Fruit Varieties Journal 48(4):251-255 1994

Growth, Productivity, Spur Quality, Light Transmission and Net Photosynthesis of 'Golden Delicious' Apple Trees on Four Rootstocks in Three Training Systems[1]

TARA AUXT BAUGHER,[2] SUMAN SINGHA,[3] DAVID W. LEACH[2] AND SANDRA P. WALTER[2]

Abstract

A study was conducted in 1990 to 1992 to compare growth and efficiency of 'Golden Delicious' apple [*Malus domestica* Borkh.] trees on four rootstocks (MM.111EMLA, M.7a, M.26-EMLA, M.9EMLA) in three training systems (3-wire palmette trellis, freestanding central leader, nonpruned). No pruning compared to central leader pruning reduced height of trees on M.9-EMLA, M.26EMLA, and M.7a but not of trees on MM.111EMLA. Trees on M.9EMLA were the smallest and most yield efficient trees; those on M.7a were the least yield efficient. Height and width were reduced in the 3-wire trellis system, yet yield efficiency was equal to that of the central leader system. Spur quality was higher in the 3-wire trellis and the central leader systems than in the nonpruned system, but there were no consistent differences among rootstocks. Light transmission was greatest in trees in the 3-wire trellis and the central leader systems and on M.9EMLA rootstock. Net photosynthesis (Pn) was greatest in trees in the 3-wire trellis system and was lowest in trees on M.9-EMLA rootstock.

Introduction

The more dwarfing clonal apple rootstocks decrease tree growth and increase light interception and production efficiency (1, 6, 10, 12). Barden and Ferree (2) reported that rootstock did not influence Pn, transpiration and specific leaf weight (SLW) of one year-old, container grown apple trees; however, with eight-year-old field-grown apple trees, Schechter et al. (12, 13) found that Pn tended to be lower on dwarfing rootstocks than on vigorous rootstocks. Autio and Southwick (1), Blizzard et al. (3), Ferree et al. (5-8) and Robinson et al. (11) demonstrated training system effects on trunk cross-sectional area (TCA), light interception, spur quality and productivity. Interactions of rootstock and training system have not been widely studied. Stutte et al. (15) conducted a carbohydrate partitioning study in which they found that training system interacted with rootstock to influence branch and fruit dry weights.

Numerous investigators have suggested that rootstock selection is important to training system success (1, 5, 7). Conversely, scientists have presented results which suggest that system management can mask rootstock effects (8). This study was initiated to compare growth and efficiency of four rootstocks in three training systems and to quantify rootstock by system interactions.

Materials and Methods

'Golden Delicious (Gibson)' trees were planted in 1986 at the West Virginia University Experiment Station, Kearneysville, in a planting comparing four rootstocks (MM.111EMLA, M.7a, M.26EMLA, M.9EMLA) and three training systems (3-wire palmette trellis, free standing central leader, nonpruned). Rootstocks were arranged in a randomized complete block design with one tree of each rootstock per block. Random blocks (three to ten,

[1]Approved for publication by the Director, West Virginia Agr. and For. Expt. Station as Scientific Article No. 2448. We gratefully acknowledge the assistance of Tim Winfield, Jim Wood, Bill Bengar, and experiment station farm and secretarial staff and grant support from the West Virginia Tree Fruit Improvement Board and the International Dwarf Fruit Tree Association Rootstock Committee.
[2]Plant and Soil Sciences Experiment Farm, West Virginia University, Kearneysville, WV 25430-0609.
[3]Department of Plant Sciences, University of Connecticut, Storrs, CT 06269-4067.

depending on type of measurement, as described below) of each system were treated as replicates for systems comparisons. Tree spacing was 3 x 3 m. All trees were headed at 66 cm at planting. Trees on the 3-wire trellis were trained to the system described by Singha et al. (14); trees in the central leader system were trained as described by Heinicke (9); and trees in the nonpruned system were neither trained nor pruned after the initial heading cut. The experimental planting was maintained according to current West Virginia University Extension pest control and cultural recommendations. Freezing temperatures reduced crops in 1989 and 1990, and the first full commercial crop was harvested in 1991.

