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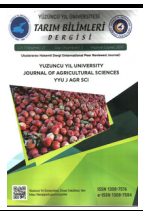

Research Article

The Effect of The Different Training Systems on Yield and Vegetative Growth of "Santa Maria" and "Deveci" Pear Cultivars

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Abstract: The study was conducted between 2012-2014 in order to determine the effects of the training systems on "Deveci" and "Santa Maria" cultivars grafted on Quince A rootstock. The effect of the training system on the TCSA and canopy volume values of the trees was significant, but there were differences in the effect depending on the cultivar. The trees, which had a thicker trunk, were obtained with Y Palmette in Santa Maria cultivar and Vertical Axis in Deveci cultivar. The yield values changed depending on the training system and cultivar. It has been determined that the trees treated in Vertical Axis and Y Palmette training systems have a higher yield. It can be said that the Deveci cultivar had a relatively higher yield. Deveci cultivar had larger fruit, and the effect of the training system varied depending on the cultivar. In Santa Maria cultivar, the fruit of the trees on which the One Arm Cordon training system was bigger. In Deveci cultivar, the larger fruit was harvested from the trees on which One Arm Cordon and Vertical Axis training systems. As a result, the training systems have been influential in the vegetative growth and yield of the trees.

Santa Maria" and "Deveci" Armut Çeşitlerinin Vejatatif Gelişimi ve Meyve Verimi Üzerine Farklı Terbiye Sistemlerinin Etkisi

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Anahtar kelimeler

Meyve büyüklüğü,
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Vertical axis.

Öz: Çalışma, Quince A üzerine aşılanmış "Deveci" ve "Santa Maria" çeşitlerinde farklı terbiye sistemlerinin etkisini belirlemek amacıyla 2012- 2014 yılları arasında yürütüldü. Ağaçlarda TCSA ve taç hacmi değerlerinde terbiye sisteminin etkisi önemliydi, ancak çeşide bağlı olarak etkide farklılıklar meydana geldi. Santa Maria çeşidinde Y Palmette, Deveci çeşidinde ise Vertical Axis terbiye sistemi ile daha kalın gövdeli ağaçlar elde edildi. Uygulanan terbiye sistemine ve çeşide bağlı olarak meyve verimi değerleri değişti. Vertical Axis ve Y Palmette uygulaması ile ağaçların daha verimli oldukları belirlendi. Deveci çeşidinin nispeten daha verimli olduğu söylenebilir. Deveci çeşidi daha büyük meyvelere sahipti ve terbiye sisteminin etkisi çeşide bağlı olarak değişiklik gösterdi. Santa Maria çeşidinde One Arm Cordon terbiye sistemi uygulanmış ağaçların meyveleri daha büyütü. Deveci çeşidinde ise One Arm Cordon ve Vertical Axis terbiye sistemleri uygulanmış ağaçlarda daha büyük meyveler hasat edildi. Sonuç olarak, terbiye sistemleri ağaçların vejetatif gelişiminde ve meyve veriminde etkili oldu.

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1. Introduction

The upright and strong tree growth in pear cultivation is one of the most significant problems affecting light interception, thus the efficiency and quality, and complicating cultural practices such as pruning and disease control. In this sense, the controlling tree size in pear will increase yield and quality in fruit by increasing light efficiency and reducing competition for the sink materials in the tree (Wang et al., 2014). The changes in light intensity in the tree cause differences in the rate of photosynthesis by affecting stomatal conductance (Baïram et al., 2019) and some non-stomatal parameters (Lin et al., 2020), and thus affect the fruit quality (Du, 2018).

The rootstock and pruning are the two most significant factors in controlling the vigorous growth of the tree and increasing the light efficiency. The main reason why quince rootstocks are preferred in pear cultivation (Mitcham and Etkins, 2007), which form smaller trees compared to clonal pear rootstocks, provide precocity and increase yield and quality in fruit, is from this situation. Pruning regulates canopy structure and nutrient distribution in fruit trees and can also increase photosynthesis and fruit yield. It has been demonstrated in many studies that light interception and distribution, which has an important efficiency in fruit yield and quality, increased as a result of pruning practices (Wang et al., 2019).

The training system is a method used to regulate tree planting and canopy formation to improve light interception and distribution to maximize fruit yield and quality (Lordan et al., 2018). The main goal of the training system in pear trees is to direct tree growth and develop a strong tree structure that will support quality fruit production. For this goal, many training systems have been developed, although it varies depending on the planting density in the pear.

The main goal in these training systems is to contribute to the maximum light interception and distribution of the tree by keeping the tree size at the desired level and thus increasing the yield and quality of the fruit. The effect of the training systems on pear growth vigor, yield, and quality has been demonstrated in many studies.

The aim of this study is to determine the effect of Vertical Ax, One Arm Cordon, and Y Palmette training systems on "Deveci" and "Santa Maria" cultivars grafted on Quince A and widely used in pear production in Turkey.

