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# Yield, Fruit Size, Red Color, and a Partial Economic Analysis for 'Delicious' and 'Empire' in the NC-140 1994 Systems Trial in Virginia

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## Abstract

In 1990 an NC-140 Orchard Systems Trial, involving 'Empire' and 'Delicious', was established near Blacksburg, VA. The 10 orchard systems were combinations of several rootstocks and three training systems. Rootstocks used for Slender Spindle (SS) planted at 2460 trees/ha, included M.9EMLA, Mark, and Budagovsky 9 (B.9); Vertical Axe (VA) planted at 1502 trees/ha, included M.26EMLA, M.9EMLA, Mark, Ottawa 3 (O.3), and Polish 1 (P.1); Central Leader (CL) planted at 1111 trees/ha, included M.26EMLA and Mark. Annual crop value was estimated each year from fruit packout data based on size and color. Annual costs per ha were estimated for orchard establishment, pruning, grass mowing, and pest control. Annual costs were subtracted from annual crop value to perform a partial economic analysis for each orchard system in each year. Total costs for trees and materials for orchard establishment were $8,888/ha for CL, $11,937/ha for VA, and $19,680/ha for SS. 'Delicious' fruit were highly colored in all systems, but fruit with >70% red color for 'Empire' was highest for VA/Mark and lowest for SS/M.9. The percentage of 'Empire' fresh fruit was highest for VA/Mark and CL/Mark and lowest for SS/M.9 and SS/B.9, but the percentage of 'Delicious' fresh fruit was not significantly influenced by orchard system. After 10 years, the net present value for 'Empire' was higher for VA/P.1 and VA/M.9 than for CL/Mark, SS/B.9 and SS/M.9. After 10 years the net present value for the 10 'Delicious' systems did not differ at the 5% level of significance, but the net present value was more than $16,000/ha higher for VA/M.26 than for SS/B.9.

## Introduction

The North American apple industry has been changing from central leader trees on semi-dwarf rootstocks planted 250 to 500 trees per ha to various intensive orchard systems utilizing dwarf rootstocks. Research trials indicate that yield can be influenced by both the number of trees per ha (8) and training system (7). Yield data from research trials involving various orchard practices are readily available. Unfortunately information required to assess the profitability of those practices is scarce, but orchards systems can influence orchard profitability (3,4). Profitability of an orchard system is not only related to yield, but is also influenced by fruit size and quality as well as production costs such as costs for trees, support systems, and pruning. In the 1990 NC-140 Systems trial, Central Leader trees were least productive and Slender Spindle trees were most productive; the Vertical Axe was intermediate (6). In this paper we present data for packout, crop value, and estimated profitability for this systems trial.

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## Materials and Methods

The planting was established in 1990 as part of a multi-location trial (6). 'Early Red One Delicious' and 'Empire' trees were grown in 10 orchard systems, each of which was a combination of training system, tree spacing, and rootstock. Ten-meter-long plots of each orchard system treatment were replicated four times in a randomized complete block design. Each plot had 8, 6, and 5 trees per system for the Slender Spindle (SS), Vertical Axe (VA), and Central Leader (CL), respectively. The ten-meter-long plots were considered the experimental units, so there was only one observation per orchard system per block. When judged to be commercially mature, all fruit of each cultivar were harvested in a single harvest. Fruits from each experimental unit were separated into six size categories with a chain sizer (1992-1993) or a weight sizer (1994-1999). Fruits were sized as follows: <5.7 cm, 5.8-6.2cm, 6.3-6.9cm, 7.0-7.5cm, 7.6-8.9cm, and >8.9cm. In 1994 -1998 the percentage of the surface colored red was estimated for each of 20 - 60 fruit per experimental unit for 'Empire'. Each year 'Delicious' fruit were highly colored (90 – 100% red), and color did not vary with orchard system, so for all systems each year 90% of 'Delicious' fruit were assumed to have adequate color to pack as fresh fruit. Because of the similarity of prices for "bag" size (6.3-6.9 cm dia.) and "tray pack" size (>7 cm dia.) fruit we assigned juice prices for fruit <6.3 cm dia. and fresh market prices for fruit >6.3 cm dia. For 'Empire' 70% red surface color was used as the minimum for fresh fruit. To estimate the amount of fresh market fruit, the annual yield (t/ha) was multiplied by the proportion of fruit >6.3 cm meeting the specified red color minimum. To calculate the crop value, the kg of fresh fruit was multiplied by a price of $0.62/kg, based on data for the Appalachian district, from autumn 1999 issues of *The Packer*. This was added to the value of juice (fruit <6.3 cm) or low-color 'Empire' apples valued at $0.088/kg., based on prices paid by National Fruit Products, Co., Winchester, VA 22604 (personal communication).

