Should New York Growers Plant Higher Density Peach Orchards?

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Under the moderate growth conditions of New York State and the relatively short orchard lifespan of peach, high density orchard planting systems offer significant early yield, and mature yield advantages over the traditional Open Center system. In our study, the Perpendicular-V system and the Tri-V system had yields and high economic returns compared to the traditional Open Center system.

New York State is on the northern limit of successful peach production areas. Peach trees in NY suffer from perennial cankers (*Cytospora spp*.) and winter cold damage in some years. This limits the useful life of a peach orchard to about 15 years. Traditionally, peach trees have been grown using the open center system at densities of 350-400 trees/ha. Mature tree height has been limited to 2.5m and tree spread has extended up to 5m in diameter. This results in rather short trees that can be harvested largely from the ground. However, the low tree density results in poor yield during the early years. In addition, the low tree stature of the NY open center system results in low mature yields that do not exceed 20 Mt/ha. Warmer peach producing areas have significantly higher yield than NY (DeJong, et al., 1994). The relatively cool summers of NY State result in moderate shoot growth and relatively slow tree development during the early years of a new orchard. Under these conditions of slow tree growth and short orchard life, high- density orchard systems have great potential to improve yield and profitability of peach orchards (Loreti and Massai, 2002).

Materials And Methods

In 1999, a replicated field trial comparing six peach orchard training systems (Open Center, Quad-V, Tri-V, Perpendicular-V, Central Leader and Slender Spindle) with three varieties [Allstar (yellow peach), Blushingstar (white peach) and Flavortop (nectarine)] all on Bailey rootstock was planted at Olcott, New York. Tree densities and spacings are given in Table 1.

The Open Center System was developed based on heading the leader at 40cm at planting. In the second year, four well-placed scaffold branches were selected and headed by one third and the leader was removed. Each of the four scaffolds was bifurcated at two-foot intervals by heading successively in the dormant seasons of the second through fourth years. The scaffolds were pruned to an angle of 50° above horizontal. In the fifth year, tree height was limited to 2.5m by lowering the top branches down to a horizontal side branch.

The Quad-V system also was developed by heading the leader at 40cm at planting. In the second year, four well-placed scaffold branches were selected and headed by one third and the leader was removed. Two of the four scaffolds were oriented to each side of the row and oriented to opposite quadrants of the tree. In the dormant seasons of the second through fourth years, the four scaffolds were pruned to an angle of 65° above the horizontal and allowed to extend to a height of 3.25m. In the late dormant season of each year, all secondary branches that were not fruiting twigs were removed back to a side shoot or bud near the scaffold. This resulted in columnar scaffold branches with the fruiting twigs produced on or near the scaffolds.

The Tri-V system was developed in a manner similar to the Quad-V system except only three scaffolds branches were allowed to develop. They were oriented perpendicular to the row with two on one

TABLE 1

Six orchard planting systems evaluated in the New York peach systems trial.

System Name	Description	Tree Density/ Ha	Tree Spacing (m)	Initial Tree Heading Height (cm)
Open Center	4 scaffold branches with 3 bifurcations.	384	4.3 X 6.1	60
Quad-V	4 scaffold branches without bifurcation and with renewal pruning.	538	3.0 X 6.1	45
Tri-V	3 scaffold branches without bifurcation and with renewal pruning.	905	2.1 X 5.2	45
Central Leader	Central trunk with permanent lower tier of 4 branches.	1,098	2.1 X 4.3	100
Perpendicular-V	2 scaffold branches without bifurcation and with renewal pruning.	1,583	1.2 X 5.2	45
Slender Spindle	Central trunk with no permanent lower tier branches.	1,922	1.2 X 4.3	100