2. Materials and Methods

2.1. Plant Material

The study was conducted in the orchard of Tokat Gaziosmanpaşa University, Faculty of Agriculture, between 2012-2014 years. In the study, the pear trees planted with 3.5 x 1 m planting density of Santa Maria and Deveci cultivars grafted on Quince A rootstock and treated with Vertical Axis, One Arm Cordon, and Y Palmette were used as plant material. The trees was irrigated with a drip irrigation system, and fertigated with 30 g of 20-20-20 N-P-K per tree per year. Fruits were hand-thinned after June drop to a spacing of 15 cm. The details of the measurements and analyzes made in the study are presented below.

2.2. Trunk Cross-Sectional Area (TCSA)

The trunk diameter was measured 15 cm above the graft union with a digital caliper with a sensitivity of 0.01 mm. The trunk cross-sectional area was calculated by using the formula $TCSA = \pi r^2$.

2.3. Canopy Volume

Two measurements were taken of the north-south and east-west directions in the middle of the tree canopy, and the canopy width (R, diameter) was determined by calculating the average of these two values. Then, the distance between the point where the lowest branch was formed and the top of the canopy was measured, and the canopy height (h) was determined in meters. Canopy volume was calculated using the formula $V = \pi r^2 h / 2$ and expressed in m^3.

2.4. Yield

Yield from each tree were weighed in each year (2012, 2013, and 2014) to find out the yield per tree, and these values were then summed to find out the cumulative yield (kg tree^{-1}). Yield per tree was multiplied by the number of trees per decare to find out the yield per decare (t da^{-1}), and these values were then summed to find out the total yield per decare (t da^{-1}).

2.5. Yield Efficiency

The yield efficiency (yield TCA^{-1}) was calculated as the ratio of yield per tree of the years 2012, 2013, and 2014 to trunk cross-sectional areas.

2.6. Fruit Weight

The weight of 20 fruit harvested randomly from each tree were measured by digital scales (Radwag, Poland) with a sensitivity of 0.01 g and average fruit weight calculated.

2.7. Statistical analyses

The trial was established in split plot design with four replications. After the data obtained were analyzed with analysis of variance, the level of the significance between the treatments was determined by the Tukey multiple comparison test. Statistical analysis was performed using the SAS package program (SAS 9.1 version, USA). The significance level was considered as $\alpha = 5\%$ in statistical analysis and interpretation of the results.

3. Results and Discussion

3.1. Vegetative Growth

The combination of the rootstock, cultivar, and training system has a significant effect on the control of the tree size in pear, which forms large trees with vertical and strong tree growth. The training system is a method used to regulate vegetative growth in trees to improve light interception and distribution in order to maximize fruit yield and quality (Lordan et al., 2018).

In the study, the effect of the training system on TCSA and canopy volume values, which are the important criteria of the vegetative development in trees, were significant, but the differences occurred in effect depending on the cultivar. When the TCSA values were examined and the last year of the study was taken into account, it was determined that the trees with Y Palmet in Santa Maria cultivar formed thicker trunks. The trees had the lowest TCSA value with the One Arm Cordon training system. In the Deveci cultivar, there were no significant differences between the trunk thickness of the trees with Y Palmette and One Arm Cordon training systems while Vertical Axis training system occurred trees with a thicker trunk. Considering these results, it can be said that the effect of the cultivar on the TCSA value of the trees is significant.

The training systems were effective in the canopy volume while it was observed that there was no cultivar effect. Because the trees with the largest trunk in both cultivars were obtained with Vertical Axis training system while it was determined that the trees with One Arm Cordon training system formed smaller canopy (Table 1). The results of the study can be explained by the contribution of the training system to the regulation of the tree structure, size and canopy volume (Wunsche and Lakso, 2000).

Table 1. Effects of the training systems on trunk cross-sectional area (TCSA) and canopy volume of Santa Maria and Deveci pear cultivars

Cultivar	Training system	TCSA (cm^2)			Canopy volume (m^3)
		2012	2013	2014	2014
Santa Maria	Vertical Axis	2.55±0.14[a]	4.28±0.22[a]	5.86±0.32[b]	2.00±0.12[a]
	One Arm Cordon	1.63±0.09[b]	2.74±0.15[b]	3.58±0.22[c]	0.71±0.05[c]
	Y Palmette	2.68±0.13[a]	4.86±0.24[a]	8.29±0.45[a]	1.70±0.09[b]
Deveci	Vertical Axis	2.77±0.17[b]	4.28±0.23[a]	8.96±0.48[a]	1.86±0.14[a]
	One Arm Cordon	3.40±0.22[a]	4.55±0.32[a]	7.99±0.39[b]	0.67±0.07[c]
	Y Palmette	2.60±0.16[b]	4.71±0.29[a]	7.71±0.41[b]	1.55±0.11[b]

Means indicated with the same lower-case letter in the same columns do not differ according to Tukey's test at P<0.05.