Labor costs were calculated at $5.00/hr for 1990-91, $5.25/hr for 1992-93, $5.50/hr for 1994-95, and $6.00/hr for 1996-99. Costs ($/hr) for equipment were $18.00 for a 55 HP four-wheel drive tractor, $16.00 for a 400-gallon air-blast sprayer, and $15.50 for a 3-m rotary mower (9). Costs for operating equipment were based on driving distance per ha, at 4.8 km/hr for each orchard system. Harvest costs were estimated to be $1.25 per box (19.05 kg). Pesticide costs were based on estimates from Virginia commercial apple producers and amount of pesticide per ha was based on tree-row-volume (2) estimates from tree size measurements. Pruning costs were based on data from Barden (1).

A partial economic analysis was performed for each experimental unit (10-m long plot). Costs for trees, support systems, pruning, mowing, pest control, and harvest were calculated on a per-hectare basis. Profit was estimated for each year by subtracting input costs from crop returns. Many production and overhead costs were ignored, and we recorded only costs that were affected by

treatments. Net present value (NPV) analysis was used to compare the overall costs and benefits of each system. The annual estimated profit was used to calculate the NPV, assuming an annual discount rate of 4.0%. NPV compares the value of a dollar today versus the value of that same dollar in the future, after taking inflation and return into account. For example, assuming a discount of 4%, the NPV of a profit of $2,000 in 1993 would be worth $1,351 in 2003. If the NPV of an orchard system is positive, then it will be profitable, however, if it is negative, then the orchard system should not be planted. Costs and crop values may not be typical for other regions, but, based on conversations with Virginia apple growers, these costs were typical for Virginia from 1990 to 1999. Tree training costs were not included because tree training techniques such as bud notching, limb spreading, limb tying, pinching, and summer pruning were not performed in this study.

## Results

Establishment costs for trees and supplies for the support systems are presented in Table 1. Labor for planting and construction of support systems was not recorded. The primary difference in costs for the three systems is in the cost of trees. Establishment costs for Slender Spindle was about twice that for Central Leader, whereas costs for Vertical Axe were intermediate. Preharvest cost estimates for each system are presented in Table 2. Costs for herbicides, spraying and mowing were slightly higher for Slender Spindle because the close row spacing created more linear distance for driving. Insecticide and fungicide costs were related to tree row volume, which was most for Vertical Axe and least for Slender Spindle trees. Pruning costs within a system were positively related to rootstock vigor. The pruning costs for Mark, which was common to all systems, was highest for Vertical Axe and lowest for Central Leader.

