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The Influence of Cultivar and Orchard System on Pruning Time per Tree, per Hectare, and per Unit of Yield

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Abstract

In 1990 an NC-140 Orchard Systems Trial was established near Blacksburg, VA. The trial had four replications of ten orchard systems, which were combinations of three training systems and several rootstocks. The training systems were Slender Spindle (SS) planted at 2460 trees/ha, Vertical Axe (VA) planted at 1502 trees/ha, and Central Leader (CL) planted at 1111 trees/ha. Rootstocks used with each system were: SS: Budagovsky 9 (B.9), Malling 9EMLA (M.9EMLA), and Mark; VA: M.9EMLA, M.26EMLA, Ottawa 3 (O.3), Polish 1 (P.1), and Mark; CL: M.26EMLA and Mark. From 1996/1997 through 1998/1999, the time required to prune each plot (same two people each year) was recorded. Pruning times for the winters of 1996/1997 through 1998/1999 were related to yields from these plots from 1997-1999. Yields per tree and per hectare, pruning time per tree and per hectare, kg of fruit per min of pruning time, and estimated cost of pruning per box of fruit all varied with cultivar as well as system. Only estimated pruning costs per box of fruit and pruning time per hectare had a significant interaction between system and cultivar. Compared to 'Empire', 'Delicious' yielded less per tree and per hectare, required more time to prune, and yielded less fruit per minute of pruning with the result that estimated pruning costs per box were 76% higher. Pruning time per tree was lowest for SS/Mark, CL/Mark, and VA/Mark and highest for VA/P.1. Pruning costs per 19.05 kg box of 'Empire' and 'Delicious' ranged from $0.11 and $0.14 for CL/Mark to $0.31 and $0.66 for VA/P.1, respectively.

In oduction

As orchard systems have been evaluated, most researchers have concentrated on tree size, yield, and mean fruit size. A somewhat more difficult task is to attempt to evaluate the feasibility of commercial application of these new orchard systems. Unfortunately, if one looks only at tree size, yield, and average fruit size, it is quite possible to overlook important differences among the orchard systems being compared. For example, fruit quality and especially color can become unacceptable with very closely planted trees (1, 6). In addition, regulation of tree size and vigor can be challenging in high density plantings, especially as the trees mature. A few reports have evaluated labor costs involved with different orchard systems. Quamme et al. (5) reported that labor efficiency was similar with VA, CL at two tree densities, and a trellis system, but that labor efficiency was lower with SS, due primarily to increased costs for tree training. Perry et al. (4) also found that hours of total labor per ton of fruit harvested was higher for SS than either CL or VA.

The objective of this experiment was to obtain data on the time required to prune trees of two cultivars in the ten orchard systems represented in the 1990 NC-140 Orchard Systems Trail and to relate these data to yield data so that pruning costs relative to yield could be estimated.

Materials and Methods

This experiment was a supplement to the 1990 NC-140 Orchard Systems Trial which was established at nine sites across North America. The orchard systems were: SS/B.9, SS/M.9EMLA, SS/Mark, VA/Mark, VA/M.9EMLA, VA/O.3, VA/M.26EMLA, VA/P.1, CL/M.26EMLA, and CL/Mark. The SS trees were spaced at 1.25 x 3.25 m (2460 trees/ha); the VA trees were spaced at 1.6 x 4 m (1502 trees per ha) ; and the CL trees were spaced at 2 x 4.5 m (1111 trees per ha) Each 20 m row in each replication represented one or-

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chard system; one half of each row was 'Early Red One Delicious'; the other half was 'Empire'. Each plot (one-half row) had 8, 6, or 5 trees each for SS, VA, and CL, respectively. The end trees in each plot served as guard trees.

Details of tree training were presented in earlier publications (2, 3). Data on yield as well as pruning times were collected on the basis of plots which consisted of 6, 4, and 3 trees for the SS, VA, and CL, respectively. Pruning was done with loppers and pole pruners from the ground as much as possible, but in the VA and CL plots, some ladder work was required. The same two people pruned each plot together in each of three winters, 1996/1997, 1997/1998, and 1998/1999, which followed the seventh, eighth, and ninth leaf, respectively. The yield data for the eighth, ninth, and tenth years were used for the calculations of pruning time per kg of fruit as well as estimating the pruning cost per 19.05 kg box of fruit.

The experiment was a RCB with four replications of ten treatments (orchard systems) with each of two cultivars. The data were analyzed by GLM procedure from SAS, and the means were separated by Duncanís multiple range test. The data are presented as means of the three years of pruning time and three years of yield.