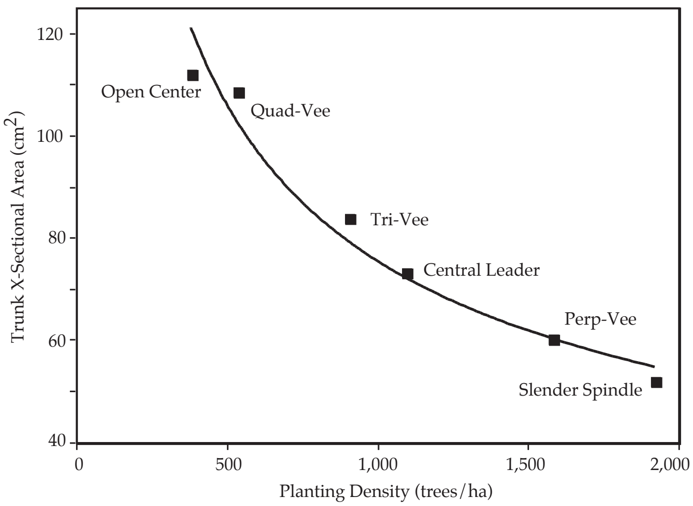

Figure 1. Effect of increasing planting density on peach tree size after 6 years in the orchard.

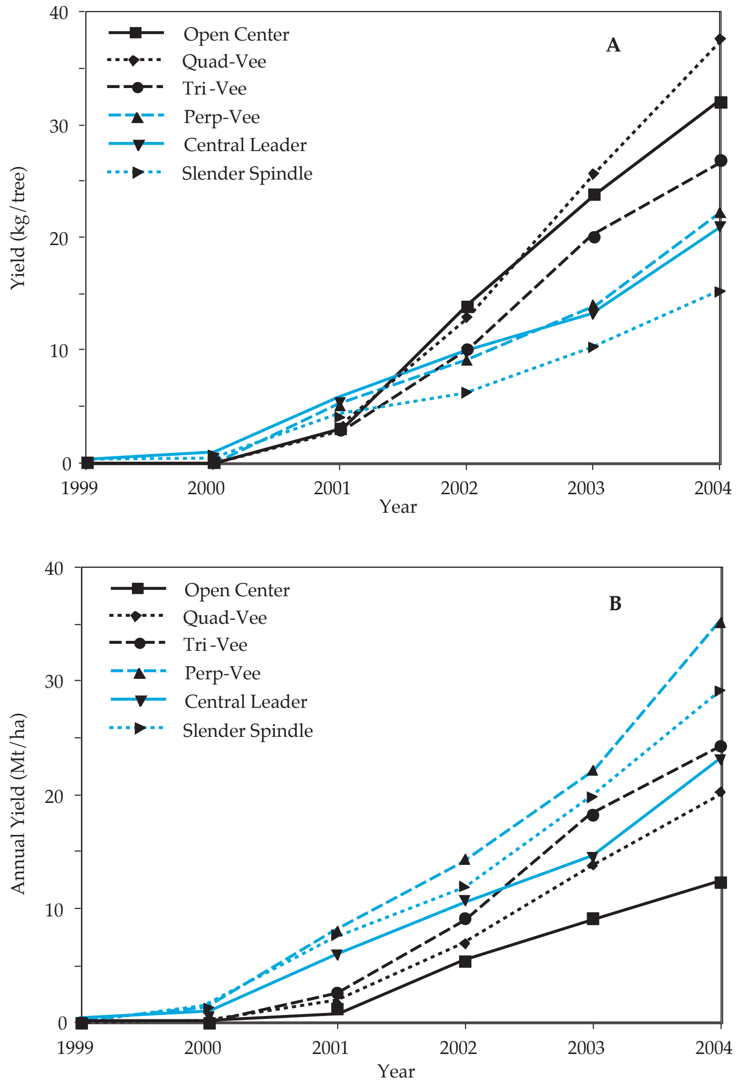

Figure 2. Annual yields per tree (A) and per hectare (B) of 6 peach orchard systems over the first 6 years of orchard development.

side and one on the other, alternating down the row. In the dormant seasons of the second through fourth years, the scaffolds were headed each year by one third to a side branch that continued in the 65° upward direction. The scaffolds were allowed to extend to a height of 3.25m. In the late dormant season each year, all secondary branches that were not fruiting twigs were removed back to a side shoot or bud near the scaffold. This resulted in columnar scaffold branches with the fruiting twigs produced on or near the scaffolds.

