitability between different training systems when trees are planted at the same density. Profitability of very high density systems like the Super Spindle system appears to be similar to the Vertical Axis system, but the investment risk is much higher due to the much higher establishment costs.

Fruit growers in New York State continue to plant higher and higher tree densities. However, there is great disparity of opinion on the optimum density. Some growers are using densities above 5,000 trees/ha and some growers on the other extreme plant densities of 500 trees/ha. The majority of growers are planting densities between 1,000 and 2,500 trees/ha. There is also considerable debate about which training system is best. Some favor the Slender Spindle system, others the Vertical Axis system, and others some version of V-systems. Our goal has been to provide research data on the production and economic performance of high density systems to assist growers in making proper planting decisions that will provide them the best return on investment. Our approach has been to compare several of the leading high density planting systems and also to compare them at several densities on growers' farms to determine the optimum density for each system and which systems are the most profitable.

The 1993 High Density Trial

We planted a replicated orchard planting systems field trial in 1993, on the farm of Eric and Bob Brown near Albion, NY. The trial was five acres in size and compared seven training systems each planted at two densities. Tree densities ranged from 1,098 to 5,980 trees/ha (Table 1). Each system had four varieties (Red Cortland, NuRedspur Delicious, Thome Empire and Regal Gala) with solid rows of each variety. Each row was 60 m long and each system was replicated three times. The site previously had been planted to apples and the soil was a sandy loam. Irrigation was applied through a trickle system with in-line emitters. The trees of Gala, Cortland and Empire were feathered at planting but the Delicious trees were whips. Annually, we measured yield, fruit size, fruit color and labor inputs for tree training and pruning.

Horticultural Results

The Super Spindle/M.9 system which had the highest tree density began production in the second year and continued with the highest yield through year 6 (Figure 1). There was almost no difference in yield between the two densities of Super Spindle. The results show that the Super Spindle system can achieve commercially important yields in the second year and maximum yields by year five. Cumulative yield by the end of year five was highest for the Super Spindle system and was related to tree density in essentially a linear manner (Figure 3). In years 7-9, the moderate density systems of Vertical Axis/M.9 and the Slender Spindle/M.9 had similar yields as the very high density Super Spindle/M.9 system. By the end of the ninth year, cumulative yield was highest for the Super Spindle/M.9 system and lowest for the Vertical Axis/M.26 system (Figure 2 and Table 2). The relationship of cumulative yield and tree density at the end of year nine was strongly curvilinear indicating that medium density systems produced essentially the same cumulative yield as

TABLE 1

Planting Systems at Brown's on-farm orchard systems trial[1].

System[2]	Spacing (m) and Tree Density (trees/ha) of Lower Density System		Spacing (m) and Tree Density (trees/ha) of Higher Density Systems	
Vertical Axis/M.26	2.1 X 4.3	(1,098)	1.5 X 4.3	(1,538)
Vertical Axis/M.9	1.8 X 3.7	(1,495)	1.2 X 3.7	(2,242)
Slender Spindle/M.9	1.8 X 3.7	(1,495)	1.2 X 3.7	(2,242)
V-Slender Spindle/M.9	1.8 X 3.7	(1,495)	1.2 X 3.7	(2,242)
Y-Trellis /M.9	1.8 X 3.7	(1,495)	1.2 X 3.7	(2,242)
V-Trellis /M.9	1.2 X 3.7	(2,242)	0.6 X 3.7	(4,485)
Super Spindle/M.9	0.6 X 3.7	(4,485)	0.45 X 3.7	(5,980)

[1] Trial was planted in April 1993.

[2] Each system used 4 varieties: Regal Gala, Thome Empire, Red Cortland and NuRedspur Delicious.