Results and Discussion

Both system and cultivar affected per-tree yields, but the interaction between cultivar and treatment was not significant (Table 1). 'Empire' yields per tree were more than 20% higher than those for 'Delicious'. Yield per tree for CL/M.26EMLA was the highest of all treatments, and was more than twice that of any of the three SS treatments. Yield per tree of VA/Mark was lower than VA/M.9EMLA and VA/M.26EMLA; yield per tree for VA/O.3 and VA/P.1 were intermediate.

Yields on a per-hectare basis were more similar among treatments than were per-tree yields (Table 1). Trees on Mark tended to yield the least per hectare, probably due to low vigor and therefore limited canopy volume. However, among the SS treatments, yields of trees on Mark were not significantly lower than those on M.9EMLA and B.9 because the very close spacing compensated for the low vigor of trees on Mark.

Pruning time per tree for 'Empire' was about 25 percent less than for 'Delicious' (Table 1). Average pruning time per tree over the three year period varied by a factor of about 4.5 among the ten systems. The greatest pruning time was required for VA/P.1, but this was only slightly greater than for VA/M.26EMLA and CL/M.26EMLA. The three combinations with Mark as the rootstock required minimal pruning as did trees of SS/B.9. Similar and intermediate pruning times per tree were required by SS/M.9EMLA and VA/M.9EMLA.

Over the three years of this study, the ratio of kg of fruit produced per minute of pruning time was approximately 60 percent higher for 'Empire' than for 'Delicious' (Table 1). Among the ten systems, the ratio of yield to pruning time was highest for CL/Mark and lowest for VA/P.1. The yield per minute of pruning time was very high for CL/Mark and VA/Mark, because these trees failed to occupy their allotted space and therefore required minimal pruning; unfortunately, their yields were relatively low. The yield per minute of pruning time for VA/M.9EMLA was about 2.4 times higher than for VA/P1. In this case, the excessive vigor in VA/ P.1 dramatically increased the pruning time with no increase in yield compared to VA/M.9EMLA..

The estimated cost of pruning per box of fruit produced provides a useful means of comparison. The significant system x cultivar interaction appears to be due to a much wider spread in costs with 'Delicious' than 'Empire' (Table 2). Over all systems, estimated pruning costs per box of fruit were about 76% higher for'Delicious' than for 'Empire'. Over both cultivars, there was a strong effect of rootstock within the training systems. For example, estimated pruning costs were 3.0 and 2.2 times higher for VA/P.1 than for VA/M.9EMLA with 'Delicious' and 'Empire', respectively. Also noteworthy is that

Table 1. Yield per tree and per hectare, pruning time per tree, and yield per minute of pruning for 'Delicious' and 'Empire' trees in ten orchard systems.

System[Z]/ cultivar	Yield[X] (kg/ tree)	Yield[X] (tonnes/ ha)	Pruning time[Y] (min/tree)	Yield (kg) per min. pruning[W]
SS/B.9	23.4 d[V]	57.4 ab	2.6 e	10.7 cde
SS/M.9EMLA	24.7 d	60.7 a	3.1 de	9.0 def
SS/Mark	20.7 d	50.8 abc	1.7 f	13.0 bc
VA/Mark	32.0 c	48.0 bc	2.3 ef	14.6 ab
VA/M.9EMLA	40.7 b	61.1 a	3.7 d	11.4 cd
VA/O.3	39.0 bc	58.6 a	5.0 c	8.2 ef
VA/M.26EMLA	39.6 b	59.6 a	6.3 b	6.7 fg
VA/P.1	34.6 bc	51.9 ab	7.6 a	4.7 g
CL/Mark	37.2 bc	41.4 c	2.4 ef	17.2 a
CL/M.26EMLA	52.5 a	58.3 ab	6.4 b	8.7 def
'Delicious'	30.9 b	49.7 b	4.7 a	8.0 b
'Empire'	37.9 a	59.9 a	3.5 b	12.9 a
ANOVA (P>F)				
System	<0.0001	<0.0001	<0.0001	<0.0001
Cultivar	<0.0001	0.0006	<0.0001	<0.0001
Sys. c cv.	0.158	0.1523	0.134	0.849

[Z]System: Main effect means pooled cross cultivars.
[Y]Cultivar: main effect means pooled across systems.
[X]Yield, (kg) per tree and tonnes per ha per year: means for 1997, 1998, 1999
[W]Pruning time: means for 1996/1997, 1997/1998, 1998/1999.
[V]Mean separation within columns and groups by Duncan's multiple range test, P=0.05.

the estimated pruning costs varied little among the three treatments with Mark as the rootstock. As the result of low vigor of trees on Mark, the required pruning was minimal, regardless of the training system.