The Perpendicular-V system was developed in a manner similar to the Quad-V system except only two scaffolds branches were allowed to develop. They were oriented perpendicular to the row. In the dormant seasons of the second through fourth years, the scaffolds were headed each year by one third to a side branch that continued in the 65° upward direction. The scaffolds were allowed to extend to a height of 3.25m. In the late dormant season each year, all secondary branches that were not fruiting twigs were removed back to a side shoot or bud near the scaffold. This resulted in columnar scaffold branches with the fruiting twigs produced on or near the scaffolds.

The Central Leader system was developed by heading the leader at 100cm at planting and removing large diameter feathers (larger than two thirds diameter of leader). During the second through the fourth years, the leader was headed by one third each year and a strong vertical shoot arising near the heading cut was trained as the leader. In the second year, a lower tier of four scaffolds was selected and pruned to horizontal by shortening each branch back to a horizontal side branch. Large diameter branches along the leader were renewed back to the trunk on an annual basis by stubbing back to a bud or side shoot near the leader. This created a columnar leader with fruiting twigs arising near the leader. Tree height was limited to 3.25m.

The Slender Spindle system was developed in a manner similar to the central leader except that no permanent lower tier scaffold branches were allowed. Large branches were renewed back to the trunk on an annual basis by cutting to a side shoot or bud near the trunk.

An economic analysis of profitability was done using actual yields, simulated packout, material costs and labor inputs through year six. We added projections of yield, packout and labor costs for years 7-15 based on average yield for years five and six. (Robinson and Hoying, 2004).

Results

Growth. After six years the largest trees (measured as trunk cross-sectional area) were from the traditional Open Center system (Figure 1). The smallest trees were from the highest density Slender Spindle system. There was a strong negative effect of tree density on tree size. The highest density system had a trunk cross-sectional area that was less than half the size of the lowest density system.

Yield. In the second year (2000) the trees had a very small crop followed by significant commercial crops in the third year and large commercial crops in the fourth-sixth years (Figure 2A). On a land area basis, the Central Leader and the Slender Spindle systems, which had the least pruning at planting, had the highest 2nd year yield/ha while all of the other four systems which required severe heading at planting, had very low 2nd year yield (Figure 2B). In the third year, the Slender Spindle and Perpendicular-V had the highest yield/ha followed by the Central Leader, Tri-V, Quad-V and Open Center, which had the lowest yield. In the fourth through sixth years, the Perpendicular-V had the highest yield followed by the Slender Spindle, Tri-V, Central

