Early performance of cv. Jonagold apple on M.9 in five tree training systems

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Abstract

Ozkan Y., Yıldız K., Küçüker E., Çekiç Ç., Özgen M., Akça Y., 2012. **Early performance of cv. Jonagold apple on M.9 in five tree training systems.** Hort. Sci. (Prague), *39*: 158–163.

The effects of five training systems on tree growth, fruit yield and some fruit characteristics were assessed in Jonagold apple cv. grafted on M.9 rootstock. The trees were trained in one of five ways: slender spindle (SS; 4,761 trees/ha), vertical axis (VA; 2,857 trees/ha), hytec (HT; 1,904 tree/ha) and two different tree densities of super spindle (L-Super S with 5,000 trees/ha; H-Super S with 10,000 trees/ha). Trunk cross-sectional area (TCA) was higher in HT and VA than SS, L-Super S and H-Super S in the 4th year. While HT had the highest cumulative yield/tree, the lowest cumulative yield was observed in H-Super S. Although HT had the highest yield/ tree, it ranked the last in cumulative yield efficiency (CYE) due to high TCA. The highest (CYE) was measured in trees trained as L-Super S. When cumulative yields (CY)/ha were evaluated, the yield advantage of high density planting was clearly evident for the first three cropping years. H-Super S systems (10,000 trees/ha) had the highest CY/ha and achieved a yield of 91.24 t/ha in year 4. HT (1,904 trees/ha) had the lowest CY/ha (33.46 t). Training systems had no consistent effect on average fruit diameter, weight, firmness, soluble solid and titratable acidity.

Keywords: training method; tree growth; yield; fruit quality; high density

A successful orchard system is the result of a designed integration of a group of component parts. These components include the rootstock, tree density, tree arrangement, tree quality, and support system, pruning and training management techniques. The component pieces must be selected carefully for an orchard system to be functional and profitable (Barritt 1992). High density plantings in apple production allow greater early productivity, an earlier return on capital investment and high yields of good quality fruit. Therefore, these systems were widely adopted by American and European fruit growers in the past three decades (Hampson et al. 2004a; Wertheim et al. 2001). Similarly, in Turkey high density planting systems were used by some apple growers for the past decade and such systems are becoming increasingly widespread in Turkey (Özkan 2008).

High density planting systems with dwarf trees make a better use of the available light than conventional low density planting systems with vigorous trees because light interception with orchard age is greater and light distribution within the canopy is better. The adverse effects of shaded canopies on flower bud induction, spur quality, fruit size, colour and internal quality are well-documented (Barritt et al. 1997). Tree height and canopy shape also affect total interception and the penetration of light into the canopy (Robinson 1997).

Supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK), TOVAG, Project No. 106 O 096.

A training system is a method of manipulating tree planting arrangement and canopy geometry to improve the interception and distribution of light, for the purpose of optimizing fruit quality and yield (Hampson et al. 2002). Many comparisons of training systems were reported in recent years. In a study of the effects of training systems on yield of cv. Elstar on dwarf rootstock and cv. Šampion apple on semidwarf, both cvs Elstar and Šampion trees trained as hytec had significantly lower yield than those trained as spindle (Buler et al. 2001). Crassweller and Smith (2004) reported that in the 4th year, little differences in cumulative yield/ha were observed between slender spindle, hytec and vertical axe. Weber (2001) found that though tree density was 3.5 times greater in super spindle than slender spindle, cumulative yield per hectare of super spindle was only 1.3 times higher than that of slender spindle. Robinson (2007) also reported that there was a curvilinear relationship between cumulative yield and tree density, and suggested optimum planting density is dependent on the influence of economic factors and the law of diminishing returns.

Our objectives of the present study were to determine the effect of different training systems on the performance of cv. Jonagold apple grafted on M.9 rootstock in terms of tree size, yield and some fruit quality parameters.

MATERIAL AND METHODS

Planting and training description. Nonfeathered trees of cv. Jonagold on M.9 rootstock were planted in north-south rows in December 2006, into a light sandy loam soil that was used for about 20 years to grow field crop. As a precaution against crown gall, the roots were dipped in Nogall® solutions (20 g/l) for 5 s before planting. Trees were planted with the bud union 10 cm above the soil line. After planting, trees were watered by hand. One week after planting drip irrigation was installed. Trellis installation was completed before the planting.

