# THE EFFECTS OF PLANTING DISTANCE AND TRAINING SYSTEM ON YIELD AND FRUIT QUALITY OF PEACH

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The objective of this study was to obtain abundant yields of high quality peaches from trees with different training system and planting spacing and to investigate the possibilities of high-density planting by limiting crown growth. Hence, this study was to examine the performance of 'Monroe'/GF 677 peach trees with different training systems and planting distances. As a result of the investigations, the highest cumulative yield per hectare was obtained from the Slender Spindle training system followed by Y-Trellis, Central Leader and Open Vase systems. With respect to planting width the cumulative yield from trees planted within a 0.5 m distance was increased due to more saplings. The results revealed no significant effect of the training system and the planting distance in respect to fruit quality characteristics and fruit quality. It was concluded that the Slender Spindle and Y-Trellis cultivation systems with 1 m row distance are suitable for peach cultivation in terms of cumulative yield and profitability, without adversely affecting fruit quality.
**Keywords:** *P. persica*, Y-Trellis, Slender Spindle, Open Vase, Central Leader

**Auswirkungen des Pflanzabstands und des Erziehungssystems auf Ertrag und Fruchtqualität von Pfirsich.** Ziel dieser Studie war es, hohe Erträge von qualitativ hochwertigen Pfirsichen von Bäumen mit unterschiedlichem Erziehungssystem und Pflanzabstand zu erhalten und die Möglichkeiten einer Kultivierung mit hoher Pflanzdichte durch Begrenzung des Kronenwachstums zu untersuchen. Daher sollte in dieser Studie die Leistung von Pfirsichbäumen ('Monroe'/GF 677) mit unterschiedlichen Erziehungssystemen und Pflanzabständen untersucht werden. Der höchste kumulierte Ertrag pro Hektar wurde mit der Schlanken Spindel erzielt, gefolgt von den V-Trellis-, Central Leader- und Open Vase-Systemen. In Bezug auf die Pflanzweite wurde der kumulierte Ertrag bei einem Abstand von 0,5 m aufgrund der höheren Anzahl von Setzlingen erhöht. Die Ergebnisse zeigten keine signifikanten Auswirkungen des Erziehungssystems und des Pflanzabstands auf die Fruchtqualitätsmerkmale und die Fruchtqualität. Es wurde festgestellt, dass die Schlanke Spindel und V-Trellis-Anbausysteme mit einem Reihenabstand von 1 m sich hinsichtlich des kumulierten Ertrags und der Rentabilität für den Pfirsichanbau eignen, ohne die Fruchtqualität zu beeinträchtigen.
**Schlagwörter:** *P. persica*, V-Trellis, Schlanke Spindel, Open Vase, Central Leader

Having a uniquely beautiful color and smell and full flavor, peach is a fruit rich in organic and mineral matters and, among all types of fruits, is highly valuable in terms of fruit quality. Extended ripening period (like 5 to 6 months) of peach cultivars improves the value of this fruit even more. In order to maintain and even increase this value, it is required to employ modern methods in peach growing and investigate and put into practice the most suitable of all cultural practices, especially pruning and training, for obtaining high-quality fruit from productive trees. Pruning and training systems, which are vital parameters in the development of modern fruit growing, determine tree shape as well as the distribution of sunlight inside the canopy and directly affect the critical balance between fruit yield and vegetative growth (Grossman and Dejong, 1998; Iannini et al., 2002). To date, numerous studies have been conducted to examine the effect of different training systems, rootstocks and planting systems on early fruit yield and quality for peach growing (Van den Ende et al., 1987; Caruso et al., 1998; Grossman and Dejong, 1998; Loreti and Massai, 2002; Farina et al., 2005; Caruso et al., 2015; Sobierajski et al., 2019; Souza et al., 2019). The traditional Open Center training system (in Turkey) at densities of 300 to 500 trees/ha results in poor yield during the early years of the orchard (Robinson et al., 2006), whereas the use of higher planting densities and different tree shapes has led to substantial yield increases in the early life of peach orchards (Layne et al., 2002). Pasa et al. (2017) carried out a study with two different peach cultivars ('Kampei' and 'Rubimel') using three different training systems and planting densities, namely Y Shape – two opposite scaffolds (2 × 5 m = 1000 trees/ha), Central Leader – a single vertical axis (2 × 5 m = 1000 trees/ha), and Open Center – 4 scaffolds (4 × 5 m = 500 trees/ha). In the study an earlier and higher yield was obtained with the Central Leader training system. In addition, they reported that yield increase did not have any negative effects on fruit size. In the scope of a study (Sobierajski et al., 2019) conducted in Brazil, the peach cultivar 'Tropic Beauty' was grown under two different training systems; namely, Y Shape and Fruiting Wall, and it was recorded that the trees trained in the Fruiting Wall system had a superior fruit quality and that the Fruiting Wall system could be an appropriate alternative to the Y Shape system. In another study (Souza et al., 2019) run in a 'BRS Rubimel' peach orchard established using the training systems of 2 scaffolds (0.75, 1, 1.25, and 1.50 m spacings) and 4 scaffolds (1, 1.50, 1.75, and 2 m spacings), a higher cumulative yield was derived from the training system with 2 scaffolds and the planting spacing of 0.75 m without any loss of fruit quality.

Peach production increases each year in Turkey. Turkey is ranked as the fifth in the world peach production, with a production amounting to 789.457 tons. In Turkey, peach trees are traditionally trained in the Open Vase system. However, it has become necessary to apply new planting and training systems to increase yield and quality using modern growing systems. Training systems are of great importance for trees to make the best use of sunlight and, as a result, photosynthesize at maximum rates and produce superior quality fruit and higher amounts of yield. Moreover, many studies conducted worldwide show, that in fruit growing both labor costs and employment problems have risen (Dejong et al., 1999; Farina et al., 2005; Pasa et al., 2017). For this reason, it is extremely important to develop and implement new training systems that reduce the need for labor force, reinforce mechanization and facilitate all cultural practices, especially harvest. Otherwise, fruit growing may become unsustainable in consideration of smaller orchards, less skilled agricultural laborers and higher labor costs. In the light of the foregoing, the primary purpose of the present study was to compare the Open Vase training system used in Turkey and the Central Leader, Y-Trellis and Slender Spindle training systems employed in different parts of the world. This study was also aimed at limiting the canopy development of the trees so as to investigate the means of denser planting than the standard. In this regard, the hypothesis of this study was to attain higher yield and higher quality products by stimulating early yield in peach trees through different planting densities and training systems. Of all studies performed in Turkey in this sense, this study is one of the first to examine fruit yield and quality over a long period of time.

## MATERIAL AND METHODS

### PLANT MATERIALS AND EXPERIMENT DESIGN

The study was conducted with the peach cultivar 'Monroe/GF 677' in the peach orchard located in the land of the Directorate of Fruit Research Institute (Eğirdir, Turkey) (37° 49' 30" N; 30° 52' 38" E; Altitude: 926 m) and established with different training systems and planting densities (December 2011). Two separate experiments (supported and freestanding) as well as four different training systems and different planting spacings were used in the design of the project orchard. The Open Vase and Central Leader systems were employed as freestanding training systems, whereas the Y-Trellis and Slender Spindle systems as supported training systems. Inter-row and intra-row spacings were 5 × 5, 5 × 4, 5 × 3, 5 × 2 and 5 × 1 m for the Open Vase and Central Leader training systems, and 5 × 2, 5 × 1.5, 5 × 1 and 5 × 0.5 m for the wired training systems. Experiments were carried out with three replications (5 trees per replication) using randomized block experimental design.