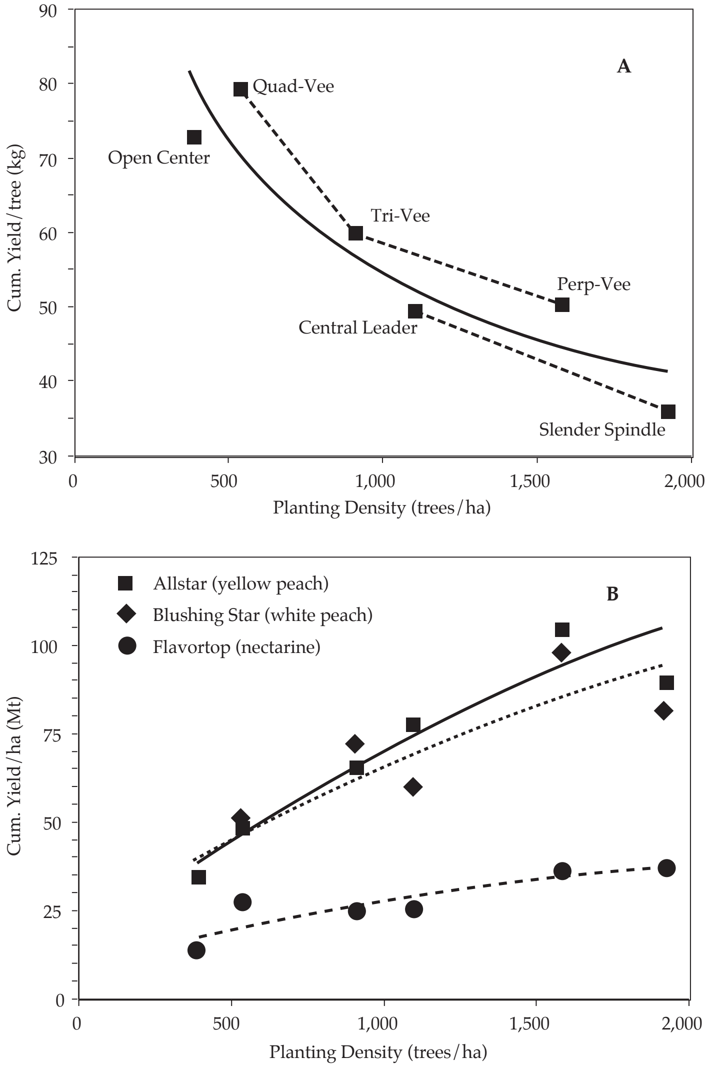

Figure 3. Effect of increasing planting density on 6-year cumulative yield per tree (A) and yield per hectare (B) of 3 peach varieties. Dotted black lines connecting the 3 V-shaped systems and the 2 pyramid-shaped systems indicate that the V-shaped systems have higher yield than the pyramid shaped systems.

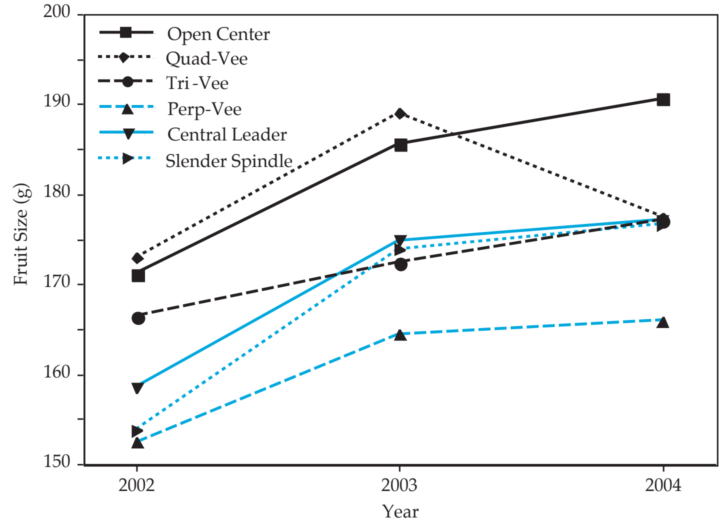

Figure 4. Annual fruit size of 6 peach orchard systems over 3 years of orchard development.

TABLE 2

Effect of 6 Orchard Planting Systems on Fruit Size and Color and Farm Gate Crop Value Over the First 6 Years.

System	Tree Density/ Ha	Av. Fruit Size (g)	Fruit Red Color (%) (2004)	Cumulative Farm Gate Crop Value/ Ha** ($)
Open Center	384	182.4 a*	46.3 b	14,961 d
Quad-V	538	179.7 a	61.5 a	24,668 c
Tri-V	905	172.0 b	56.7 a	28,583 b
Central Leader	1,098	170.1 b	61.9 a	28,573 b
Perpendicular-V	1,583	160.9 c	61.4 a	38,695 a
Slender Spindle	1,922	168.1 b	60.2 a	36,207 a
LSD p≤0.05		6.7	5.9	3,539

*Means followed by the same letter are not significantly different. (p≤0.05, n=9)
** Excludes picking, storage and packing costs.

Leader, Quad-V and Open Center systems.

Cumulative yield per tree was negatively related to planting density in a curvilinear manner (Figure 3A). The highest density system had slightly less than one half the cumulative yield per tree as the lowest density system. The three V systems had greater than expected yield from the regression relationship, and the two pyramid shaped systems had lower than expected yield. Cumulative yield per ha was positively related to tree density; however, there was an interaction with variety (Figure 3B). The yellow peach (Allstar) and the white peach (Blushing Star) gave similar responses at each density, but the nectarine (Flavortop) had significantly lower yield at each density. For the two high yielding varieties, the Perpendicular-V had the highest cumulative yield (100 Mt/ha) followed by the Slender Spindle, Central Leader, Tri-V, Quad-V and the Open Center system (27 Mt/ha). The best system had approximately 3X the yield of the poorest system. With the nectarine, the Slender Spindle and the Perpendicular-V had the highest cumulative yield (37 Mt/ha) followed by the Central Leader, Tri-V, Quad-V and the Open Center System (15 Mt/ha). The best system had approximately 2.5X the yield of the poorest system.