The spaces between tree row and within row were 3.0 × 0.7 m for slender spindle (SS) (4,761 trees/ha), 3.5 × 1.0 m for vertical axis (VA) (2,857 trees/ha), 3.5 × 1.5 m for hytec (HT) (1,904 trees/ha). For the super spindle (Super S), two different spacings were used as H Super, 2.0 × 0.5 m (10,000 trees/ha) and L-Super S, 2.0 × 1.0 m (5,000 trees/ha).

Slender spindle (SS) trees were classically trained (Wertheim 1978), with a final target height of 2.5 m. Plants were headed at 90 cm and planted 10 cm south of bamboo canes with the bud union facing the canes. Annually, vigorous upright leaders of SS were removed and replaced with a weaker branch to devigorate the leader.

Super spindle trees were developed without pruning at planting, and the leader was not headed until year 4. Acutely angled shoots and feathers that were more than half the diameter of the central leader were removed. In 3rd leaf year, two-year old branches with weak annual shoots were cut back to promote shoot strength. Water sprouts were removed through ripping. In leaf year 4, fruiting wood replacement continued and tree height was limited by one single cut into two-year old generative wood (Weber 2001; Robinson 2007).

Vertical axes of trees were developed by heading the leader at 120 cm above the graft union at planting and shortening each feather by 1/3 their length. Leaders were not headed from the second through the fourth year. At the beginning of the fourth year, large diameter limbs were removed back to the trunk with an angled cut to develop replacement limbs (Lespinasse, Delort 1986; Robinson 2007).

To obtain hytec, the leader shoot was headed ~60 cm above the graft union at planting. A side shoot was directed upwards to form a new leader. Replacing the leading shoot by a side shoot was repeated for three years (Barritt 1992).

The experiment was laid out in a randomized complete-block design with three blocks, each consisting of three rows of trees. There were 25 trees in each row. Each experimental plot contained five trees in each of the three rows. Data were collected from the three central trees in the middle rows, using the remaining trees as guards.

Cultural practices. The orchard was irrigated with drip irrigation each year from May to mid-October. Double lateral tapes were used for per tree row. Drip emitters were placed on the both side of the trunk, at distance of 25 cm. Emitter spacing was 1 m, and emitter flow rates were 2 l/h. Trees were watered three times a week for 5 h each time in 2007 (1st leaf year). In subsequent years the schedule was changed to daily irrigation for ~3 h in order to accommodate the fast draining soil. Total water applied was about 800 l in 2007, and 1,400 to 1,450 l per emitter annually during 2008–2010. All trees were fertigated with 30 g of 20-20-20 N-P-K/

Table 1. Mean trunk cross-sectional area (TCA) and tree canopy volume for cv. Jonagold/M.9 apple trees in different training systems

Training system	TCA (cm^2)			Canopy volume (m^3)
	2008	2009	2010	2010
SS	2.36[a*]	6.50[b]	9.41[c]	1.7[cd]
VA	2.75[a]	8.25[a]	11.96[b]	3.0[b]
HT	2.76[a]	8.87[a]	14.85[a]	4.13[a]
L-Super S	2.66[a]	6.15[b]	8.74[cd]	2.50[bc]
H-Super S	2.60[a]	5.15[b]	7.17[d]	1.45[d]

*means in the same column followed by the same letter are not significantly different according to the Duncan's multiple range test (P = 0.05); SS – slender spindle (4,761 trees/ha), VA – vertical axis (2,857 trees/ha), HT – hytec (1,904 trees/ha), L-Super S – super spindle tree density (5,000 trees/ha), H-Super S – super spindle tree density (10,000/trees/ha)

tree/year year from irrigation start up, followed by 15-0-0 at 75 g/m of row. Fertigation was completed by August 20 in each year. To control apple scab (caused by *Venturia inaequalis*), a fungicide (Flint 15 g/100 l) was applied before bloom, at pink tip and at petal-fall. Foliar urea was applied at a rate 3.5 kg/ha (1% w/v) after harvest. Fruits were hand-thinned after June drop to a spacing of 15 cm. Black textile mulches were used for weed control in the tree rows.