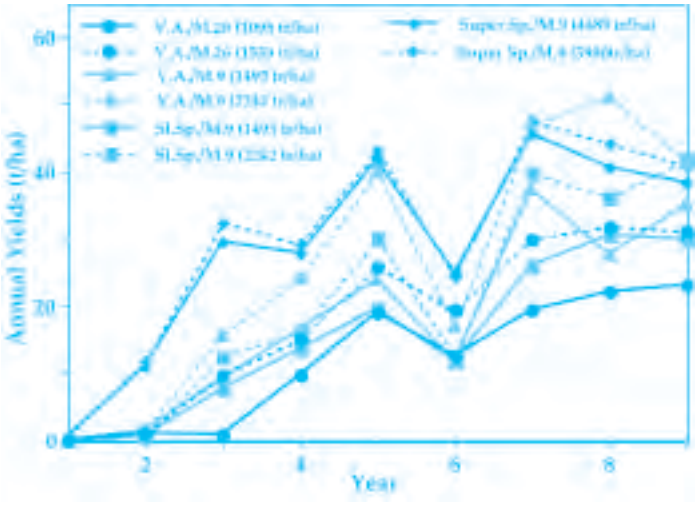

Figure 1. Annual Yields over 9 years of Gala trained to 4 planting systems and 2 spacings at the Brown's Planting Systems Trial.

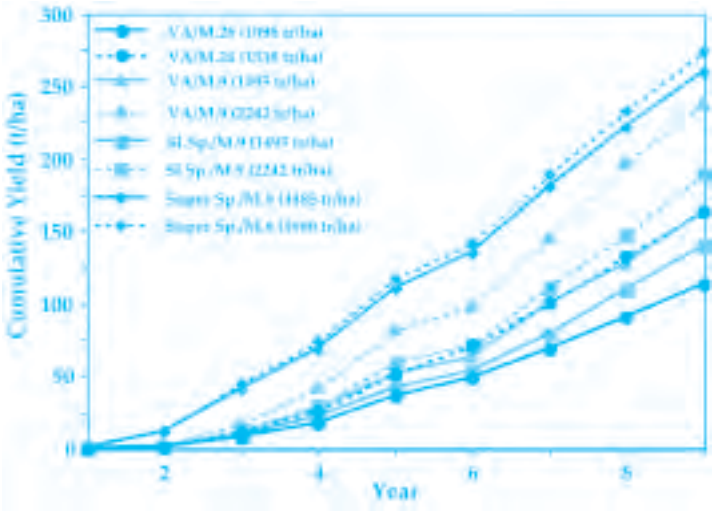

Figure 2. Cumulative yields over 9 years of Gala trained to 4 planting systems and 2 spacings at the Brown's Planting Systems Trial.

the high density system. It is likely that as the orchard ages, the relationship will be even more strongly curvilinear. The changing relationship indicates that the highest density systems have greater advantage in the early years, but, in the later years, the advantage disappears. This means that the very high density systems would have the greatest potential if orchard life is short or if fruit prices are very high in the early years of an orchard life.

In this study, there were no significant differences in cumulative yield among the four systems planted at the same two densities (Vertical Axis. Slender Spindle, Y-trellis, and V-Slender Spindle). Most of the differences in yield in this study were related to planting density. This indicates that the four leading modern training systems can all result in high yields since they all utilize the same principles of minimal pruning and good light distribution.

The largest average fruit size was with the Slender Spindle/M.9, the Vertical Axis/M.9 and the V-Slender Spindle/M.9 systems (Table 2). The V-trellis/M.9, Y-trellis/M.9, and the Vertical Axis/M.26 systems had intermediate fruit size while the Super Spindle/M.9 had the smallest fruit size. To a large extent, the smaller fruit size on the Super Spindle system was likely the result of larger crop.

Fruit red color was greatest with the Vertical Axis/M.26 system (Table 2). There were no differences in average fruit color between all of the other systems. The Vertical Axis/M.26 system had the most space between the trees and the most open canopy which likely resulted in the slightly improved fruit red color; however, all of the systems have good color due to