**Table 1. Establishment cost ($/ha) for three orchard systems based on 1990 prices.**

| | Central Leader | | | Vertical Axe | | | Slender Spindle | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | Quantity | Cost ($/unit) | Cost ($/ha) | Quantity | Cost ($/unit) | Cost ($/ha) | Quantity | Cost ($/unit) | Cost ($/ha) |
| Trees | 1,111 | 6.00 | 6,666 | 1,561 | 6.00 | 9,366 | 2,460 | 6.00 | 14,760 |
| Posts (6' x 5") | 1,111 | 2.00 | 2,222 | --- | --- | --- | --- | --- | --- |
| Posts (12' x 4") | --- | --- | --- | 22 | 9.00 | 154 | --- | --- | --- |
| Posts (10' x 5") | --- | --- | --- | 178 | 7.00 | 1,246 | --- | --- | --- |
| Posts (8' x 4") | --- | --- | --- | --- | --- | --- | 2,460 | 2.00 | 4,920 |
| Bamboo Poles (10') | --- | --- | --- | 1,111 | 1.00 | 1,111 | --- | --- | --- |
| Wire | --- | --- | --- | 1,220 m | 0.05 | 60 | --- | --- | --- |
| Total Cost ($/ha) | --- | --- | 8,888 | --- | --- | 11,937 | --- | --- | 19,680 |

**Table 2. Estimated preharvest costs ($/ha) for labor and equipment in the fifth year (1994) for 10 apple orchard systems.**

| | Central Leader | | Slender Spindle | | | Vertical Axe | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Costs ($/ha)** | **M.26** | **Mark** | **B.9** | **M.9** | **Mark** | **M.26** | **M.9** | **Mark** | **O.3** | **P.1** |
| Pesticides | 475 | 475 | 423 | 423 | 423 | 613 | 613 | 613 | 613 | 613 |
| Herbicides | 51 | 51 | 64 | 64 | 64 | 57 | 57 | 57 | 57 | 57 |
| Tractor Operator | 229 | 229 | 319 | 319 | 319 | 281 | 281 | 281 | 281 | 281 |
| Pruning | 652 | 244 | 586 | 699 | 287 | 901 | 529 | 329 | 715 | 1,086 |
| Tractor | 124 | 124 | 172 | 172 | 172 | 141 | 141 | 141 | 141 | 141 |
| Sprayer | 221 | 221 | 265 | 265 | 265 | 248 | 248 | 248 | 248 | 248 |
| Mower | 26 | 26 | 30 | 30 | 30 | 29 | 29 | 29 | 29 | 29 |
| Total | 1,778 | 1,370 | 1,859 | 1,972 | 1,560 | 2,270 | 1,898 | 1,698 | 2,084 | 2,455 |

**Table 3. Percentage of 'Empire' fruit surface colored red and percentage of fruit with at least 70% red color for 10 orchard systems in five years.**

| System | 1994 | 1995 | 1996 | 1997 | 1998 | Mean |
|---|---|---|---|---|---|---|
| | | | *Red surface color (%)* | | | |
| CL M.26 | 77 bc [z] | 63 d | 61 d | 88 | 72 e | 72 d |
| CL Mark | 83 a | 76 a | 71 ab | 82 | 80 bcd | 78 ab |
| SS B.9 | 72 cde | 65 cd | 60 d | 86 | 75 de | 71 d |
| SS M.9 | 71 de | 64 cd | 72 a | 85 | 83 ab | 75 c |
| SS Mark | 68 e | 55 e | 53 e | 83 | 72 e | 66 e |
| VA M.26 | 81 ab | 70 bc | 68 abc | 92 | 80 bc | 78 bc |
| VA M.9 | 82 a | 69 bcd | 61 d | 90 | 78 cd | 76 bc |
| VA Mark | 76 cd | 72 ab | 65 bcd | 86 | 77 cde | 75 c |
| VA O.3 | 86 a | 76 a | 70 ab | 85 | 87 a | 81 a |
| VA P.1 | 82 a | 68 bcd | 63 cd | 86 | 81 bc | 76 bc |
| P-value | 0.010 | 0.004 | 0.025 | 0.528 | 0.025 | 0.004 |
| | | | *Fruit with at least 70% red color (%)* | | | |
| CL M.26 | 88 abc | 85 ab | 41 | 86 | 72 | 65 abc |
| CL Mark | 98 a | 80 a | 64 | 80 | 82 | 81 ab |
| SS B.9 | 76 bc | 43 bc | 45 | 70 | 71 | 59 bc |
| SS M.9 | 67 c | 30 c | 38 | 71 | 71 | 52 c |
| SS Mark | 70 bc | 56 abc | 70 | 92 | 92 | 72 abc |
| VA M.26 | 86 abc | 66 ab | 45 | 93 | 84 | 70 abc |
| VA M.9 | 92 abc | 58 abc | 42 | 92 | 89 | 70 abc |
| VA Mark | 96 ab | 78 a | 65 | 91 | 94 | 83 a |
| VA O.3 | 87 abc | 68 ab | 38 | 93 | 82 | 69 abc |
| VA P.1 | 94 ab | 64 ab | 56 | 88 | 89 | 76 ab |
| P-value | 0.002 | 0.001 | 0.049 | 0.483 | 0.062 | 0.001 |