Fruit Quality. Average fruit size in years three through six was greatest with the Open center and Quad-V systems, intermediate with the Tri-V, the Central Leader and the Slender Spindle, and smallest with the Perpendicular-V system (Table 2, Figure 4). Fruit red color in 2004 was similar for all of the systems (approximately 60%) except the Open Center system, which had significantly poorer color (46%).

Economics. In year two, farm gate crop value was highest for the Slender Spindle but by year three the Perpendicular-V had similar crop value as the Slender Spindle (Figure 5A). By year six the crop value of the Perpendicular-V system exceeded the returns of the Slender Spindle. The Open Center system had the lowest crop value in each of the years. Accumulated crop value over six years was highest for the Perpendicular-V system ($38,695/ha) followed by the Slender Spindle, Tri-V, Central Leader, Quad-V and was lowest for the Open Center system ($14,961/ha) (Table 2). Estimated profitability over a 15-year orchard life showed that all systems were profitable except the Open Center with Flavortop (Figure 5B). The relationship between tree density and profitability was curvilinear; however, there was an interaction with variety. The yellow peach (Allstar) and the white peach (Blushing Star) generated similar shaped quadratic response curves. The optimum density was 1,329 trees/ha for Allstar (yellow peach), and 1,406 trees/ha for Blushing Star (white peach). The nectarine had significantly lower profitability at each density, and the curve increased with increasing density up to 1900 trees/ha (highest density of this experiment). For the two high yielding varieties, the Perpendicular-V system exceeded the profitability predicted from its density while the open center, the central leader and the slender spindle had lower than expected profitability.

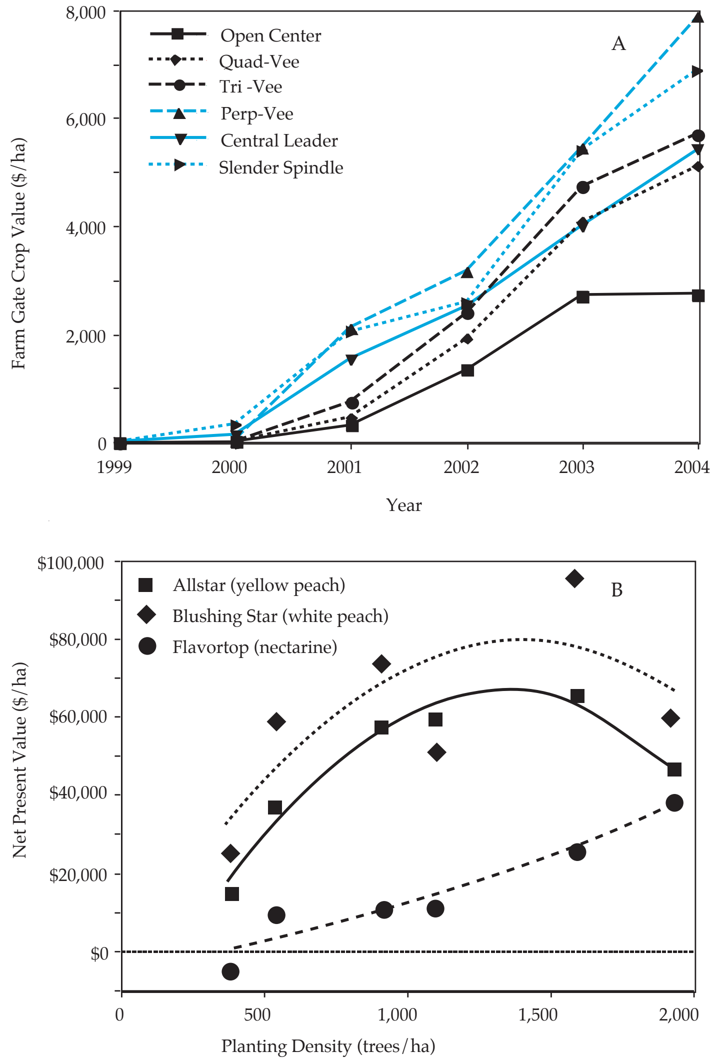

Figure 5. Annual crop value (A) and estimated 20 year Net Present Value (B) of 3 peach varieties trained to 6 peach orchard systems at various planting densities over the first 6 years of orchard development.