Pruning time per hectare varied widely with cultivar, system, and rootstock (Table 3). The significant interaction between cultivar and system reflects the greater differences between cultivars for the SS than the other treatments. In spite of the significant interaction, the ranking of treatments was generally similar for the two cultivars. The greatest time requirement was for VA/P.1 followed by VA/M.26EMLA. With 'Delicious' the pruning time required by SS/M.9EMLA was considerably higher than for VA/M.9EMLA; with 'Empire', these two treatments were more similar. The high pruning times for several systems reflect excessive vigor resulting from close spacing and the required pruning to hold the trees within their allotted space. These data, in conjunction with the kg of yield per minute of pruning (Table 1), provide ample evidence that yield alone is not an adequate indicator of the viability of a particular orchard system.

These data also emphasize the management problems which result when the vigor of the scion/rootstock combination is not properly matched with the training system and tree spacing

For example, with Mark, both CL and VA trees did not fully occupy their allotted space; at the other extreme was VA/P.1 which was much too vigorous for the spacing and required excessive amounts of pruning.

Although the data on yield per minute of pruning time might be interpreted as being evidence of the desirability of CL/Mark because of the very high ratio (Table 1), further evaluation leads to a rather different conclusion. For the three years of this study, mean yield of CL/Mark was 41.3 tonnes/ha as compared to the yield of VA/M.9EMLA which was 61.1 tonnes/ha or approximately 1.5 times as high. With-

Table 2. Estimated cost of pruning[Z] per box (19.05kg) of fruit from 'Delicious' and 'Empire' apple trees in ten orchard systems.

	Est. pruning cost ($ per box)		
System	'Delicious'	'Empire	System Mean
SS/B.9	0.28 cd[Y]	0.15 bc	0.21
SS/M.9EMLA	0.34 bc	0.16 bc	0.25
SS/Mark	0.17 e	0.14 bc	0.15
VA/Mark	0.17 e	0.11 c	0.14
VA/M,9EMLA	0.22 de	0.14 bc	0.18
VA/O.3	0.31 bc	0.19 bc	0.25
VA/M.26EMLA	0.40 b	0.23 ab	0.31
VA/P.1	0.66 a	0.31 a	0.48
CL/Mark	0.14 e	0.11 c	0.12
CL/M.26EMLA	0.33 bc	0.17 bc	0.25
Cultivar mean	0.30	0.17	-
ANOVA[X]			

[Z]Data based on mean yield for 1997, 1998, and 1999 and pruning times for 1996/1997, 1997/1998, and 1998/1999 and labor cost of $6.00 per hour.
[Y]Mean separation within groups by Duncan's multiple range test, P=0.05.
[X]ANOVA (P>F): system: <0.0001, culitvar<0.0001, system/cultivar <0.0001.

out striking differences in fruit color and/or quality, it seems apparent that VA/M.9EMLA is a more desirable treatment in spite of somewhat higher pruning requirements. In a similar comparison, the greater desirability of VA/M.9EMLA over SS/M.9EMLA is that although the two treatments had similar per hectare yields, the estimated pruning cost per box was about 28 percent less with VA/M.9EMLA than with SS/M.9EMLA.

In contrast to our data, those published by Perry et al. (4) and Quamme et al. (5) included labor for summer pruning/training, thinning, and harvest as well. Quamme et al. (5) presented data on cumulative labor over the first nine years of the trial so direct comparison with our data for years 6-9 is difficult. They concluded that overall labor efficiency was somewhat lower for SS than for VA or CL, primarily due to increased time devoted to training SS trees. Another important difference between the data of Quamme et al. (5) and both ours and those of Perry et al. (4) is that the range in rootstock/scion vigor was relatively low in British Columbia and relatively high in the NC-140 studies in Michigan and Virginia. In spite of these differences, the general conclusions are not greatly different among the three experiments.