### TRAINING SYSTEMS AND PRUNING

#### OPEN VASE

Lower and higher planting densities (400 to 2000 trees/ha) were realized with this system. The trees were trained to the traditional Open Vase system. They were grown so as to have a vase shape without any leader but with 4 to 5 lateral branches.

#### CENTRAL LEADER

Lower and higher planting densities (400 to 2000 trees/ha) were realized with this system. The trees were trained to the traditional Central Leader system.

#### SLENDER SPINDLE

This system allowed for a very high planting density (1000 to 4000 trees/ha). The trees were supported by vertical bamboos mounted to a 3-wires system and a 3-meter-length support system. During the first year's dormant period, the leader, which had already developed and hardened, was directed and tied in such a way as to twist spirally around the bamboo. On the other hand, lateral branches were tied to the support system with a branch angle of 45 to 60 degrees. No branch removal was made unless the lateral branches on the trunk were very close to each other and overlapping. The tips of the trees spaced at 2 m and 1.5 m on the row were pruned. The weak branches of the trees spaced at 0.5 m and 1 m on the row were cut back, and the tips of such weak branches were pruned. The same processes were repeated for the 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ year. Starting from the 5th year, the main trunk of each tree twisted spirally around the bamboo support and the trees reached the desired height of 3 m, filled the spacing between rows and eventually reached the year of full yield. The growth rate of the leader decelerated as the main trunk twisted spirally around the bamboo support. In this way, its height was kept between 2.5 and 3.5 m. The trees had a narrow and cone-shaped form. From the 5th year, the number of cuttings cut during pruning has decreased; in general, weak branches are cut at all spacings.

#### Y-TRELLIS

This system allowed for a very high planting density (1000 to 4000 trees/ha). One lateral branch that had developed properly on the tree trunk in the inter-row direction during the planting year vegetation period was attached to the 3-meter-length bamboo mounted to the galvanized 3-wires system, which extended along the row in the shape of Y, so as to grow with an angle of 70 degrees. During the first year's dormant period, the process of tying was carried out depending on the length of the secondary lateral branches, which had already

grown and hardened. Lateral branches were thinned in fish bone shape in the intra-row direction to the support system. They were allowed to develop on each main secondary branch with a spacing of 10 to 15 cm. In the following years, this process was maintained for annual shoots. As for older shoots, those which were weaker were cut back in denser planting applications depending on planting spacing. Not only cutting back but also tip pruning was performed as planting spacing increased. (The tips of the trees spaced at 2 m and 1.5 m on the row were pruned. The weak branches of the trees spaced at 0.5 m and 1 m on the row were cut back, and the tips of such weak branches were pruned). As a result of these processes performed by the end of the 4th year and as from the 5th year on, the trees showed an ideal vegetative progress, reached the desired height (3 m), filled the spacing between rows and eventually reached the year of full yield. As of the 5th year, the number of cuttings cut during pruning has decreased; in general, weak branches are cut at all spacings.

### CULTURAL TREATMENTS

Cultural practices (irrigation, pesticide and herbicide application, etc.) were conducted as standard. Plant nutrition activities were carried out by means of fertigation based on the fertilization schedule obtained from the results of the annual soil analysis. Fruit on the trees were thinned manually so as to compare yield and quality differences between the treatments (training systems and planting densities). Thinning was done right before (or at the time of) stone hardening and roughly 35 days after full bloom or when fruit weight reached 2.0 g on average (Childers, 1976). Besides, summer pruning was performed mid or late June. During summer pruning, the shoots that had grown upright and hindered sunlight as well as the branches that were dead and situated on top of each other were removed from the trees. In addition, shoots were bent and tied to the wires.

### MORPHOLOGICAL MEASUREMENTS

Starting from planting, some morphological measurements (trunk diameter (mm), canopy width (cm), tree height (cm)) were made. Trunk diameter was measured by calipers (10 cm above the grafting point). Data from 2018 and 2019 were taken into consideration in the study.

### YIELD EFFICIENCY

In the study, 6 years' (2014, 2015, 2016, 2017, 2018 and 2019) yield values (yield per tree (kg/tree), yield per trunk cross-section (kg/cm$^2$), yield per hectare (kg/ha), cumulative yield per tree (kg/tree), cumulative yield per trunk cross-section (kg/cm$^2$), and cumulative yield per hectare (kg/ha)) were calculated.

### SOME FRUIT QUALITY PARAMETERS

In the study, 15 fruit were physically analyzed for each replication (fruit width (mm), fruit length (mm), fruit weight (g), fruit flesh firmness (N) and fruit color (L*, a*, b*, C*, hu°)). Fruit firmness was measured on both sides of each fruit and by using a texture analyzer (Lloyd Instruments LF Plus, Largo, FL, USA) incorporating an 8 mm diameter probe. The results were expressed as Newton (N). Fruit color was measured along the equatorial axes of fruit using a Minolta CR-300 colorimeter (Osaka, Japan). Within the scope of the chemical analysis (soluble solids content (SSC), titratable acidity (TA) and pH), fruit juice was measured in three parallels. The last two years' (2018 and 2019) data on fruit quality traits were evaluated.

### STATISTICAL EVALUATION

The study was conducted as two separate experiments with three replications (5 trees per replication) using randomized block experimental design. The data obtained were subjected to analysis of variance on the SAS-JMP 8.0 package. LSD multiple comparison test was used to determine the differences between averages.

# RESULTS

## MORPHOLOGICAL MEASUREMENTS

In consideration of the 2018 and 2019 data, according to the variance analysis results of the Slender Spindle and Y-Trellis systems, tree height and trunk diameter were found to be statistically significant ($p < 0.05$) based on both training systems and planting densities. In terms of tree width, the interaction of training system and planting density was also statistically significant ($p < 0.05$) (Table 1). In both years, compared to the Y-Trellis system (2276.00 cm - 74.58 cm), the Slender Spindle system (323.34 cm - 316.88 cm) formed higher trees. In terms of tree width, the intra-row spacings of 1 m and 1.5 m in the Y-Trellis system stood out (261.33 cm and 259.67 cm, respectively). In the Slender Spindle system, tree width increased in direct proportion to planting density, and the highest canopy width was obtained with the trees spaced at 2 m on the row (211 cm - 213.67 cm). In terms of trunk diameter, the Slender Spindle system (62.65 mm - 71.90 mm) constituted a thicker tree trunk than the Y-Trellis system (59.34 mm - 68.40 mm). Planting densities were compared in terms of trunk diameter, and it was found that trunk diameter increased in line with the intra-row spacing and that the highest trunk diameter (69.92 mm - 80.41 mm) was produced by the training systems with an intra-row spacing of 2 m (Table 1).

According to the results of the analysis of variance performed on the Open Vase and Central Leader training systems, the interaction of training system and planting density was statistically significant ($p < 0.05$) in terms of tree height in both years (Table 2). As a result of the evaluation of tree heights, it was found that the highest trees (340.15 cm - 374.67 cm) were obtained from the Central Leader system where a planting spacing of 1 m was applied. In both 2018 and 2019, neither the interaction of training system and planting density nor training systems and planting densities were statistically significant in terms of tree width. In terms of trunk diameter, however, only the differences between planting densities were found to be statistically significant ($p < 0.05$); the trees with a planting density of 5 m had the highest trunk diameter (Table 2).