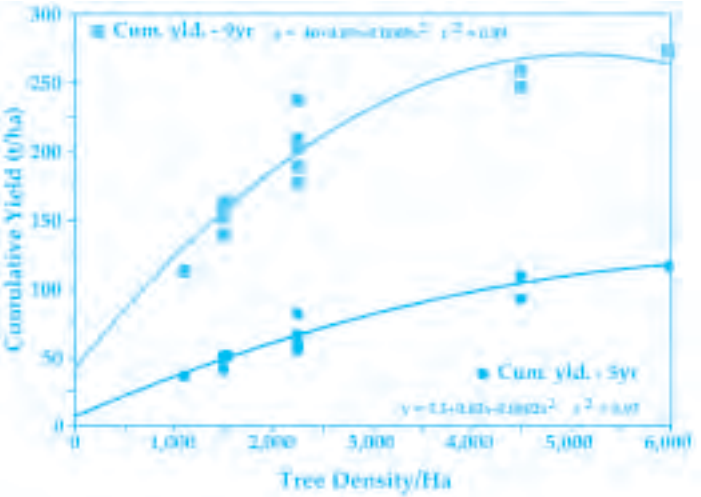

Figure 3. Relationships of cumulative yield and tree density a the end of year 5 and year 9 of Gala trained to 7 planting systems and 2 spacings at the Brown's Planting Systems Trial.

TABLE 2

Yields and fruit quality of 4 apple varieties (Red Cortland, NuRedspur Delicious, Thome Empire, and Regal Gala) trained to 7 orchard planting systems and 2 spacings at Brown's orchard planting systems trial.

System	Tree Spacing m	9 Yr. Cum. Yield (t/ha)	8 Yr. Average Fruit Size (g)	5 Yr. Average Fruit Color (%)
Vertical Axis/M.26	2.1 X 4.3	113	184	52
Vertical Axis/M.26	1.2 X 3.7	151	180	49
Vertical Axis/M.9	1.8 X 3.7	134	196	47
Vertical Axis/M.9)	1.2 X 3.7	179	192	46
Slender Sp./M.9	1.8 X 3.7	132	198	46
Slender Sp./M.9	1.2 X 3.7	164	196	47
V-Slender Sp./M.9	1.8 X 3.7	133	197	47
V-Slender Sp./M.9	1.2 X 3.7	164	190	45
Y-Trellis/M.9	1.8 X 3.7	132	187	46
Y-Trellis/M.9	1.2 X 3.7	164	184	47
V-Trellis/M.9	1.2 X 3.7	146	192	47
V-Trellis/M.9	0.6 X 3.7	191	180	47
Super Spindle/M.9	0.6 X 3.7	234	171	48
Super Spindle/M.9	0.45 X 3.7	262	170	46
LSD ρ≤0.05		26	8	3

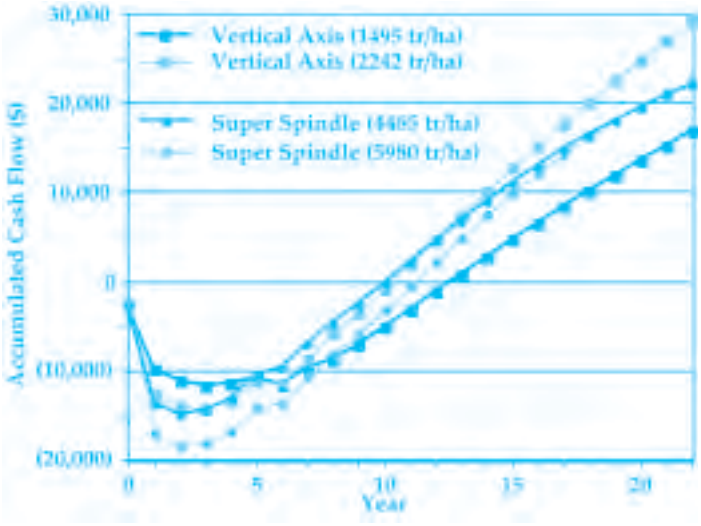

Figure 4. Projected cash flow through year 22 of Gala trained to 2 planting systems and 2 spacings at the Brown's Planting Systems Trial.