Measurements and statistical analysis. Trunk diameter 15 cm above the bud union was measured with digital callipers in mid November each year. The average of two readings (north-south and east-west) was converted to trunk cross-sectional area (TCA) for analysis. Canopy volume (m^3) was calculated only in 2010. Some trees flowered in the first year after planting (2007), but the trees were not allowed to fruit, thus yield values were not calculated for 2007. Following the 2008 growing season, annual yields, yield efficiency (yield/TCA), cumulative yield and cumulative yield efficiency (cumulative yield/TCA in 2010) were calculated. Calculations for average fruit weight and crop load (number of fruit/cm^2 TCA) were done using the total number of fruits/tree. Fruit characteristics, such as fruit diameter, firmness, soluble solids (%) and titratable acidity (%) were determined using a randomly selected sample of 10 fruits/tree.

Statistical analyses were done with the SAS software package (SAS Institute, Cary, USA). TCA, canopy volume and yield data were analyzed by the analysis of variance, and the means were separated by using the Duncan's multiple range test.

To adjust for the effect of crop load (expressed as fruit number/cm^2 TCA; Robinson et al. 1991) on fruit characteristics, crop load was included as a quantitative source of variation in the analysis of variance for fruit characteristics. Means separation was carried out using the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Trunk cross-sectional area (TCA) is often used as a convenient non-destructive estimate of overall tree size (Barden, Marini 2001). TCA of trees was similar for all training systems in 2008 (Table 1). In subsequent years, significant differences in TCA were observed between the training systems. In 2009 and 2010, trees trained as HT or VA had higher TCA than those trained as SS L-Super S and H-Super S. While VA and HT trees had similar TCA in 2009, in 2010 the trees trained as HT had higher TCA than those trained as VA. Similar results were observed in 2010 for canopy volume. In contrast to the findings of Buler et al. (2001) that training the leader in the zigzag shape of HT reduced growth and canopy size, the highest canopy volume was observed in HT, and the smallest in H-Super S. The changes in tree growth were likely a result of differences of tree density rather than training systems, which was also reported (Hampson et al. 2004a; Robinson 2007).

Training systems did not exert any significant effects on yield/tree in 2008 (2^{nd} leaf year) (Table 2). In 2009, HT, SS and L-Super S had similar yields/tree, but H-Super S and VA had significantly lower yields. In the 4^{th} leaf year (2010), HT and VA, low density systems, had higher yields/tree than H-Super S. Cumulative yield over the first three crop years was significantly higher for HT than SS and H-Super S. Cumulative yields of the trees trained as VA or

Table 2. Yield per tree and yield efficiency of cv. Jonagold/M.9 apple trees in different training systems

Training system	Yield (kg/tree)			Cumulative yield (kg/tree)	YE (kg/cm²)			CYE (kg/cm)
	2008	2009	2010		2008	2009	2010	
SS	0.75[a*]	5.10[ab]	5.74[cd]	11.59[bc]	0.31[a]	0.80[a]	0.61[ab]	1.23[ab]
VA	1.78[a]	4.11[bc]	7.41[ab]	13.30[ab]	0.64[a]	0.51[a]	0.62[ab]	1.12[ab]
HT	0.69[a]	5.85[a]	8.51[a]	15.05[a]	0.24[a]	0.66[a]	0.58[b]	1.02[b]
L-Super S	0.80[a]	5.03[ab]	6.90[bc]	12.73[ab]	0.31[a]	0.82[a]	0.80[a]	1.47[a]
H-Super S	0.70[a]	3.29[c]	5.14[d]	9.13[c]	0.27[a]	0.63[a]	0.73[ab]	1.29[ab]

*means in the same column followed by the same letter are not significantly different according to the Duncan's multiple range test (P = 0.05); YE – yield efficiency, CYE – cumulative yield efficiency, for other abbreviations see Table 1

L-Super S were slightly lower than at trees trained as HT. The super spindle system had significantly higher cumulative yields (CY) in the low density planting. Generally, yield/tree was higher in low density training systems than in high density systems. Similar results were also reported (Weber 2001; Hampson et al. 2002; 2004b).