Table 1: Morphological features of trees of 'Monroe/GF 677' peach on Slender Spindle and Y-Trellis training systems (2018 and 2019)

| Training System | Plant distance (m) | Length (cm) | | Width (cm) | | Trunk diameter (mm) | |
|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Slender Spindle** | 0.5 | 290.00 | 288.20 | 138.67d* | 140.00e* | 50.19 | 57.11 |
| | 1 | 322.67 | 317.67 | 169.67c | 173.33d | 60.78 | 69.90 |
| | 1.5 | 336.00 | 330.00 | 187.67c | 187.33d | 66.23 | 76.16 |
| | 2 | 344.67 | 331.67 | 211.00c | 213.67c | 73.41 | 84.42 |
| **Y-Trellis** | 0.5 | 252.67 | 253.67 | 234.33b | 238.67b | 46.28 | 53.87 |
| | 1 | 294.67 | 293.00 | 260.00a | 261.33a | 60.24 | 69.28 |
| | 1.5 | 285.00 | 280.67 | 258.67a | 259.67a | 64.40 | 74.07 |
| | 2 | 271.67 | 271.00 | 255.00a | 255.00ab | 66.42 | 76.39 |
| **Training System Mean** | | | | | | | |
| **Slender Spindle** | | 323.34a* | 316.88a* | 176.75 | 178.58 | 62.65a* | 71.90a* |
| **Y-Trellis** | | 276.00b | 274.58b | 252.58 | 253.67 | 59.34b | 68.40b |
| | Plant distance mean | | | | | | |
| | 0.5 | 306.34b* | 270.93b* | 186.5 | 189.33 | 48.24c* | 55.49d* |
| | 1 | 308.67a | 305.33a | 215.5 | 217.33 | 60.51b | 69.59c |
| | 1.5 | 310.50a | 305.33a | 223.67 | 223.50 | 65.32b | 75.11b |
| | 2 | 308.17a | 301.33a | 233.00 | 234.33 | 69.92a | 80.41a |
| **P values** | | | | | | | |
| **Training System (TS)** | | 0.0010 | 0.0003 | <.0001 | <.0001 | 0.0145 | 0.0072 |
| **Plant distance (Pd)** | | 0.0422 | 0.0453 | <.0001 | <.0001 | <.0001 | <.0001 |
| **TS X Pd** | | 0.7169 | 0.5190 | 0.0010 | 0.0010 | 0.2487 | 0.1506 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

Table 2: Morphological features of trees of 'Monroe/GF 677' peach on Open Vase and Central Leader training systems (2018 and 2019)

| Training System | Plant distance (m) | Length (cm) | | Width (cm) | | Trunk diameter (mm) | |
|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Open Vase** | 1 | 194.67c* | 202.33c* | 190.12 | 201.67 | 69.02 | 78.22 |
| | 2 | 195.67c | 203.33c | 209.00 | 216.33 | 70.06 | 80.56 |
| | 3 | 201.33c | 211.67c | 212.00 | 232.67 | 67.62 | 77.76 |
| | 4 | 175.67c | 188.33c | 189.67 | 201.67 | 73.48 | 84.50 |
| | 5 | 206.67c | 213.67c | 234.67 | 238.67 | 78.63 | 90.43 |
| **Central Leader** | 1 | 340.15a | 374.67a | 178.12 | 184.00 | 70.12 | 77.95 |
| | 2 | 318.67b | 328.67b | 223.67 | 231.33 | 74.57 | 85.76 |
| | 3 | 302.67b | 308.33b | 212.00 | 218.33 | 74.28 | 85.42 |
| | 4 | 298.67b | 307.33b | 210.67 | 225.00 | 79.13 | 91.00 |
| | 5 | 313.67b | 325.33b | 251.33 | 255.00 | 84.94 | 97.69 |
| **Training System Mean** | | | | | | | |
| **Open Vase** | | 199.59 | 203.87 | 258.87 | 338.20 | 71.76 | 82.29 |
| **Central Leader** | | 314.77 | 328.87 | 215.16 | 222.73 | 76.61 | 87.57 |
| | Plant distance mean | | | | | | |
| | 1 | 267.41 | 288.50 | 184.12 | 192.83 | 69.66b* | 78.09b* |
| | 2 | 257.17 | 266.00 | 216.34 | 223.83 | 72.32b | 83.16b |
| | 3 | 252.00 | 260.00 | 212.00 | 225.50 | 70.95b | 81.59b |
| | 4 | 237.17 | 247.83 | 200.17 | 213.33 | 76.31ab | 87.75ab |
| | 5 | 260.17 | 269.50 | 243.00 | 246.83 | 81.79a | 94.07a |
| **P values** | | | | | | | |
| **Training System (TS)** | | <.0001 | <.0001 | 0.4250 | 0.3523 | 0.2850 | 0.1013 |
| **Plant distance (Pd)** | | 0.0245 | 0.0116 | 0.3789 | 0.4170 | 0.0246 | 0.0351 |
| **TS X Pd** | | 0.0443 | 0.0160 | 0.4589 | 0.4598 | 0.1084 | 0.9209 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

## YIELD

As a result of the analysis of variance on the Slender Spindle and Y-Trellis training systems, no statistical difference was observed between yield per tree (kg/tree) values for 2014. For 2015, 2016, 2017, 2018 and 2019, only the differences between planting spacings were found to be statistically significant ($p < 0.05$) (Table 3). In 2015, a significantly lower yield was acquired from the trees spaced at 0.5 m compared to other spacings. Besides, it was determined that, in statistical terms, the planting spacings of 1, 1.5 and 2 m affected yield in the same way. In 2016, 2017, 2018 and 2019, the average yield per tree of the trees spaced at 2 m stood out and presented higher values (28.36, 22.41, 14.37 and 14.06 kg/tree, respectively) (Table 3).

In terms of cumulative yield per tree and cumulative yield per hectare, only the differences between planting spacings were statistically significant ($p < 0.05$). In terms of cumulative yield per trunk cross-section, however, only the differences between training systems were found to be statistically significant ($p < 0.05$). The highest cumulative yield per tree was obtained from the trees planted with the planting densities of 2 m (98.45 kg/tree) and 1.5 m (89.10 kg/tree), whereas the highest cumulative yield per hectare from the trees planted with the planting densities of 0.5 m (167.82 trees/ha) and 1 m (144.279 trees/ha). The Y-Trellis system gave the highest cumulative yield per trunk cross-section with 2.04 kg/cm$^2$ (Table 3).

Given the results of the analysis of variance run on the Open Vase and Central Leader training systems, the interaction of training system and planting spacing in 2014 and both training systems and planting spacings in 2015, 2016, 2017, 2018 and 2019 were statistically significant ($p < 0.05$) (Table 4). In 2014, all planting spacings in the Central Leader system produced a higher yield per tree compared to those in the Open Vase system. The highest yield was obtained from the Central Leader system - 2 m (11.64 kg/tree), whereas the lowest was from the Open Vase system - 4 m (4.14 kg/