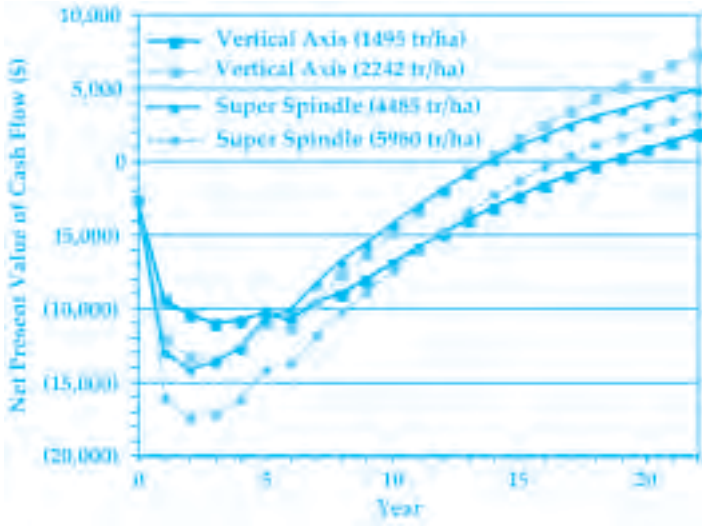

Figure 5. Net Present Value (NPV) of projected cash flow through year 22 of Gala trained to 2 planting systems and 2 spacings at the Brown's Planting Systems Trial.

the small tree size and open canopies.

Among varieties, Cortland was the most productive variety followed by Gala, Empire and then Delicious.

Economic Results

An economic analysis of cash flow and profitability was done using actual yields, fruit quality, material costs and labor inputs through year nine. We added projections of yield, quality and labor for years 10-22 based on average yield for years 7-9. Each of the planting systems was evaluated from an investment perspective by calculating the Net Present Value (NPV) of the investment over 22 years and by calculating the Internal Rate of Return (IRR) of the investment (White and DeMarree, 1992). The Net Present Value of the investment at any year can be determined from the value at that year. Thus, for a planned orchard life span of less than 22 years, the comparisons among systems can be made by the relative ranking of NPV at that year. For simplicity, only the results of Gala with four systems are presented in Figures 4-7.

Comparisons of cumulative cash flow showed that the Super Spindle/M.9 system which had the highest tree density was the most expensive to establish ($16,000/ha in the first year) and had the greatest cumulative negative cash flow in year 2 ($18,000/ha) (Figure 4). The Vertical Axis/M.9 system required $12,000/ha to establish and had a maximum negative cash flow of $14,000/ha in year three. At the end of year 9 none of the systems had a positive cumulative cash flow, but the low density Super Spindle/M.9 (4485 trees/ha) and the high density Vertical Axis/M.9 system (2,242 trees/ha) were the closest to breaking even. Projected to year 22, the greatest cash flow was with the high density Vertical Axis/M.9 system. The low density Vertical Axis system was lower with both densities of Super Spindle/M.9 intermediate.

Among varieties, Gala was the most profitable due to higher fruit prices, although Cortland was the most productive variety. Profitability of Gala was followed by Empire, Cortland, and then Delicious, which was the least productive and not profitable with any system.

Profitability among systems as measured by net present value analysis (NPV)

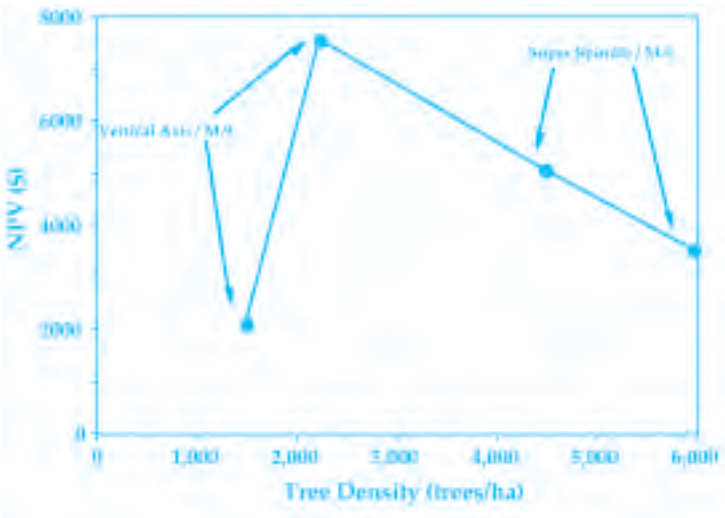

Figure 6. Effect of tree density on Net Present Value (NPV) of projected cash flow of Gala trained to 2 planting systems and 2 spacings at the Brown's Planting Systems Trial.