In 1991, tree height, in-row spread and trunk diameter (20 cm above soil line) were measured after terminal bud set, and fruit weight per tree (kg) was determined at harvest. Trunk diameter was converted to trunk cross-sectional area (TCA, cm^2), and yield efficiency (kg/cm^2) was determined. On July 18, 1990 and August 4, 1991, five non-fruiting, single spurs on three-year-old wood were randomly sampled from each of four replicates. Bud diameter, leaves/spur, leaf area/spur and SLW were determined. On uniformly sunny days of late July/early August of 1990, 1991 and 1992, P_n was measured between 9:30 to 11:30 am on 3 fully expanded, light exposed mid-terminal leaves from the periphery of each of three or four replicates (same replicates from which spurs were sampled) with an ADC LCA-3 portable infrared gas analyzer. Leaves were selected from horizontal shoots and measured in their natural position.

Table 1. Size and yield efficiency of 'Golden Delicious' apple trees on 4 rootstocks in 3 training systems at the end of the sixth growing season (1991).

	Rootstock			
Training system	M.9EMLA	M.26EMLA	M.7a	MM.111EMLA
		Tree height (m)		
3-wire	2.88Cc[z]	3.05Bc	3.00Bc	3.17Ab
Central leader	3.68Ca	3.84Ba	3.89Aa	3.88Aa
Nonpruned	3.15Cb	3.35Bb	3.74Bb	4.10Aa
		In-row tree width (m)		
3-wire	2.01Bb	2.14Ab	2.12Ab	2.01Ab
Central leader	3.21Ba	3.40Aa	3.46Aa	3.43Aa
Nonpruned	2.92Ca	3.10Ba	3.76Aa	3.71Aa
		TCA (cm^2)		
3-wire	33Cb	41Bb	48Ab	45Ab
Central leader	41Ca	46ABa	49Aab	46Bab
Nonpruned	37Ca	48Ba	52Aa	55Aa
		Yield efficiency (kg fruit/cm^2 TCA)		
3-wire	0.56Ab	0.41Bb	0.23Cb	0.34Bb
Central leader	0.54Ab	0.50Bb	0.29Cb	0.39Bb
Nonpruned	0.81Aa	0.66Ba	0.57Ca	0.71Ba
	Height	Width	TCA	Fruit/TCA
Rootstock:	***	***	***	***
System:	***	***	**	***
R x S:	**	**	NS	NS

[x]Mean separation within growth parameter and rootstock or system by DNMRT (upper case letters for rows, lower case letters for columns). ***, **, NS: p = 0.001, 0.01 or nonsignificant, respectively.

Photosynthetic photon flux transmission (PPFT) was measured 10:00 to 10:30 am on the same days with a LI-COR LI-1915B line quantum sensor light wand positioned in an E-W orientation, on the south side of each of the same replicates in the mid-section of the tree canopy. Readings were expressed as percent of available PPFT as determined in full sun.

Data were analyzed using the analysis of variance (ANOVA) procedure of Statistical Analysis System (SAS) Institute Inc. (1991). Means were separated by the Duncan's new multiple range test (DNMRT).

Results and Discussion

Tree Size and Yield Efficiency

Rootstock by system interactions were found in tree height and tree width (Table 1). No other interactions were found. 'Golden Delicious' on M.9EMLA, M.26EMLA or M.7a were tallest in the central leader system and shortest in the 3-wire trellis. Trees on MM.111EMLA in the 3-wire trellis were shorter than those in the central leader or the nonpruned systems. Trees on M.9EMLA in all training systems were the shortest, whereas nonpruned and 3-wire trellis trained trees on MM.111-EMLA and central leader trained trees on MM.111EMLA and M.7a were the tallest. In-row tree spread was greater in central leader trained and nonpruned trees than in 3-wire trellis trained trees. Trees on M.9EMLA had a narrower in-row spread than trees on the other rootstocks in both the central leader and 3-wire trellis systems. Nonpruned trees on MM.111EMLA and M7a had a greater spread and on M.9EMLA had a lesser spread than trees on M.26-EMLA.

Trunk cross-sectional area was larger in nonpruned and central leader trained trees than in 3-wire trellis trained trees (Table 1). Trees on MM.111EMLA and M.7a had a larger TCA than trees on M.9EMLA. Yield efficiency was higher in nonpruned trees than in trees trained to the central leader or the 3-wire trellis systems. Trees on M.9EMLA had a higher yield efficiency than trees on the other rootstocks, whereas those on M.7a had the lowest yield efficiency.