Table 3: Yield efficiency of 'Monroe/GF 677' peach on Slender Spindle and Y-Trellis training systems

| Training System | Plant distance (m) | Density (tree/ha) | Yield (kg/tree) | | | | | | Cumulative yield (kg/tree) | Cumulative yield (t/ha) | Yield efficiency (kg/cm²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | | | |
| Slender Spindle | 0.5 | 4000 | 7.80 | 4.76 | 9.56 | 9.50 | 4.73 | 5.15 | 41.49 | 165.97 | 1.62 |
| | 1 | 2000 | 11.09 | 10.03 | 18.04 | 16.24 | 7.80 | 7.09 | 70.30 | 140.59 | 1.82 |
| | 1.5 | 1330 | 10.08 | 10.54 | 21.62 | 17.35 | 13.11 | 10.97 | 83.67 | 111.28 | 1.83 |
| | 2 | 1000 | 8.57 | 9.81 | 30.90 | 19.72 | 14.72 | 15.36 | 99.08 | 99.08 | 1.74 |
| Y-Trellis | 0.5 | 4000 | 7.04 | 5.48 | 8.91 | 8.76 | 4.75 | 7.47 | 42.42 | 169.68 | 1.85 |
| | 1 | 2000 | 9.75 | 12.15 | 17.95 | 14.04 | 9.01 | 11.09 | 73.98 | 147.97 | 1.96 |
| | 1.5 | 1330 | 9.50 | 13.02 | 25.27 | 22.06 | 10.14 | 14.52 | 94.53 | 125.72 | 2.19 |
| | 2 | 1000 | 8.75 | 11.38 | 25.83 | 25.10 | 14.01 | 12.75 | 97.82 | 97.83 | 2.15 |
| **Training System Mean** | | | | | | | | | | | |
| **Slender Spindle** | | | 9.39 | 8.79 | 20.03 | 15.70 | 10.09 | 9.64 | 73.6344 | 129.23 | 1.75b* |
| **Y-Trellis** | | | 8.76 | 10.51 | 19.49 | 17.49 | 9.48 | 11.46 | 77.1884 | 135.30 | 2.04a |
| | Plant distance mean | | | | | | | | | | |
| | 0.5 | | 7.42 | 5.12b* | 9.23c* | 9.13c* | 4.74d* | 6.31c | 41.96c* | 167.82a* | 1.74 |
| | 1 | | 10.42 | 11.09a | 18.00b | 15.14b | 8.40c | 9.09b | 72.14b | 144.28b | 1.89 |
| | 1.5 | | 9.79 | 11.78a | 23.45ab | 19.70a | 11.63b | 12.75a | 89.10a | 118.50c | 2.01 |
| | 2 | | 8.66 | 10.60a | 28.36a | 22.41a | 14.37a | 14.06a | 98.45a | 98.45d | 1.95 |
| **P values** | | | | | | | | | | | |
| **Training System (TS)** | | | 0.5930 | 0.0928 | 0.8031 | 0.1331 | 0.2547 | 0.0551 | 0.4255 | 0.3440 | 0.0060 |
| **Plant distance (Pd)** | | | 0.3031 | 0.0008 | 0.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | 0.1970 |
| **TS X Pd** | | | 0.9719 | 0.9211 | 0.5624 | 0.0713 | 0.0699 | 0.0638 | 0.7753 | 0.8357 | 0.7200 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

tree). Compared to 2014, yield per tree was notably lower in both training systems in 2015. It is assumed that such an extreme decrease in yield in the Open Vase and Central Leader training systems was caused by the late frost in the spring of 2015. Yield values increased in all training systems in 2016 and 2017 and became stable in the following years. Overall, of all years, the Central Leader system had higher yield values than the Open Vase system (Table 4). In the Open Vase and Central Leader training systems, the differences between training systems and planting spacings in terms of cumulative yield per tree and cumulative yield per trunk cross-section and the differences between the interactions of training systems and planting spacings in terms of cumulative yield per hectare were statistically significant ($p < 0.05$) (Table 4). Cumulative yield per tree was 96.07 kg/tree in the Central Leader system and 63.90 kg/tree in the Open Vase system. During the 6-year period, cumulative yield per hectare was 77.19 trees/ha in the Central Leader system and 51.51 trees/ha in the Open Vase system. It was determined that cumulative yield per hectare differed substantially by planting spacing and that such differences increased based on planting density. The trees spaced at 0.5 m had a cumulative yield of 102.27 trees/ha on average. Again, the Central Leader system (1.60 kg/cm²) had a higher yield per trunk cross-section than the Open Vase system (1.21 kg/cm²) (Table 4).

Table 4: Yield efficiency of 'Monroe/GF 677' peach on Open Vase and Central Leader training systems

| Training System | Plant distance (m) | Density (tree/ha) | Yield (kg/tree) 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Cumulative yield (kg/tree) | Cumulative yield (t/ha) | Yield efficiency (kg/cm²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Open Vase** | 1 | 2000 | 7.17cd* | 2.14 | 8.94 | 9.77 | 6.10 | 7.71 | 41.83 | 83.66c* | 0.90 |
| | 2 | 1000 | 4.76de | 1.27 | 14.37 | 19.14 | 9.77 | 10.49 | 59.79 | 59.80de | 1.17 |
| | 3 | 670 | 6.86c-e | 1.04 | 18.38 | 23.38 | 12.37 | 14.12 | 76.14 | 51.01e | 1.64 |
| | 4 | 500 | 4.13e | 1.34 | 12.08 | 20.96 | 11.83 | 13.39 | 63.73 | 31.87f | 1.13 |
| | 5 | 400 | 7.70bc | 2.53 | 13.83 | 26.68 | 12.79 | 14.46 | 77.97 | 31.19f | 1.22 |
| **Central Leader** | 1 | 2000 | 9.03a-c | 3.86 | 16.51 | 13.39 | 7.71 | 9.93 | 60.44 | 120.88a | 1.31 |
| | 2 | 1000 | 11.64a | 4.04 | 27.36 | 25.73 | 14.83 | 14.79 | 98.39 | 98.39b | 1.70 |
| | 3 | 670 | 10.25ab | 2.46 | 30.95 | 28.43 | 16.42 | 16.43 | 104.95 | 70.32d | 1.91 |
| | 4 | 500 | 7.58bc | 2.06 | 25.25 | 30.44 | 14.08 | 17.73 | 97.14 | 48.57e | 1.48 |
| | 5 | 400 | 8.40bc | 7.08 | 28.55 | 32.41 | 19.34 | 23.65 | 119.44 | 47.77e | 1.60 |
| **Training System Mean** | | | | | | | | | | | |
| **Open Vase** | | | 6.12 | 1.67b* | 13.52b* | 19.99b* | 10.57b* | 12.03b* | 63.90b* | 51.51 | 1.21b* |
| **Central Leader** | | | 9.38 | 3.90a | 25.72a | 26.08a | 14.48a | 16.51a | 96.07a | 77.19 | 1.60a |
| | Plant distance mean | | | | | | | | | | |
| | 1 | | 8.10 | 3.00ab* | 12.73c* | 11.58c* | 6.91c* | 8.82c* | 51.14c* | 102.273 | 1.11b* |
| | 2 | | 8.20 | 2.66b | 20.87ab | 22.44b | 12.30b | 12.64bc | 79.09b | 79.092 | 1.43ab |
| | 3 | | 8.55 | 1.75b | 24.66a | 25.91ab | 14.40ab | 15.28ab | 90.54ab | 60.664 | 1.77a |
| | 4 | | 5.86 | 1.70b | 18.66b | 25.70ab | 12.96b | 15.56ab | 80.44b | 40.218 | 1.31b |
| | 5 | | 8.05 | 4.81a | 21.19ab | 29.54a | 16.06a | 19.06a | 98.71a | 39.482 | 1.41ab |
| **P values** | | | | | | | | | | | |
| **Training System (TS)** | | | <.0001 | 0.0014 | <.0001 | 0.0003 | 0.0004 | 0.0037 | <.0001 | <.0001 | 0.0043 |
| **Plant distance (Pd)** | | | 0.0702 | 0.0252 | 0.0028 | <.0001 | <.0001 | 0.0021 | <.0001 | <.0001 | 0.0332 |
| **TS X Pd** | | | 0.0447 | 0.3255 | 0.6835 | 0.7224 | 0.4203 | 0.4887 | 0.5173 | 0.0314 | 0.9726 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

## SOME FRUIT QUALITY PARAMETERS

### SOME PHYSICAL ANALYSES (FRUIT WIDTH, LENGTH, WEIGHT, FLESH FIRMNESS)

In 2018, only differences in fruit flesh firmness were statistically significant ($p < 0.05$) between training systems and planting densities. In 2019, differences in fruit width, fruit length, fruit weight and fruit flesh firmness were not significant between training systems and planting densities or the interactions of training systems and planting densities (Table 5). In both years, in terms of fruit width, fruit length and fruit weight, better results were obtained from the Y-Trellis system compared to the Slender Spindle system and from the planting density of 2 m compared to other planting densities. However, those differences were not statistically significant. In 2018, the fruit of the trees trained in the Slender Spindle system (24.55 N) were firmer than those of the trees trained in the Y-Trellis system (18.00 N). Moreover, the trees planted at a spacing of 2 m produced firmer fruit (32.56 N) compared to other planting spacings (Table 5).