Discussion

In this study, the wider plant spacings resulted in larger trees after six years than at the closer plant spacings. The strong effect of increasing tree density on limiting tree growth was likely due to two effects. 1) At the higher densities, the canopy of the tree was limited by pruning beginning in the third year, which likely reduced total carbohydrate supply and thus tree size. With the Slender Spindle and the Central Leader systems, the main pruning strategy was to remove large diameter limbs each year to limit trees to an allotted space. When this is repeated over several years, the size of the canopy remains small and presumably root system size is also limited. 2) Inter-tree root competition for water and nutrients may have also contributed to reduced tree size at the high planting densities. From a practical viewpoint this result indicates that even with peach trees on seedling rootstocks there is a large range of tree densities that are manageable.

The strong positive relationship between tree density and cumulative yield/ha at the end of year six indicates that for New York conditions there is great benefit to high-density orchards. This is in contrast to results in warmer climates (e.g. California) which have shown that the yield benefits of high-density peach orchards are short lived and that the high density systems require more summer pruning to manage tree vigor at close plant spacings (DeJong et al. 1994; Loreti and Massai, 2002). In the New York climate, trees grow less vigorously than in California, so that the yield advantage of high plant densities in NY is much longer and the management of tree vigor at close plant spacings is not so problematic. In fact, in our study, fruit color was the poorest at the lowest plant spacings indicating that at the higher planting densities shoot growth was manageable and did not cause excessive shading and reduced fruit color.

Tree shape appeared to have an effect on yield performance independent of planting density with the V systems performing better than the pyramid shaped systems. Although the Slender Spindle system had the highest tree density, it had less cumulative yield than the slightly lower density Perpendicular-V system. This was likely due to excessive pruning of the Slender Spindle at the highest tree densities. The V shaped trees (Quad-V, Tri-V and Perpendicular-V) had higher yield than predicted from the common relationship of tree density and yield. In contrast, the pyramid shaped trees had lower yield than predicted. This is similar to results by Chalmers and Van den Ende (1989) and DeJong et al. (1999). It is likely this difference was due to higher light interception and distribution within the V canopy (Iannini, et al., 2002).

The curvilinear relationship of yield and tree density indicates that the optimum planting density depends on the influence of economic factors and the law of diminishing returns. Our preliminary economic analysis showing projected yields from year 6 to year 15 indicate that the optimum density is somewhat less than the maximum density that can be managed. Similar economic results were reported by DeJong et al., (1999), in the warmer climatic conditions of California. The optimum density in the present study is similar to that reported by Loreti and Massai (2002) and is very similar to the optimum planting density for dwarf apple trees (Robinson and Hoying, 2004). There appears to be a significant economic advantage to the V shape with peach (DeJong et al., 1999).

Conclusions

- Under the moderate growth conditions of New York State and the relatively short orchard lifespan, high-density orchard planting systems offer a significant early yield and mature yield advantages over the traditional open center system.

- Even the highest density systems (Slender Spindle and Perpendicular-V) were quite manageable in this climate and produced 2-3 times as much yield over the first six years as did the Open Center system.

- The more severe pruning required at maturity with the Slender Spindle made it inferior to the Perpendicular-V system in annual yield in the last year of the study indicating that at maturity the V systems would be superior

- Farm gate crop value and long-term profitability were much higher for the high density systems than the Open Center system. The optimum density appears to be about 1,000 trees/ha.

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Acknowledgement

We thank Dan Sievert of Niagara Orchards for hosting this experiment on his farm.

Steve Hoying is an Area extension educator in orchard management in the Lake Ontario region of New York State. Terence Robinson is a research and extension professor at Cornell's Geneva Experiment Station who leads Cornell's research and extension program in high-density orchard systems. Robert Andersen is a recently retired emeritus professor of Horticulture at Cornell's Geneva Experiment Station who specializes in the breeding and culture of stone fruits.