The conclusion that M.9EMLA produced the smallest and most yield efficient tree confirms earlier reports by Autio and Southwick (1), Ferree

Table 2. Spur quality of 'Golden Delicious' apple trees on 4 rootstocks in 3 training systems during the 5th and 6th growing seasons.

Treatment	Bud diameter (mm)		Leaves/spur (no.)		Leaf area/spur (cm^2)		SLW (mg/cm^2)	
	1990	*1991*	*1990*	*1991*	*1990*	*1991*	*1990*	*1991*
M.9EMLA	2.9	3.0	6	6b[z]	55.4	70.5	11.8b	11.3
M.26EMLA	3.0	2.9	5	7a	58.1	65.5	13.0a	11.3
M.7a	2.9	3.0	6	7a	55.0	70.2	11.7b	10.8
MM.111EMLA	3.0	2.9	5	7a	61.8	61.5	11.2b	10.8
3-wire	2.9	3.0a	5b	6b	57.5	70.6a	11.8a	11.4a
Central leader	3.0	3.0a	6a	7a	56.2	69.2a	12.5a	11.1a
Nonpruned	2.9	2.9b	6a	7a	59.0	60.9b	11.6b	10.8b
Rootstock:	NS	NS	NS	*	NS	NS	**	NS
System:	NS	*	*	*	NS	*	*	*
R X S:	NS	NS	NS	NS	NS	NS	NS	NS

[z]Mean separation within year and rootstock or training system by DNMRT. **, *, NS: p = 0.01, 0.05 or nonsignificant, respectively.

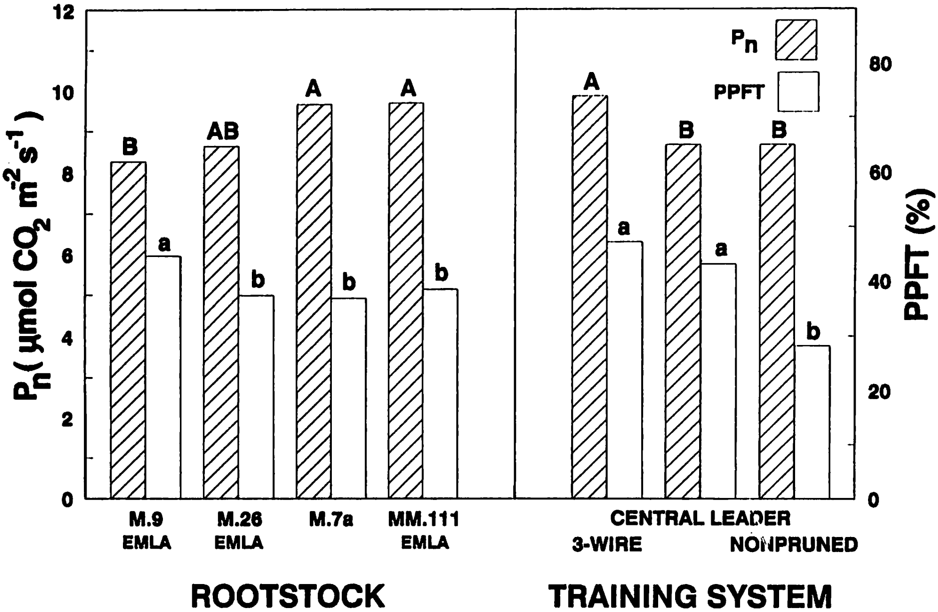

Figure 1. Three-year averages (late July/early August, 1990-1992) of photosynthesis and light interception, by rootstock and training system, in 'Golden Delicious' planted in 1986. Mean separation within P_n (upper case) or PPFT (lower case) by Duncan's new multiple range test, p = 0.05.

(6) and others. The poor yield efficiency of M.7a is in agreement with a report by Robinson et al. (11) in which central leader trained 'Empire' and 'Delicious' on M.7a were the least yield efficient of four orchard production systems. Height and width were reduced in the 3-wire trellis system, yet yield efficiency was equal in the 3-wire trellis and the central leader systems. This finding is consistent with reports of similar yield efficiencies across systems when tree spacings are equal (4).