[z] Mean separation within response variable and columns by Tukey's Test, 5% level; n=4.

*'Empire'*. Orchard systems had a significant influence on red surface color in four of the five years that data were collected (Table 3). In most years the most highly colored fruit were harvested from VA/O.3 and CL/Mark, whereas SS/Mark and SS/B.9 trees produced fruit with the least color. In most years the systems involving Central Leader and Vertical Axe systems produced the highest percentage of fruit with adequate red color to qualify as fresh fruit (Table 3). Generally, the most juice apples were produced by SS/M.9, SS/B.9, VA/M.26 and VA/M.9, and the fewest juice apples were produced on Mark rootstock regardless of training system (Table 4). For fresh fruit, VA/P.1 ranked highest and CL/Mark ranked lowest. SS/M.9 was the only system to produce less than 50% fresh fruit, whereas CL/Mark produced 72% fresh fruit. Cumulative yield for SS/M.9, VA/M.26, VA/O.3, VA/M.9 and VA/P.1 was higher than that of CL/Mark (Table 4). Cumulative crop value after five years was highest for VA/P.1 and lowest for CL/M.26 and CL/Mark. Cumulative crop value after 10 years was highest for VA/P.1 and lowest for CL/Mark. Cumulative NPV after five years was higher for VA/P.1 than for SS/M.9, SS/B.9, CL/M.26, and CL/Mark. Cumulative NPV after 10 years was highest for VA/P.1 and VA/M.9 and lowest for CL/Mark, SS/B.9 and SS/M.9.

Although this study was not designed to compare training systems or rootstocks, and differences were not always significant at the 5% level, after 10 years all vertical axe systems were more profitable than the other five orchard systems. Although not significantly different, M.26 appeared to be a better rootstock than Mark for Central Leader training because it produced a larger

**Table 4. Cumulative yield, crop value, and net present value (NPV) after 10 years for 10 apple orchard systems with 'Empire'.**

| | Cumulative yield for 10 years | | | | Cumulative crop value ($/ha) | | Cumulative NPV ($/ha) | |
|---|---|---|---|---|---|---|---|---|
| System | Juice (T/ha) | Fresh (T/ha) | Total (T/ha) | Fresh (%) | 5 years | 10 years | 5 years | 10 years |
| CL M.26 | 115 bc [z] | 152 bc | 268 ab | 59 bc | 25,577 c | 104,605 abc | 4,558 bcd | 45,053 ab |
| CL Mark | 48 d | 129 c | 178 b | 72 a | 25,675 c | 84,251 c | 6,236 bcd | 37,337 b |
| SS B.9 | 130 ab | 149 bc | 279 ab | 53 cd | 32,228 bc | 103,809 bc | 1,126 cd | 36,779 b |
| SS M.9 | 173 a | 147 bc | 321 a | 46 d | 33,133 bc | 106,539 abc | 483 d | 36,352 b |
| SS Mark | 91 bcd | 171 abc | 263 ab | 65 ab | 41,627 abc | 114,255 abc | 9,257 abcd | 47,959 ab |
| VA M.26 | 122 ab | 202 ab | 324 a | 62 bc | 44,947 ab | 136,207 ab | 14,849 abc | 62,429 ab |
| VA M.9 | 121 ab | 205 ab | 326 a | 63 bc | 45,953 ab | 137,743 ab | 16,997 ab | 66,402 a |
| VA Mark | 67 cd | 192 ab | 269 ab | 71 a | 46,020 ab | 125,150 abc | 18,093 ab | 61,623 ab |
| VA O.3 | 125 ab | 185 abc | 310 a | 60 bc | 42,724 abc | 125,916 ab | 13,830 abcd | 57,017 ab |
| VA P.1 | 110 bc | 219 a | 328 a | 67 ab | 52,905 a | 145,461 a | 20,585 a | 68,041 a |
| P-value | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