3.2. Fruit Set and Size

In the study, it can be said that the increase in the yield values per tree depending on the years, the trees do not reach the full yield age, and the low yield is due to this situation. Yield values changed depending on the training system. While the lowest values for both cultivars in terms of yield and yield efficiency per tree were recorded in the trees treated with One Arm Cordon training system, it was determined that the trees were more efficient with the Vertical Axis and Y Palmette training systems. Although it was not revealed statistically in the study, it can be said that Deveci cultivar is relatively more efficient (Table 2). Musacchi et al. (2011), who reported that there were differences in yield depending upon the training system on the pear, suggested that the efficiency is higher with Vertical Axis training system, in line with our study results.

The differences in fruit yield and size depending on the training systems treated to the trees can be explained by the effect of the training systems on the light interception in the canopy. Anthony et al. (2020) reported that the light interception and distribution within the canopy differed with the different training systems, while Corelli-Grappadelli and Lakso (2007) revealed that the training system could affect the development, position, and angle of the branches and thus the light interception, which has an effect on fruit yield and quality. The changes in light intensity in the tree cause differences in the rate of photosynthesis by affecting stomatal conductance (Baïram et al., 2019) and some non-stomatal parameters (Sun et al., 2018; Xie et al., 2018), and thus affect the fruit quality (Ran et al., 2012; Jajo et al., 2014).

Table 2. Effects of the training systems on yield of Santa Maria and Deveci pear cultivars

Cultivar	Training system	Yield (kg $tree^{-1}$)			Cumulative yield (kg $tree^{-1}$)	Yield efficiency (kg cm^{-2})
		2012	2013	2014	2014	2014
Santa Maria	Vertical Axis	2.30±0.25[a]	5.05±0.22[a]	7.60±0.32[a]	14.95±0.54[a]	2.97±0.12[a]
	One Arm Cordon	1.75±0.18[b]	2.50±0.12[c]	3.80±0.14[c]	8.05±0.32[b]	2.22±0.09[b]
	Y Palmette	2.26±0.17[a]	4.71±0.15[a]	6.71±0.23[b]	13.68±0.35[a]	2.88±0.10[a]
Deveci	Vertical Axis	2.02±0.16[a]	6.07±0.25[a]	8.68±0.33[a]	16.77±0.52[a]	3.01±0.17[a]
	One Arm Cordon	1.90±0.13[c]	3.10±0.11[c]	4.16±0.21[c]	9.16±0.25[b]	2.43±0.11[b]
	Y Palmette	2.87±0.20[a]	5.02±0.15[b]	7.42±0.29[b]	15.31±0.31[a]	2.96±0.14[a]

Means indicated with the same lower-case letter in the same columns do not differ according to Tukey's test at P<0.05.

In the study, there were no differences in fruit size depending on the year, while the effect of the training system was significant. Deveci cultivar had larger fruit, and the effect of the training system varied depending on the cultivar. The effect of the training system was not observed in the last year of the study in Santa Maria cultivar, while in other years, it was found that the fruit of the trees with One Arm Cordon training system were larger, and there were no significant differences between the other

two training systems. In Deveci cultivar, the training system created the differences in fruit size along with the study. In terms of fruit size in this cultivar, the larger fruit was harvested from trees with One Arm Cordon and Vertical Axis training systems, while it was determined that the trees occurred relatively smaller fruit with Y Palmette training system (Table 3). As a matter of fact, many studies have shown that light interception and distribution, which has a significant effect on fruit size, increase as a result of pruning practices (Jung and Choi, 2010; Zhao et al., 2018).

As a result, the training system has been effective in the vegetative development of the trees and yield. One Arm Cordon training system can be treated to control vegetative development. Vertical axis and One Arm Cordon training systems can be recommended for fruit yield.

Table 3. Effects of the training systems on fruit mass of Santa Maria and Deveci pear cultivars

Cultivar	Training system	Fruit mass (g)		
		2012	2013	2014
Santa Maria	Vertical Axis	217±5.00^{b}	218±4.98^{b}	222±4.99^{a}
	One Arm Cordon	230±5.20^{a}	231±5.01^{a}	225±5.03^{a}
	Y Palmette	216±5.12^{b}	211±4.42^{b}	216±4.88^{a}
Deveci	Vertical Axis	277±5.33^{a}	274±5.23^{a}	278±5.21^{a}
	One Arm Cordon	272±5.28^{a}	270±5.21^{ab}	276±5.07^{ab}
	Y Palmette	259±5.31^{b}	263±5.18^{b}	268±4.99^{b}

Means indicated with the same lower-case letter in the same columns do not differ according to Tukey's test at $P<0.05$.

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