Spur Quality, Photosynthesis and Light Transmission

The only significant differences in 1990 in spur quality were in leaves/spur and SLW, while in 1991, differences also existed in bud diameter and leaf area/spur (Table 2). Both years, no. leaves/spur was lowest in the 3-wire trellis compared to the other systems, and SLW was lowest in the nonpruned system. No. leaves/spur in 1991 was lowest in trees on M.9EMLA; SLW in 1990 was highest in trees on M.26-EMLA. Nonpruned trees had lower spur diameters and leaf areas/spur than trees in other systems in 1991.

Net photosynthesis and PPFT followed similar trends during mid-summer of 1990, 1991 and 1992. A limited number of replicates (in both rootstocks and systems) could be measured with a portable infrared gas analyzer during a two hour time frame, and P_n means were statistically different in only one of three years. The data presented (Fig. 1) were analyzed over the three-year period rather than by year to reduce the error term. Leaf P_n was higher in 3-wire trellis trained trees than in trees trained to the other systems and was lower in trees on M.9-EMLA than in trees on M.7a or MM.111EMLA. Light transmission was greater in the 3-wire trellis and central leader systems than in nonpruned trees.

Light transmission was greater in the 3-wire trellis and central leader systems than in nonpruned trees. Light transmission was greater in 'Golden Delicious' trees on M.9EMLA than in trees on the other rootstocks.

Spur quality was poorest in the nonpruned system compared to the pruned systems but there were no consistent differences among rootstocks. The spur quality data appeared to be related to the light transmission data, as has been noted by other researchers (5). Differences in yield efficiency among rootstocks and systems were consistent with PPFT but appeared to be unrelated to shoot leaf Pn Schechter et al. (13) reported similar results in a comparison of rootstocks. The reduced P_n rate in M.9EMLA rootstock may be a dwarfing mechanism, whereas the reduced P_n rate in the nonpruned system may be explained by poor spur quality.

Conclusions

This study has several implications for commercial orchardists. First, since pruning and training interact with rootstock to influence tree size, growers must consider both when selecting tree spacing for a new orchard. For maximum size control, light transmission and yield efficiency growers in similar environments should select M.9EMLA rootstock (compared to M.26-EMLA, M.7a or MM.111EMLA) and the 3-wire trellis (compared to the central leader system). Training system and rootstock had opposing effects on net photosynthesis—the P_n rate was increased by 3-wire trellis training but decreased by M.9EMLA rootstock. The reduced P_n on M.9EMLA rootstock has been reported by other researchers (12, 13) and may be related to sink-source strength.

Literature Cited

1. Autio, W. R. and F. W. Southwick. 1993. Evaluation of a spur and a standard strain of 'McIntosh' on three rootstocks and one dwarfing interstem over ten years. Fruit Var. J. 47(2):95-102.
2. Barden, J. A. and D. C. Ferree. 1979. Rootstock does not affect net photosynthesis, dark respiration, specific leaf weight, and transpiration of apple leaves. J. Amer. Soc. Hort. Sci. 104(4):526-528.
3. Blizzard, S. H., S. Singha, T. A. Baugher, and B. D. Cayton. 1988. Yield and fruit quality of apple trees under three high density management systems. Fruit Var. J. 42(2):67-72.
4. Clayton-Greene, K. 1989. Apple production and tree training. Compact Fruit Tree 22:8-11.
5. Ferree, D. C. 1989. Influence of orchard management systems on spur quality, light, and fruit within the canopy of 'Golden Delicious' apple trees. J. Amer. Soc. Hort. Sci. 114(6):869-875.
6. Ferree, D. C. 1992. Performance of 'Golden Delicious' on two rootstocks and four dwarfing interstems over 10 years. Fruit Var. J. 46(2):93-97.
7. Ferree, D. C., R. C. Funt, and B. L. Bishop. 1989. Yield and production efficiency of four apple cultivars in selected orchard management systems. J. Amer. Soc. Hort. Sci. 114(6):863-868.
8. Ferree, D. C., J. R. Schupp, S. H. Blizzard, T. A. Baugher, and I. J. Warrington. 1989. Influence of five orchard management systems on canopy composition, light penetration and net photosynthesis of 'Golden Delicious' apple. Acta Hort. 243:131-140.
9. Heinicke, D. R. 1975. High-density apple orchards—planning, training and pruning. ARS-USDA Agr. Handbook No. 458.
10. Larsen, F. E., S. S. Higgins, and C. A. Dolph. 1992. Rootstock influence over 25 years on yield, yield efficiency and tree growth of cultivars 'Delicious' and 'Golden Delicious' apple [*Malus domestica* Borkh]. Scientia Horticulturae 49:63-70.
11. Robinson, T. L., A. N. Lakso, and S. G. Carpenter. 1991. Canopy development, yield, and fruit quality of 'Empire' and 'Delicious' apple trees grown in four orchard production systems for ten years. Amer. Soc. Hort. Sci. 116(2):179-187.
12. Schechter, I., D. C. Elfving, and J. T. A. Proctor. 1991. Canopy development, photosynthesis, and vegetative growth as affected by apple rootstocks. Fruit Var. J. 45(4):229-237.
13. Schechter, I., D. C. Elfving, and J. T. A. Proctor. 1991. Apple rootstock. Can. J. Bot. 69:295-300.
14. Singha, S., T. A. Baugher, and S. H. Blizzard. 1990. Intensive orcharding, a total system approach—3-wire trellis. WVU Coop. Ext. Serv. Circ. OM107.
15. Stutte, G. W., T. A. Baugher, S. P. Walter, D. W. Leach, D. M. Glenn, and T. J. Tworkoski. 1994. Rootstock and training system affect dry matter and carbohydrate distribution in 'Golden Delicious' apple trees. J. Amer. Soc. Hort. Sci. (in press).