As can be seen in Table 6, in terms of physical quality criteria for the Open Vase and Central Leader training systems, only the differences between training systems

Table 5: Some physical quality properties of fruit of 'Monroe/GF 677' peach on Slender Spindle and Y-Trellis training systems

| Training System | Plant distance (m) | Width (mm) | | Length (mm) | | Weight (g) | | Firmness (N) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Slender Spindle** | 0.5 | 75.11 | 71.39 | 68.43 | 65.07 | 217.41 | 182.73 | 18.72 | 24.30 |
| | 1 | 75.74 | 73.44 | 69.56 | 66.98 | 228.29 | 201.41 | 16.85 | 20.26 |
| | 1.5 | 75.72 | 73.91 | 70.05 | 67.35 | 223.87 | 200.31 | 21.86 | 20.41 |
| | 2 | 77.11 | 75.40 | 72.96 | 68.97 | 242.57 | 217.51 | 40.78 | 17.25 |
| **Y-Trellis** | 0.5 | 76.75 | 74.44 | 68.99 | 67.21 | 236.13 | 203.62 | 16.41 | 23.43 |
| | 1 | 78.58 | 74.95 | 72.35 | 69.25 | 251.55 | 219.18 | 14.81 | 17.29 |
| | 1.5 | 76.04 | 73.12 | 70.12 | 67.00 | 223.62 | 195.29 | 16.45 | 19.73 |
| | 2 | 78.27 | 74.48 | 71.94 | 68.19 | 241.83 | 214.37 | 24.33 | 13.08 |
| **Training System Mean** | | | | | | | | | |
| **Slender Spindle** | | 75.92 | 73.54 | 70.25 | 67.09 | 228.04 | 200.49 | 24.55a* | 20.55 |
| **Y-Trellis** | | 77.41 | 74.25 | 70.85 | 67.91 | 238.28 | 208.12 | 18.00b | 18.38 |
| | Plant distance mean | | | | | | | | |
| | 0.5 | 75.93 | 72.91 | 68.71 | 66.14 | 226.77 | 193.17 | 17.57b* | 23.86 |
| | 1 | 77.16 | 74.20 | 70.95 | 68.11 | 239.92 | 210.30 | 15.83b | 18.78 |
| | 1.5 | 75.88 | 73.52 | 70.08 | 67.17 | 223.75 | 197.80 | 19.16b | 20.07 |
| | 2 | 77.69 | 74.94 | 72.45 | 68.58 | 242.20 | 215.94 | 32.56a | 15.16 |
| **P values** | | | | | | | | | |
| **Training System (TS)** | | 0.1425 | 0.2567 | 0.5368 | 0.3738 | 0.3074 | 0.2740 | 0.0066 | 0.3564 |
| **Plant distance (Pd)** | | 0.4711 | 0.1467 | 0.0838 | 0.2638 | 0.4586 | 0.1013 | 0.0002 | 0.1031 |
| **TS X Pd** | | 0.8241 | 0.0996 | 0.5618 | 0.5078 | 0.7410 | 0.4093 | 0.0846 | 0.9361 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

were found to be statistically significant ($p < 0.05$) for fruit flesh firmness in 2018. However, in 2019, the differences not only between training systems but also between planting spacings were significant for fruit width and fruit flesh firmness values. For fruit weight, only the differences between training systems were significant ($p < 0.05$). The Central Leader system stood out for fruit flesh firmness in both years. In 2019, both fruit width and fruit weight were higher in the Open Vase system (77.68 mm - 235.92 g). Moreover, the trees spaced at 2 m showed better results in terms of both fruit width (79.07 mm) and fruit flesh firmness (22.32 N) (Table 6).

### FRUIT COLOR (OBSERVATIONAL COLOR, L*, a*, b*, C*, H°)

Color measurements were made with the fruit of the trees trained in the Slender Spindle and Y-Trellis training systems. The interaction of training system and planting spacing was found to be statistically significant only in terms of observational color values in 2018 and in terms of C* values in 2019 (Table 7). Skin color of the fruit was observed, and it was concluded that in 2018 relative color value was higher in the fruit produced by the trees trained in the Slender Spindle system and planted at the spacings of 1 m and 1.5 m. Similar, but statistically insignificant differences were

Table 6: Some physical quality properties of fruit of 'Monroe/GF 677' peach on Open Vase and Central Leader training systems

| Training System | Plant distance (m) | Width (mm) | | Length (mm) | | Weight (g) | | Firmness (N) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Open Vase** | 1 | 76.96 | 75.78 | 70.17 | 68.32 | 240.21 | 218.87 | 15.76 | 14.12 |
| | 2 | 77.24 | 79.91 | 70.02 | 72.51 | 234.25 | 255.90 | 17.00 | 11.04 |
| | 3 | 76.52 | 77.57 | 68.87 | 69.71 | 225.72 | 238.02 | 17.53 | 8.76 |
| | 4 | 74.50 | 76.15 | 67.85 | 68.92 | 216.75 | 220.56 | 24.25 | 13.23 |
| | 5 | 78.85 | 79.01 | 71.09 | 70.29 | 254.07 | 246.27 | 19.13 | 15.76 |
| **Central Leader** | 1 | 76.52 | 75.76 | 69.24 | 68.67 | 239.14 | 211.89 | 23.45 | 21.37 |
| | 2 | 75.20 | 73.84 | 68.61 | 67.59 | 215.42 | 200.59 | 23.92 | 18.57 |
| | 3 | 75.72 | 75.88 | 69.26 | 68.05 | 225.73 | 217.64 | 21.36 | 12.49 |
| | 4 | 79.38 | 73.93 | 70.77 | 68.12 | 252.11 | 206.75 | 26.88 | 18.71 |
| | 5 | 79.30 | 79.12 | 73.08 | 71.35 | 266.18 | 245.40 | 20.48 | 28.88 |
| **Training System Mean** | | | | | | | | | |
| **Open Vase** | | 76.81 | 77.68a* | 69.60 | 69.95 | 234.20 | 235.92a* | 18.73b* | 12.58b* |
| **Central Leader** | | 77.22 | 75.71b | 70.19 | 68.76 | 239.72 | 216.45b | 23.22a | 20.00a |
| | Plant distance mean | | | | | | | | |
| | 1 | 76.74 | 75.77b* | 69.70 | 68.49 | 239.68 | 215.38 | 19.61 | 17.75ab* |
| | 2 | 76.22 | 76.88b | 69.31 | 70.05 | 224.84 | 228.25 | 20.46 | 14.81bc |
| | 3 | 76.12 | 76.73b | 69.07 | 68.88 | 225.72 | 227.83 | 19.45 | 10.63c |
| | 4 | 76.94 | 75.04b | 69.31 | 68.52 | 234.43 | 213.65 | 25.56 | 15.97bc |
| | 5 | 79.07 | 79.07a | 72.09 | 70.82 | 260.12 | 245.83 | 19.80 | 22.32a |
| **P values** | | | | | | | | | |
| **Training System (TS)** | | 0.6683 | 0.0075 | 0.5210 | 0.0887 | 0.5786 | 0.0126 | 0.0439 | 0.0007 |
| **Plant distance (Pd)** | | 0.3105 | 0.0129 | 0.2360 | 0.1444 | 0.1871 | 0.0634 | 0.3234 | 0.0120 |
| **TS X Pd** | | 0.2223 | 0.0508 | 0.5152 | 0.0821 | 0.5172 | 0.1643 | 0.8416 | 0.5693 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

found in 2019. In the same year, the highest C* value (39.27) was obtained from the planting spacing of 2 m in the Slender Spindle system and the lowest (34.62) from that of 2 m in the Y-Trellis system (Table 7). As a result of the analysis of variance conducted on observational color and L*, a*, b*, C*, h° values in the Open Vase and Central Leader training systems, it was found that only a* value was statistically significant between the training systems in 2019 and that the Open Vase system formed redder fruit (Table 8).