Yield efficiency did not differ among training systems in 2008 and 2009 (Table 2). Although HT had the highest yield/tree, it ranked last in yield efficiency due to high TCA in 2010. Similarly, cumulative yield efficiency (CYE) was the lowest in trees trained as HT. The only significant difference for CYE appeared between HT and L-Super S.

While H-Super S had the highest yield/ha in 2008 (2nd leaf year), HT had the lowest yield (Table 3). This was expected based on the number of trees per hectare. Yield/ha harvested from trees trained as VA was not significantly different from that of H-Super S, although the number of trees in VA was three and a half time less than that in H-Super S. The early high yield may be a result of less pruning in VA compared to other training systems. Heavy pruning is known to delay bearing (Campbell et al. 1996; Miller 1984). This yield superiority of VA was not observed in subsequent two years.

When cumulative yields/ha were evaluated, the yield advantage of high density planting was clearly evident for the first three cropping years. Robinson (1992) also found that early fruit yields were primarily a function of tree density. Similarly, Hampson et al. (2004b) reported that initially cumulative yield/ha was a linear function of tree density, systems had no significant influence and the relationship subsequently became curvilinear as trees at intermediate densities produced more per tree than trees in high density planting.

Training systems had no consistent effect on average fruit diameter and fruit mass (Table 4). In 2009, HT had the largest fruit, but in 2010, the largest fruits were harvested from SS and VA systems. The average weight of fruits collected from HT trees was the greatest in 2009, but VA systems produced greatest average fruit weight in 2010. However, there was no significant difference in average fruit weight between VA and HT systems in both 2009 and 2010. The tendency for larger fruit weight in VA and HT may be related to lower tree density. Average fruit weight declined with increasing tree density in some previous studies (Corelli, Sansavini 1989; Tustin et al. 1993) but not others (Palmer et al. 1989; Wagenmakers, Callesen 1995).

Table 3. Yield per hectare of cv. Jonagold/M.9 apple trees in different training systems

Training system	Yield (t/ha)			Cumulative yield (t/ha)
	2008	2009	2010	
SS	3.55[c*]	24.30[a]	27.35[bc]	55.21[bc]
VA	5.91[ab]	13.70[b]	24.71[cd]	44.32[cd]
HT	1.54[d]	13.01[b]	18.92[d]	33.46[d]
L-Super S	4.01[c]	25.17[a]	34.48[b]	63.66[b]
H-Super S	7.01[a]	32.87[a]	51.37[a]	91.24[a]

*means in the same column followed by the same letter are not significantly different according to the Duncan's multiple range test (P = 0.05); for other abbreviations see Table 1

Table 4. Least-squares means for average fruit diameter and fruit weight (adjusted for crop load) for cv. Jonagold apple trees grown under different training systems

Training system	Fruit diameter (mm)			Fruit weight (g)		
	2008	2009	2010	2008	2009	2010
SS	76.9[a*]	77.4[b]	78.9[a]	202.3[a]	216.4[b]	221.4[b]
VA	75.5[a]	79.4[b]	80.2[a]	197.3[a]	237.1[ab]	259.1[a]
HT	73.7[a]	94.4[a]	71.3[b]	182.8[a]	256.4[a]	243.3[ab]
L-Super S	72.1[a]	76.9[b]	71.3[b]	166.4[a]	213.1[b]	211.3[b]
H-Super S	71.9[a]	76.3[b]	66.6[c]	171.3[a]	217.1[b]	207.5[b]

*means in the same column followed by the same letter are not significantly different according to the LSD (P = 0.05); for abbreviations see Table 1

The differences among training systems for fruit firmness, soluble solid and titratable acidity changed according to year and meaningful differences were not observed. According to measurements made at harvest in 2010, fruit firmness ranged from 9.2 kg (VA) to 10.3 kg (HT), soluble solids from 12.2% (VA) to 14.8% (SS), and titratable acid from 0.27% (VA) to 0.52% (SS).

Consequently, according to the results from the first three cropping years, high density system of super spindle with 10,000 trees/ha appeared to be more productive in terms of yield per hectare. Greater early productivity and an earlier return on capital investment are very important for apple growers. However, as reported elsewhere (Hampson et al. 2004a; Robinson 2007), this advantage of high density systems may decline over time. Therefore, decision on selecting training systems would need to be based on results from many more years.