Additional data which are needed to more fully evaluate orchard systems are data on establishment costs and packout of the crop. When the percent packout based on both fruit size and color varies among treatments, the cost of pruning per box of packed fruit would differ somewhat from the estimated costs in this paper. As recently reported for the NC-140 1990 Cultivar/Rootstock Trial in Virginia, rootstock can affect both fruit size and color (1). With the large spread in tree vigor and canopy density among the systems in this trial, there were sizeable differences in fruit color (unpublished data). In general it would seem logical that trees such as VA/P.1 and VA/M.26EMLA which required maximum pruning (Table 3) would be the most likely to have lower levels of red color, thereby reducing packout and increasing pruning costs per box of fruit packed. On the basis of these data, the advantage of maximum production with minimal pruning costs would appear to lie with a system such as VA/M.9EMLA.

Table 3. Pruning time for 'Delicious' and 'Empire' apple trees in ten orchard systems[Z].

System	Pruning time (hr/ha) 'Delicious'	'Empire'	System mean
SS/B.9	137 d[Y]	73 fg	105
SS/M.9EMLA	162 c	94 de	127
SS/Mark	79 f	58 gh	68
VA/Mark	64 g	52 hi	58
VA/M.26EMLA	105 e	80 ef	93
VA/O.3	139 d	111 c	125
VA/M.26EMLA	185 b	129 b	157
VA/P.1	209 a	172 a	191
CL/Mark	49 h	39 i	44
CL/M.26EMLA	139 d	97 d	118
Cultivar mean	126	91	-
ANOVA[X]			

[Z]Mean for 1996/1997, 1997/1998, and 1998/1999.
[Y]Mean separation within groups by Duncan's multiple range test. P=0.05.
[X]ANOVA (P>F): system <0.0001, cultivar <0.0001, system x cultivar 0.0008.

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'Sunbest' Nectarine

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'Sunbest' nectarine, [*Prunus persica* (L.) Batsch], is released for grower trial by the Florida Agricultural Experiment Station. Trees of 'Sunbest' produce an attractive, sweet tasting, yellow and melting flesh, semi-freestone fruit intended for fresh use. It is expected to replace 'Sunraycer' nectarine because it is similar in bloom and ripening time and has larger and more attractive fruit. 'Sunbest' originated from a 1992 cross of 'Sunraycer' nectarine x 'Suncoast' nectarine, was selected and propagated in 1994, and tested as Fla. 94-15n.

Standards and methods used in this program to evaluate genotypes have been described (3). 'Sunbest' fruit have been observed at Gainesville on trees budded onto 'Flordaguard' seedlings and the following description of fruit summarizes 5 years of observation on trees 3 to 7 years old. Trees of 'Sunbest' are estimated to require 225 chill units based on full bloom occurring 2 days before the standard (2) of 'Sunred' nectarine, that blooms in early February at Gainesville. 'Sunbest' has fruited well where the coldest month averages 16 to 17C (1) and in colder locations in the absence of spring frost. Thus, we expect 'Sunbest' to be grown successfully where 'Sunraycer' nectarine and 'Flordaglo' peach have been successful. Fruit ripen in early May at Gainesville, about 85 to 90 days from full bloom and about 3 days before 'Sunraycer' nectarine and 'Flordaglo' peach.

Trees are semi-upright, vigorous, and require summer pruning when grown in a vase training system to permit light penetration for formation of strong fruiting wood in the lower half of the tree. Trees at Gainesville set a high number of flower buds, have few blind nodes (5), and exhibit little bud failure prior to bloom (6). Flower bud density is higher than for most standard varieties because internode length is shorter. Fruit set is high and thinning will be required in the absence of spring frost at Gainesville to attain an average of 2 1\2 inch diameter fruit weighing 120 to 140 grams. Fruit picked at the commercial harvest stage of maturity are 90 to 100 percent bright red over a yellow ground color. The skin is relatively free of sugar speckles, compared to 'Sunblaze' nectarine. Fruit shape is long-oval with no suture bulge and rounded at the tip. The flesh may contain small red flecks, but has no red at the pit. Flesh is firm, with good sweetness, and does not brown readily on bruised or cut surfaces. Pits are medium small and have little tendency to split.

Leaves have 4 to 6 large reniform glands. Flowers are non-showy and pink. Anthers are yellow with little anthocyanin and pollen is bright yellow and abundant. Leaves and fruit have shown no bacterial spot [*Xanthomonas campestris* pv. *pruni* (Sm.) Dye] in test plantings where known susceptible genotypes show typical symptoms.

A plant patent has been filed for 'Sunbest' and a propagation agreement is available through Florida Foundation Seed Producers, Inc., P.O. Box 309, Greenwood, FL 32443. Bud wood is non-in-

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