## SOME CHEMICAL ANALYSES (SSC, PH, TA)

In the fruit of the trees trained in the Slender Spindle and Y-Trellis training systems, SSC was statistically significant ($p < 0.05$) between planting spacings and pH between the interactions of training systems and planting spacings in 2018. In 2019, however, TA and pH traits were statistically significant ($p< 0.05$) only between training systems (Table 9). A higher SSC (14.98 %) was encountered in the fruit of the trees spaced at 2 m in 2018. In terms of TA, the Slender Spindle system stood out at the planting spacing of 2 m in 2018 (0.63 %) and at all planting spacings in 2019 (0.90 %). In both 2018 and 2019, the highest pH (3.63 % and 3.36 %) was obtained from the Y-Trellis system (Table 9). Given the fruit chemical traits (SSC, pH, TA) in the Open Vase and Central Leader training systems (Table 9), the differences between SSC amounts were statistically significant ($p < 0.05$) only in 2018. The Open Vase system had a higher SSC (14.65 %) than the Central Leader system (Table 10).

Table 7: Fruit color (observational color and L*, a*, b*, C*, h°) of 'Monroe/GF 677' peach on Slender Spindle and Y-Trellis training systems

| Training System | Plant distance (m) | Observational color (%) | | L | | a | | b | | C* | | h° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Slender Spindle** | 0.5 | 65.00b* | 68.33 | 37.37 | 44.62 | 29.44 | 28.88 | 17.62 | 22.80 | 34.72 | 37.38ab* | 29.59 | 36.92 |
| | 1 | 73.33a | 73.33 | 41.34 | 42.72 | 29.33 | 28.45 | 21.28 | 20.61 | 37.39 | 35.74bc | 33.73 | 34.56 |
| | 1.5 | 73.33a | 73.33 | 36.67 | 45.14 | 29.84 | 27.32 | 17.04 | 23.09 | 34.67 | 36.81a-c | 28.82 | 38.12 |
| | 2 | 61.67b | 66.67 | 39.18 | 44.01 | 30.23 | 30.98 | 21.07 | 23.24 | 37.66 | 39.27a | 33.53 | 35.50 |
| **Y-Trellis** | 0.5 | 66.67b | 66.67 | 40.15 | 45.81 | 29.08 | 26.82 | 19.46 | 24.06 | 35.34 | 37.48ab | 32.65 | 39.91 |
| | 1 | 63.33b | 71.67 | 37.93 | 43.11 | 31.64 | 29.53 | 19.04 | 21.22 | 37.25 | 36.78a-c | 29.93 | 34.30 |
| | 1.5 | 63.33b | 70.00 | 39.87 | 43.60 | 30.75 | 29.43 | 20.92 | 21.47 | 37.61 | 36.84a-c | 32.84 | 34.86 |
| | 2 | 63.33b | 71.67 | 40.33 | 42.09 | 29.54 | 27.81 | 20.13 | 19.65 | 36.22 | 34.62c | 32.83 | 33.32 |
| **Training System Mean** | | | | | | | | | | | | | |
| **Slender Spindle** | | 68.33a* | 70.4167 | 38.64 | 44.12 | 29.71 | 28.91 | 19.25 | 22.43 | 36.11 | 37.30 | 31.42 | 36.27 |
| **Y-Trellis** | | 64.16b | 70.0000 | 39.57 | 43.66 | 30.25 | 28.40 | 19.89 | 21.60 | 36.60 | 36.43 | 32.06 | 35.60 |
| | Plant distance mean | | | | | | | | | | | | |
| | 0.5 | 65.83ab* | 67.5000 | 38.76 | 45.21 | 29.26 | 27.85 | 18.54 | 23.43 | 35.03 | 37.43 | 31.12 | 38.42 |
| | 1 | 68.33a | 72.5000 | 39.64 | 42.91 | 30.48 | 28.99 | 20.16 | 20.92 | 37.32 | 36.26 | 31.83 | 34.43 |
| | 1.5 | 68.33a | 71.6667 | 38.27 | 44.37 | 30.30 | 28.37 | 18.98 | 22.28 | 36.14 | 36.83 | 30.83 | 36.49 |
| | 2 | 62.50b | 69.1667 | 39.76 | 43.05 | 29.89 | 29.40 | 20.60 | 21.45 | 36.94 | 36.94 | 33.18 | 34.41 |
| **P values** | | | | | | | | | | | | | |
| **Training System (TS)** | | 0.0072 | 0.7660 | 0.4969 | 0.5681 | 0.5408 | 0.5107 | 0.6992 | 0.2761 | 0.7413 | 0.1847 | 0.6947 | 0.5750 |
| **Plant distance (Pd)** | | 0.0233 | 0.0790 | 0.8342 | 0.1763 | 0.7639 | 0.5086 | 0.7790 | 0.1302 | 0.7059 | 0.6300 | 0.7383 | 0.0888 |
| **TS X Pd** | | 0.0058 | 0.1913 | 0.3140 | 0.4767 | 0.6152 | 0.0810 | 0.5454 | 0.1255 | 0.7625 | 0.0261 | 0.3305 | 0.2963 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

Table 8: Fruit color (observational color and L*, a*, b*, C*, h°) of 'Monroe/GF 677' peach on Open Vase and Central Leader training systems