[z] Mean separation within response variable and columns by Tukey's Test, 5% level; n = 4.

canopy than Mark. However, Mark was better than the more vigorous B.9 and M.9 for Slender Spindle training. The relatively nonvigorous O.3 and Mark rootstocks produced canopies too small for the tree spacing in the Vertical Axe system. The reason the Vertical Axe system was most profitable is because establishment costs were moderate, the pruning costs were low, the yields were high, and when averaged over all five rootstocks, Vertical Axe trees produced 65% fresh apples while the average of the other five systems was only 59% fresh apples.

*'Delicious'*. VA/M.9 produced more juice apples than CL/M.26, CL/Mark, and SS/B.9; others were intermediate (Table 5). The amount of fresh fruit apples produced during 10 years was not significantly affected by orchard system. Total yield was higher for VA/M.9 than for CL/Mark; others were intermediate. The three systems with the highest production of fresh apples produced about 71% fresh apples, whereas VA/M.9 produced 67% fresh apples, but VA/M.9 still produced more fresh fruit than the four systems with highest percentage of fresh fruit apples (CL/M.26, CL/Mark, SS/Mark and SS/B.9). Cumulative crop value after five years ranked highest for VA/M.26 and VA/M.9 and CL/M.26, CL/Mark, whereas SS/B.9 ranked lowest (Table 5). Means for cumulative crop value after 10 years did not differ significantly for the 10 orchard systems, but the five Vertical Axe systems averaged $15,500/ha more than the average of the other five orchard systems (Table 5). Cumulative NPV after five years ranked highest for VA/M.9, VA/O.3, and VA/M.26, whereas SS/B.9 and SS/M.9 were the only systems with a negative NPV (Table 5). Cumulative NPV after 10 years was not influenced significantly by orchard systems.

**Table 5. Cumulative yield, crop value, and net present value (NPV) after 10 years for 10 apple orchard systems with 'Delicious'.**

| | Cumulative yield for 10 years | | | | Cumulative crop value ($/ha) | | Cumulative NPV ($/ha) | |
|---|---|---|---|---|---|---|---|---|
| System | Juice (T/ha) | Fresh (T/ha) | Total (T/ha) | Fresh (%) | 5 years | 10 years | 5 years | 10 years |
| CL M.26 | 67.8 b [z] | 163.6 | 231.4 ab | 71 | 23,705 b | 107,416 | 4,649 abc | 48,519 |
| CL Mark | 60.4 b | 146.0 | 206.4 b | 71 | 24,254 b | 95,845 | 4,907 abc | 45,925 |
| SS B.9 | 65.1 b | 163.9 | 229.4 ab | 71 | 23,618 b | 107,366 | -4,675 c | 40,956 |
| SS M.9 | 73.9 ab | 156.4 | 230.3 ab | 68 | 26,276 ab | 103,471 | -3,402 bc | 56,714 |
| SS Mark | 72.1 ab | 187.2 | 259.3 ab | 72 | 34,484 ab | 122,417 | 4,289 abc | 53,574 |
| VA M.26 | 83.8 ab | 193.3 | 277.1 ab | 70 | 40,302 a | 127,227 | 11,391 a | 57,624 |
| VA M.9 | 97.9 a | 202.6 | 300.6 a | 67 | 41,066 a | 134,250 | 12,956 a | 56,714 |
| VA Mark | 87.1 ab | 172.6 | 259.7 ab | 66 | 33,446 ab | 122,417 | 7,466 ab | 50,052 |
| VA O.3 | 87.8 ab | 182.3 | 270.0 ab | 68 | 35,197 ab | 120,747 | 8,125 a | 53,561 |
| VA P.1 | 77.9 ab | 165.9 | 243.8 ab | 74 | 32,842 ab | 109,706 | 5,250 | 43,882 |
| P-value | 0.004 | 0.260 | 0.046 | | 0.001 | 0.202 | 0.004 | 0.464 |