References

Barden J.A., Marini R.P., 2001. Comparison of methods to express growth, size and productivity of apple trees. Journal of the American Pomological Society, *55*: 251–256.

Barritt B.H., 1992. Intensive Orchard Management. Good Fruit Grower, Yakima, Washington: 221.

Barritt B.H., Drake S.R, Konishi B.S., Rom C.R., 1997. Influence of sunlight level and rootstock on apple fruit quality. Acta Horticulturae, *451*: 569–577.

Buler Z., Mika A., Treder W., Chlebowska D., 2001. Influence of new training systems of dwarf and semidwarf apple trees on yield its quality and canopy illumination. Acta Horticulturae, *557*: 253–259.

Campbell J.E., Nicol H.I., Cullis B.R., 1996. Effect of four different canopy shapes on apple yields. Australian Journal of Experimental Agriculture, *36*: 489–499.

Corelli L., Sansavini S., 1989. Light interception and photosynthesis related to planting density and canopy management in apple. Acta Horticulturae, *243*: 159–174.

Crassweller R.M., Smith D.E., 2004. Will high density work for processing apples? Acta Horticulturae, *639*: 661–665.

Hampson C.R., Quamme H.A., Brownlee R.T., 2002. Canopy growth, yield and fruit quality of 'Royal Gala' apple tree grown for eight years in five tree training systems. HortScience, *37*: 627–631.

Hampson C.R., Quamme H.A., Kappel F., Brownlee R.T., 2004a. Varying density with constant rectangularity: I. Effects on apple tree growth, and light interception in three training systems over ten years. HortScience, *39*: 501–506.

Hampson C.R., Quamme H.A., Kappel F., Brownlee R.T., 2004b. Varying density with constant rectangularity: II. Effects on apple tree yield, fruit size, and fruit color development in three training systems over ten years. HortScience, *39*: 507–511.

Lespinasse J.M., Delort J.F., 1986. Apple tree management in vertical axis: appraisal after ten years of experiments. Acta Horticulturae, *160*: 139–155.

Özkan Y., 2008. The high density planting in Turkey. The Yield with Gübretaş, *15*: 15–16.

Miller S.S., 1984. Effect of various training systems on canopy development in four apple cultivars. Acta Horticulturae, *146*: 293–303.

Palmer J.W., Bünemann G., Sansavini S., Wagenmakers P.S., Winter F., 1989. The international planting systems trial. Acta Horticulturae, *243*: 231–241.

Robinson T.L., 1992. Performance of Y-shaped canopies at various angles in comparison with central leader trained trees. Acta Horticulturae, *322*: 79–86.

Robinson T.L., 1997. Interaction of tree form and rootstock on light interception, yield and efficiency of 'Empire', 'Delicious' and 'Jonagold' apple trees trained to different systems. Acta Horticulturae, *451*: 427–436.

Robinson T.L., 2007. Effects of tree density and tree shape on apple orchard performance. Acta Horticulturae, *732*: 405–414.

Robinson T.L., Lakso A.N., Carpenter S.G., 1991. Canopy development, yield, and fruit quality of 'Empire' and 'Delicious' apple trees grown in four orchard production systems for ten years. Journal of the American Society for Horticultural Science, *116*: 179–187.

Tustin D.S., Hirst P.M., Cashmore W.M., Warrington I.J., Stanley C.J., 1993. Spacing and rootstock studies with central leader apple canopies in a high vigour environment. Acta Horticulturae, *349*: 169–177.

Wagenmakers P.S., Callesen O., 1995. Light distribution in apple orchard systems in relation to production and fruit quality. Journal of Horticultural Science and Biotechnology, *70*: 935–948.

Weber M.S., 2001. Optimizing the tree density in apple orchards on dwarf rootstocks. Acta Horticulturae, *557*: 229–234.

Wertheim S.J., 1978. Pruning of slender spindle types trees. Acta Horticulturae, *65*: 173–180.

Wertheim S.J., Wagenmakers P.S., Bootsma J.H., Groot M.J., 2001. Orchard systems for apple and pear: conditions for success. Acta Horticulturae, *557*: 209–227.

Received for publication February 10, 2012
Accepted after corrections May 29, 2012

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