| Training System | Plant distance (m) | Observational color (%) | | L | | a | | b | | C* | | h° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Open Vase** | 1 | 66.67 | 63.33 | 40.80 | 45.82 | 32.60 | 29.13 | 22.70 | 24.97 | 40.48 | 39.22 | 33.26 | 38.52 |
| | 2 | 65.00 | 65.00 | 33.99 | 41.14 | 29.02 | 29.21 | 14.75 | 19.83 | 32.71 | 35.87 | 26.38 | 32.32 |
| | 3 | 68.33 | 65.00 | 36.50 | 42.37 | 32.07 | 28.11 | 19.53 | 21.43 | 38.20 | 36.41 | 29.51 | 34.49 |
| | 4 | 75.00 | 68.33 | 36.77 | 40.81 | 32.63 | 28.06 | 18.44 | 19.77 | 37.77 | 35.26 | 28.42 | 33.02 |
| | 5 | 70.00 | 66.67 | 36.73 | 46.43 | 32.37 | 27.95 | 19.51 | 25.98 | 38.12 | 39.52 | 29.70 | 40.66 |
| **Central Leader** | 1 | 70.00 | 66.67 | 39.98 | 46.86 | 31.38 | 25.35 | 22.61 | 24.12 | 39.81 | 36.46 | 33.93 | 40.85 |
| | 2 | 70.00 | 70.00 | 38.20 | 47.45 | 32.94 | 25.75 | 20.58 | 25.60 | 39.26 | 38.02 | 30.96 | 41.63 |
| | 3 | 68.33 | 66.67 | 38.54 | 43.41 | 31.39 | 27.75 | 20.61 | 21.69 | 38.18 | 35.98 | 31.50 | 35.87 |
| | 4 | 65.00 | 65.00 | 39.55 | 45.01 | 30.51 | 27.55 | 21.18 | 23.06 | 37.82 | 36.77 | 32.67 | 37.37 |
| | 5 | 70.00 | 68.33 | 36.60 | 43.38 | 31.79 | 28.17 | 18.71 | 22.49 | 37.43 | 37.09 | 29.00 | 36.53 |
| **Training System Mean** | | | | | | | | | | | | | |
| **Open Vase** | | 69.00 | 65.67 | 36.96 | 43.32 | 31.74 | 28.49a* | 18.98 | 22.40 | 37.45 | 37.26 | 29.46 | 35.80 |
| **Central Leader** | | 68.67 | 67.33 | 38.58 | 45.22 | 31.60 | 26.92b | 20.74 | 23.39 | 38.50 | 36.86 | 31.61 | 38.45 |
| | Plant distance mean | | | | | | | | | | | | |
| | 1 | 68.33 | 65.00 | 40.39 | 46.34 | 31.99 | 27.24 | 22.65 | 24.55 | 40.15 | 37.84 | 33.60 | 39.69 |
| | 2 | 67.50 | 67.50 | 36.09 | 44.30 | 30.98 | 27.48 | 17.66 | 22.72 | 35.98 | 36.95 | 28.67 | 36.98 |
| | 3 | 68.33 | 65.83 | 37.52 | 42.89 | 31.73 | 27.93 | 20.07 | 21.56 | 38.19 | 36.20 | 30.50 | 35.18 |
| | 4 | 70.00 | 66.67 | 38.16 | 42.91 | 31.57 | 27.81 | 19.81 | 21.41 | 37.79 | 36.02 | 30.55 | 35.19 |
| | 5 | 70.00 | 67.50 | 36.67 | 44.91 | 32.08 | 28.06 | 19.11 | 24.23 | 37.77 | 38.30 | 29.35 | 38.60 |
| **P values** | | | | | | | | | | | | | |
| **Training System (TS)** | | 0.8670 | 0.3810 | 0.1930 | 0.08970 | 0.8380 | 0.0159 | 0.1710 | 0.3307 | 0.3480 | 0.5571 | 0.1190 | 0.0892 |
| **Plant distance (Pd)** | | 0.8990 | 0.8908 | 0.2300 | 0.2444 | 0.8480 | 0.9001 | 0.1830 | 0.1881 | 0.2440 | 0.1607 | 0.2050 | 0.2439 |
| **TS X Pd** | | 0.1800 | 0.6915 | 0.6650 | 0.1041 | 0.0820 | 0.1336 | 0.4710 | 0.0682 | 0.2090 | 0.0989 | 0.6690 | 0.1113 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

Table 9: Some chemical quality properties of fruit of 'Monroe/GF 677' peach on Slender Spindle and Y-Trellis training systems

| Training System | Plant distance (m) | SSC (%) | | TA (%) | | pH | |
|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Slender Spindle** | 0.5 | 13.83 | 15.23 | 0.45c* | 0.93 | 3.54 | 3.23 |
| | 1 | 14.23 | 15.13 | 0.54a-c | 1.00 | 3.66 | 3.20 |
| | 1.5 | 13.93 | 15.20 | 0.59ab | 0.90 | 3.60 | 3.31 |
| | 2 | 14.50 | 14.67 | 0.63a | 0.77 | 3.53 | 3.25 |
| **Y-Trellis** | 0.5 | 11.90 | 14.90 | 0.60ab | 0.87 | 3.60 | 3.32 |
| | 1 | 13.10 | 14.43 | 0.54a-c | 0.72 | 3.63 | 3.41 |
| | 1.5 | 14.60 | 15.03 | 0.49bc | 0.72 | 3.74 | 3.33 |
| | 2 | 15.47 | 13.93 | 0.57a-c | 0.68 | 3.56 | 3.39 |
| **Training System Mean** | | | | | | | |
| **Slender Spindle** | | 14.13 | 15.06 | 0.55 | 0.90a* | 3.58 | 3.25b* |
| **Y-Trellis** | | 13.77 | 14.58 | 0.55 | 0.75b | 3.63 | 3.36a |
| | Plant distance mean | | | | | | |
| | 0.5 | 12.87b* | 15.07 | 0.53 | 0.90 | 3.57 | 3.27 |
| | 1 | 13.67ab | 14.78 | 0.54 | 0.86 | 3.65 | 3.31 |
| | 1.5 | 14.27ab | 15.12 | 0.54 | 0.81 | 3.67 | 3.32 |
| | 2 | 14.98a | 14.30 | 0.60 | 0.73 | 3.55 | 3.32 |
| **P values** | | | | | | | |
| **Training System (TS)** | | 0.4740 | 0.0937 | 0.8601 | 0.0127 | 0.2059 | 0.0043 |
| **Plant distance (Pd)** | | 0.0476 | 0.1695 | 0.3280 | 0.1689 | 0.1020 | 0.7369 |
| **TS X Pd** | | 0.1505 | 0.8475 | 0.0321 | 0.4828 | 0.4868 | 0.2542 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

Table 10: Some chemical quality properties of fruit of 'Monroe/GF 677' peach on Open Vase and Central Leader training systems

| Training System | Plant distance (m) | SSC (%) | | TA (%) | | pH | |
|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Open Vase** | 1 | 14.03 | 12.80 | 0.42 | 0.65 | 3.56 | 3.65 |
| | 2 | 14.87 | 13.97 | 0.42 | 0.72 | 3.68 | 3.39 |
| | 3 | 14.90 | 13.47 | 0.42 | 0.67 | 3.67 | 3.43 |
| | 4 | 14.40 | 12.57 | 0.51 | 0.70 | 3.62 | 3.39 |
| | 5 | 15.07 | 12.97 | 0.44 | 0.85 | 3.53 | 3.44 |
| **Central Leader** | 1 | 14.10 | 12.57 | 0.47 | 0.72 | 3.55 | 3.39 |
| | 2 | 13.83 | 14.67 | 0.44 | 0.78 | 3.59 | 3.56 |
| | 3 | 14.40 | 12.07 | 0.46 | 0.67 | 3.63 | 3.34 |
| | 4 | 13.73 | 14.50 | 0.49 | 0.70 | 3.51 | 3.35 |
| | 5 | 14.53 | 14.90 | 0.40 | 0.85 | 3.58 | 3.24 |
| **Training System Mean** | | | | | | | |
| **Open Vase** | | 14.65a* | 13.15 | 0.44 | 0.72 | 3.61 | 3.46 |
| **Central Leader** | | 14.12b | 13.74 | 0.46 | 0.74 | 3.57 | 3.38 |
| | Plant distance mean | | | | | | |
| | 1 | 14.07 | 12.68 | 0.44 | 0.68 | 3.56 | 3.52 |
| | 2 | 14.35 | 14.32 | 0.43 | 0.75 | 3.64 | 3.48 |
| | 3 | 14.65 | 12.77 | 0.44 | 0.67 | 3.65 | 3.39 |
| | 4 | 14.07 | 13.53 | 0.50 | 0.70 | 3.56 | 3.37 |
| | 5 | 14.80 | 13.93 | 0.42 | 0.85 | 3.56 | 3.34 |
| **P values** | | | | | | | |
| **Training System (TS)** | | 0.0292 | 0.3121 | 0.6596 | 0.5707 | 0.3526 | 0.2183 |
| **Plant distance (Pd)** | | 0.1805 | 0.3124 | 0.2098 | 0.1297 | 0.3734 | 0.4207 |
| **TS X Pd** | | 0.6536 | 0.3083 | 0.6270 | 0.9715 | 0.7226 | 0.3197 |

* In each column, values followed by the same letter are not significantly different at P < 0.05 level according to Duncan's multiple range test.