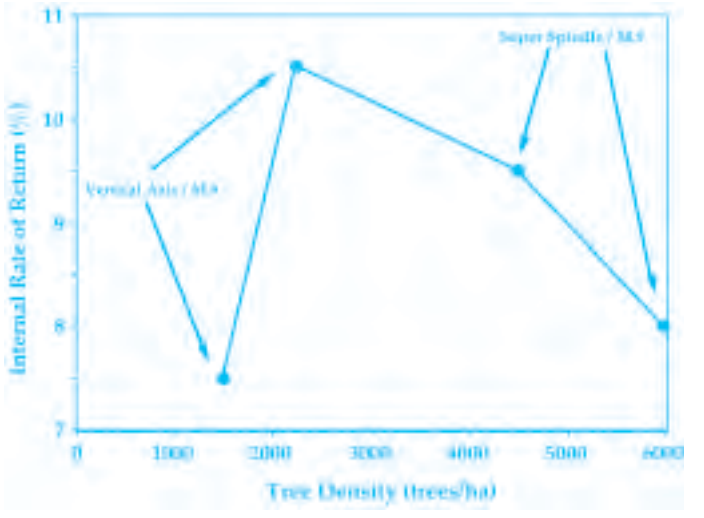

Figure 7. Effect of tree density on Internal Rate of Return (IRR) of investment in different planting systems of Gala (Brown's Planting Systems Trial).

of the investment after 22 years was highest for the high density Vertical Axis/M.9 system (Figure 5). Both the lower density Super Spindle and the higher density Vertical Axis system became profitable in year 10 with the higher density Super Spindle system in year 11 and the lower density Vertical Axis system in year 13. The lower density Super Spindle and the higher density Vertical Axis systems had very similar profitability for orchard life spans of 10-13 years. But for longer orchard life spans, the higher density Vertical Axis was more profitable.

Using a 22-year orchard lifetime, NPV and Internal Rate of Return (IRR) were curvilinearly related to tree density with intermediate densities giving the highest profitability (Figures 6 and 7). These data indicate that for a 22-year orchard life span and with the moderate vigor soil used in this study, there is a clear optimum of orchard planting density between 2,000 and 3,000 trees/ha. With shorter orchard life spans we predict a rather broad optimum planting density between 2,000 and 4,500. However, these data clearly show that, regardless of orchard life span, even the relatively modest density of 2,200 trees per ha can be as profitable as the very high densities.

Our results show that the Super Spindle system can be profitable, but it must have an orchard life of at least 10-11 years. Even at the relatively short orchard life of 10-13 years, the Super Spindle systems were not more profitable than the more moderate density Vertical Axis system. Even though profitability of the Super Spindle system appears to be similar to the Vertical Axis system, the investment risk is much higher due to the much higher establishment costs. From an investment perspective this will require a higher IRR for the Super Spindle to justify planting this system. To improve the profitability of this system and reduce the risk, either the establishment cost must be reduced through less expensive trees or very high fruit prices must be obtained during years 2-6 when the Super Spindle system has the greatest yield.

Conclusions

Long-term orchard planting systems trials such as the one at Brown's farm in New York have provided data which can be used to compare different training systems and to predict for growers which planting density and training system is most profitable. Two important results of this study complement the results of our earlier studies:

1. There were no large differences in yield, quality or profitability between different training systems when they were planted at the same density.
2. Increasing tree planting density results in increased cumulative yield, but with a curvilinear relationship.

In addition, results of this study provide more precise information on profitability and optimum planting density: We conclude that:

1. With replant soils in New York State such as the one used in this study, all densities up to 5,500 trees/ha are manageable and productive.
2. The optimum planting density depends on economic factors, not horticultural limitations.
3. Under New York State conditions, the optimum density for profitability is between 2,200 and 3,000 trees/ha.
4. The super high density systems can be profitable, but with traditional tree prices, they are not more profitable than more moderate densities of around 2,200 trees/ha.
5. The super high density systems require lower establishment costs and higher fruit prices to be the most profitable.
6. The investment risk increases with increased investment costs making the super spindle system riskier from an investment perspective.

References

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