[z] Mean separation within response variable and columns by Tukey's Test, 5% level; n =4.

## Discussion

Cumulative yield was similar for the two cultivars. Pooled over all orchard systems, cumulative yield was 287 t/ha for 'Empire' and 251 t/ha for 'Delicious'. Fresh fruit production was similar for the two cultivars; 175 t/ha for 'Empire' and 173 t/ha for 'Delicious'. Packout was higher for 'Delicious' because 'Empire' did not color as well. Averaged over all years, the percentage of fresh fruit was 63% for 'Empire' and 70% for 'Delicious'. However, juice apple production was 34 t/ha higher for 'Empire' than for 'Delicious' and this probably is why average cumulative NPV after 10 years was similar for the two cultivars: $50,700/ha for 'Delicious' and $51,900/ha for 'Empire'.

The relative performance of most orchard systems was similar for the two cultivars. However, SS/M.9 was more profitable with 'Delicious' than with 'Empire'. Cumulative yield was relatively high for SS/B.9 for both cultivars, but only 54% of the crop packed as fresh fruit for 'Empire'. In a previous study crop value was also relatively low for 'Empire'/B.9 (1). Results from these two studies indicate that B.9 may be poor a choice for 'Empire' in Virginia.

Differences in relative yield may explain why VA/P.1 was more profitable for 'Delicious' than with 'Empire'. Compared to the average of all 10 systems, cumulative yield of VA/P.1 was 3% lower for 'Delicious' and 14% higher for 'Empire'. Harper et al. (5), in Pennsylvania, reported that the influence of rootstock on cash flow depended on the cultivar. O.3 was the best rootstock for 'York Imperial', 'Stayman', and 'Smoothee Golden Delicious', but M.26 EMLA was the best for 'Rome Beauty'. These results indicate that weak-growing cultivars, such as 'Empire', may perform well on vigorous rootstocks, such as P.1, in Virginia. To the contrary, P.1 may be too vigorous for vigorous cultivars such as nonspur 'Delicious'. The heavy pruning required to maintain tree size likely reduced yields and increased pruning costs. Barden (1) reported that pruning costs per box of fruit for VA/P.1 were $0.66 for 'Delicious' and only $0.31 for 'Empire'.

The partial economic analysis presented here is valid only when using the assumed costs and returns. If costs for trees or labor increase without similar increases in fruit prices, the Slender Spindle system, which requires the most trees and labor, may become less profitable. Orchard systems with the higher tree densities or more expensive support systems may become less profitable during times with high interest rates on borrowed money. The opposite would be true if fruit prices increase more than do wages for agricultural workers.

The two methods of evaluating fruit color did not always agree. For example, SS/Mark had the lowest mean for red surface color, but ranked third for percentage of fruit with 70% red color. Similarly, VA/O.3 ranked first for red surface color, but ranked only seventh for percentage of fruit with 70% red color. These data indicate that data on red surface color may not be a good indicator of fruit value.

The tree spacings used in this study were not appropriate for some systems. Trees on Mark could have been spaced closer for Central Leader and Vertical Axe

training systems, whereas VA/P.1, VA/M.26, and SS/M.9 should have been spaced further apart. Results from this study confirm previous conclusions (6), where Vertical Axe training system was very productive but, at some locations such as Virginia, the relative performance of an orchard system may differ with cultivar, so more than one cultivar should be included in orchard systems trials.

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