## DISCUSSION

In fruit growing, it is of great importance to organize tree training and pruning as well as orchard establishment in the most proper way possible for obtaining not only early and high yield but also high-quality products. In this study, it was concluded that training systems and planting spacings had a significant impact on early yield, abundant and high-quality products. The effects of training systems and planting spacings on growth and development were investigated, and it was determined that important differentiations took place. Compared to the Y-Trellis system (274.58 cm), the Slender Spindle system (316.88 cm) formed higher trees. Since the Y-Trellis system consists of two primary branches at a certain angle (80 to 100°) on opposite sides, height is thought to be under more control in this training system compared to the Slender Spindle system. In the Slender Spindle system, upper parts of the trees were laid down onto the wire over 3 m at the time of summer pruning. For this reason, it is concluded that tree height usually remained around 3 m. Some sources (Loreti and Pisani, 1992; Dejong et al., 1994; Rom and Blackburn, 1998; Rom et al., 1999; Rom, 2000; Rom, 2002) report that there are training systems which resemble the Y-Trellis system, like Tatura Trellis and Perpendicular V, and the Slender Spindle system, like Fusetto. The findings obtained in the scope of this study are in compliance with the said sources, showing that necessary measures have been done regarding training systems.

The lowest tree width (140.00 cm) was obtained from the trees spaced at 0.5 m on the row and trained to the Slender Spindle system. As a matter of course, tree width increased in direct proportion to intra-row spacing. Increasing planting density restricted tree growth; performing summer pruning in earlier years led to a decrease in tree width. The trees planted at a spacing of 2 m were observed to have thicker trunks. It is clearly seen from trunk diameters that tree development was restricted with increasing planting density. The Central Leader and Open Vase training systems were compared in terms of tree development, and the Central Leader system was found to have formed much higher trees than the Open Vase system. Overall, of all training systems subject to this study, the Slender Spindle and Central Leader training systems, which possessed a leader, formed higher trees, and the Slender Spindle system had the narrowest canopy, while the Y-Trellis system the widest. However, in the Y-Trellis system, the canopy widened only towards the inter-row direction; growth in the intra-row direction was not allowed. The lateral branches at the intra-row spacing were thinned in the shape of fish bone and allowed to develop on each main secondary branch with a spacing of 10 to 15 cm. On the other hand, the primary branches that had grown on bamboos in the inter-row direction were allowed not to develop outside the support system as from the 4$^{th}$ year but to bear fruit in this way in the following years. With regard to tree trunk diameters and areas, the freestanding Open Vase and Central Leader training systems constituted thicker trunks as a result of wider planting spacings. As a matter of fact, there are several studies (Loreti and Pisani, 1992; Furukawa, 2000; Layne et al., 2002; Robinson, 2007; Platon, 2007) stating that planting density is one of the key factors for trunk cross-section.

Cumulative yield per tree was between 41.49 and 99.08 kg/tree in the Slender Spindle system, 42.42 and 97.82 kg/tree in the Y-Trellis system, 60.44 and 119.44 kg/tree in the Central Leader system, and 41.83 and 77.97 kg/tree in the Open Vase system. As is seen, the Central Leader system ranked first, whereas the Open Vase system was the last. Cumulative yield per hectare was found to be between 99.08 and 165.97 trees/ha in the Slender Spindle system, 97.83 and 169.68 trees/ha in the Y-Trellis system, 47.77 and 120.88 trees/ha in the Central Leader system, and 31.19 and 83.66 trees/ha in the Open Vase system. Yield increased in direct proportion to planting density. Training systems have a great impact on yield increase. In this case, the cumulative yield per hectare obtained from the trees planted at the spacings of 1 and 2 m was respectively ~ 84 and 60 tons in the Open Vase system, ~ 121 and 98 tons in the Central Leader system, ~ 141 and 99 tons in the Slender Spindle system, and ~148 and 98 tons in the Y-Trellis system. As can be seen, the Central Leader and Y-Trellis training systems reached similar yield values on the same intra-row planting spacing. Even if the orchard was estab-

lished with the same number of trees, the importance of training systems stands out quite clearly. Just like other studies (Dejong et al., 1992; Furukawa et al., 1992; Barone et al., 1995; Loreti and Pisani, 1992; Furukawa, 2000; Layne et al., 2002; Öztürk et al., 2009; Pasa et al., 2017; Souza et al., 2019), the present study reveals that laying its branches down onto the wires in the early period enables the tree to proceed to the generative phase faster and also may have positive effects on earlier productivity . In the supported Slender Spindle and Y-Trellis training systems, the summer pruning performed in the year following the year of planting enabled the trees to bear earlier and more fruit and allowed for a balance between tree age and fruit production. Thus, this study proved a substantial increase in yield as of the 3rd year.

Given all training systems and planting densities, similar results were attained for fruit width, fruit length, fruit weight and fruit flesh firmness. Numerous studies (Bargioni et al., 1983; Horton, 1985; Furukawa et al., 1992; Dejong et al., 1992; Barone et al., 1995; Hoying et al., 2005) report that both supported training systems and the training systems with lower canopy volume like Central Leader, Fusetto, Perpendicular-V, etc. bear heavier fruit than the training systems with higher canopy volume like Open Vase, etc.

Souza et al. (2019) in their study on the 2-scaffold and 4-scaffold training systems with the peach cultivar 'BRS Rubimel' determined that the 2-scaffold training system gave higher cumulative yield without any loss of fruit quality. In line with their study, the present study showed that quality parameters like fruit weight and fruit flesh firmness were not adversely affected and 1st grade fruit were produced. All of the training systems and planting spacings gave very close results for fruit color values in L*, a*, b*, C* and h° in both years. Fruit color, which is an essential quality parameter especially in peaches, did not suffer any loss of quality with changing training systems or increasing planting spacings. Differences between fruit color values were observed based on fruit skin color, and the trees planted at planting spacings of 1 and 1.5 m and trained in the Slender Spindle system stood out with fruit skin color formation. Other similar studies also reported the absence of quality loss, and some studies (Barone et al., 1995; Hoying et al., 2005) even reported to have obtained redder fruit in the training systems with lower canopy volume. No major differences were detected in the chemical traits (SSC, pH, TA) of fruit between training systems and planting spacings, but, in 2018, SSC increased as the planting density decreased in the supported training systems and a higher SSC was obtained from the Open Vase system. Lack of significant differences in fruit quality traits indicates that, generally speaking, training systems and planting spacings have a consistent effect in this respect; in the peach cultivar 'Monroe', none of the treatments had an adverse effect on fruit quality.

## CONCLUSION

In conclusion, as a result of the analyses based on training systems, the highest cumulative yield per hectare was obtained from the Y-Trellis system, followed by the Slender Spindle, Central Leader and Open Vase systems. As a result of the analyses based on planting densities, 0.5 m and 1 m stood out with cumulative yield because of having more saplings. Yield per unit area increased in parallel with the increase in planting density, which resulted from obtaining higher yield in the early years especially in denser planting applications. Furthermore, compared to other training systems, supported training systems led to an increase in yield without reducing fruit quality. The planting density of 0.5 m resulted in higher yield (t/ha) but made orchard management more difficult. All in all, it is suggested to grow 'Monroe' on the GF 677 rootstock using the Y-Trellis and Slender Spindle training systems and a planting spacing of 1 m in terms of both cumulative yield and applicability without any adverse effects on fruit quality.

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