Prunus Breeders Meeting — 1994

W. B. SHERMAN

The 1994 Prunus (formally Peach) Breeders Meeting was hosted by the University of Florida, Gainesville on May 20 and 21. Membership of this group consists of public and private stonefruit breeders and genetists. Participation from foreign countries is normal and this year representatives from Australia, Brazil, Canada, Italy, and Thailand were among the 28 in attendance including 3 graduate students from Texas A&M University and one from the University of Florida. States of Alabama, Florida, Georgia, Michigan, New Jersey, South Carolina, Texas, Wisconsin, and West Virginia had representatives. There was round table discussion for 2 days including an orchard tour highlighting the fruiting nursery and a fruit display with samples from Florida, Georgia, and Texas. A few peach samples were early ripening with nonmelting flesh for the fresh market, a major goal of the Florida breeding program.

The Prunus Breeders will meet in 1995 at Vineland at the invitation of Dr. Neil Miles. This meeting will be the week following the joint ASHS and CSHS meeting in Montreal.

Spacing High-bush Blueberries

'Bluecrop' and 'Blueray' blueberries spaced at .61m within the row had higher per hectare yields than plants at .92 and 1.22m within row spacing. However, during the last 2 years, yields at the closest spacing were reduced on a per plant basis due to competition. Plant spacing did not affect fruit size over the 5 year study. From: Moore et al. 1993, *HortScience* 28:1162-1163.

Ozone Effects on Raspberry

At low concentrations little response was evident. However at levels above 0.24μl/liter ozone 'Heritage' cane height was reduced as well as node count, cane diameter, and dry weight. These changes were accompanied by a 52% decrease in yield, caused mainly by a reduction in fruit count. In contrast, vegetative and yield characters of 'Redwing' were not affected by ozone. From Sullivan et al. *HortScience* 29:1059-1061.

Performance of Polish Rootstocks and Interstems

Results of a 10 year study with 'Lobo.' 'Spartan,' and 'Empire' on P.22 and 'Spartan' on B.195 were similar in size to trees on M.9. Trees on P.1, P.2, and I-TE-F were similar in size to M.26. All trees with interstems of B.9 and P.2 were larger or similar in size to those on M.9. Cropping efficiencies were highest for 'Lobo' and 'Spartan' on B.195, P.22, and interstem trees of P.22, B.9, and P.2. For 'Empire' the most efficient were interstems of P.22, P.2, and B.9 and trees on M.9. Interstem trees of B.9, P.2, and P.22 planted 15 cm deeper did not reduce cumulative crop but decreased the number of suckers/tree. For Polish conditions trees on P.22 and P.2 rootstocks and interstems with B.9 and P.2 planted 15 cm deeper were most suitable. From Czynczyk and Omiecinska. 1992. *Fruit Science Reports* Vol. XIX(3):115-124.