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Araştırma Makalesi / Research Article

Effects of Canopy Position on Fruit Quality of Kiwifruit (cv. Hayward)

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Abstract
This study investigated the effect of fruit-bearing orientation of the Actinidia deliciosa 'Hayward' (kiwifruit) on fruit quality. Plant age and canopy position significantly affected the physico-chemical properties of kiwifruit. Fruit length, thickness and weight was increased on the branches in the south and east side of vine. Southern fruits were in the most exposed canopy orientation and had higher soluble solid content and more dry matter than those associated with other canopy orientations. We conclude that fruit-bearing orientation affects fruit quality via the canopy effect. It was suggested to collect the fruits separately according to their orientation. Result is valuable for improving the post-harvest quality and harvesting criteria of fruits.

Keywords: *Actinidia deliciosa*; bearing direction; fruit quality; firmness; soluble solid content

1. Introduction

The kiwifruit (Ac*tinidia deliciosa*) belonging to the family Actinidiaceae, is a woody climber found growing in the tropical and subtropical regions. It has become one of the high commercial valuable fruits in recent years. It is widely grown in countries that have favorable ecological conditions, namely, Italy, France, Chile, Italy, Turkey, etc. At present, Hayward is the most planted kiwifruit species in the world because of consistency in fruit quality (Garcia et al., 2012). Hayward is planted in many countries due to its high commercial value because of high productivity, greater weight and higher content of soluble solids compared with other cultivars (Burdon et al., 2004; Ferguson and Seal, 2008; Li et al., 2021). Kiwifruit is a useful source of antioxidant components, such as ascorbic acid and polyphenolic, which exert protective effects against various degenerative diseases (Beck et al., 2011, Giovanelli et al., 2014). It has a high nutritional value as a rich resource of potassium, vitamin E, and folic acid (Huang and Ferguson, 2003). The fibrous structure of kiwifruit prevents heart disease, increases water retention in the intestine, improves the digestive health, and has a positive effect on diabetes (Richardson et al., 2018). Canopy microclimate especially light intensity affected fruit yield and quality most. Light has been regarded as the principal energy source and one of the most important environmental factors (Dong et al., 2014). Fruit development primarily depends on the illumination intensity (Jackson, 1989; Gonzalez-Talice et al., 2013). Light from the south had a comparatively higher intensity, while it was relatively lower from the north, mainly because the branches and leaves on the southern part of the canopy shaded the light from the north. The fruit quality distributions within the different side of canopy were quite different. The canopy microclimate is a specific plant growth environment and climatical factors such as temperature and light are changed with fruit orientation that one of the most principal factors affecting the quality and quantity of fruits (Asrey et al., 2007; Pandey et al., 2007). The amount of soluble solid content in fruits has a major influence the consumer buying decision and varies with the fruit position on canopy (Lu, 2004; Peng, Lu, 2007). The fruit yield and quality mainly depend on the response to light by a tree with a certain canopy structure (Miller et al., 2001; Lechaudel et al., 2013; Shiukhy et al., 2014). Orchard design, row orientation and pruning system has been studied to find the ideal solution for irradiance effects for kiwi vines (Miller et al., 2001; Bostan and Günay, 2014; Hopkirk et al., 1986). Row orientation influences on fruit quality were confirmed (Hopkirk et al., 1986; Maldera et al., 2021). Some of the results showed that row orientation effected fruit quality and amount (Tous et al., 2014; Gomez-del-Campo et al., 2009; Hunter et al., 2017), while others did not find any significant differences between exposures in orchards with row oriented N-S and E-W (Maldera et al., 2021; Trentacoste et al., 2015). Very few studies have dealt with the row orientation and altitude effects together (Bak et al., 2014). Effects of canopy orientation has not studied for kiwi vines before; and there are limited studies on the effects of branch facing in the literature. The position of a kiwifruit in the canopy figures out its external and internal quality due to microclimatic variation within the canopy. Even within a single fruit the soluble solids concentration is changed in different direction of fruit, with a higher value on east and north side (Hopkirk et al., 1986). A certain canopy position could be needed to obtain the proper fruit growth. Kiwifruits from different side of the vine canopy belonged to different populations and need to particular care for healthy storage period. At the time of commercial harvest, producer collects all fruit in a one harvesting time without classifieds. Hence, commercial cultivation of kiwifruit involves segregation of fruits harvested from various parts of the vine. As a result of innovative technologies, specific picking of fruits could be possible. Therefore, the aim of this study was to find the effects of fruit-bearing orientation and age of the vine on the quality of kiwifruit. By this study, explain the quality differences of different oriented fruits and effective evaluation for yields will be possible.

2. Materials and Methods

2.1. Plant material and study area

The study was carried in 2018, in an indoor commercial kiwi orchard, which belongs to the Kocaeli Provincial Directorate of Agriculture and Forestry, Turkey. Mature kiwi vines (cv Hayward) at 12- and 25-year-old were used in this trial. The pollinator was Matua cultivar and the ratio of female to male plants was 8:1; the male kiwi vines were arranged in rows. Vines were planted at intervals of 4 × 4 m, and a T-wire training system was applied. The orchard is in zone 35, the middle meridian of 27 zones in a 6-degree (35°27.6′ N) coordinate system, located 2.8 km away from the sea at an altitude of 6 m. The terrain is essentially completely level, with only a slight southeast–northeast slope of 0.37%. The soil type is low calcareous and clay-loamy structure with 7.7 pH value; however, the soil is deficient in organic matter. The annual average temperature is 14.8 °C; the lowest and highest temperatures of 1.7 and 31.0 °C were recorded in January and July in the year 2018, respectively. The average summer temperature is approximately 30 °C. Annual rainfall was 668.8 mm in 2018; an extremely low precipitation was recorded in August and September (8.4 and 5.2 mm, respectively). The average relative humidity was 79.2% and the lowest precipitation occurred in August and April (13.4 and 15 mm, respectively), while the highest precipitation occurred in May (215.2 mm) (Figure 1).

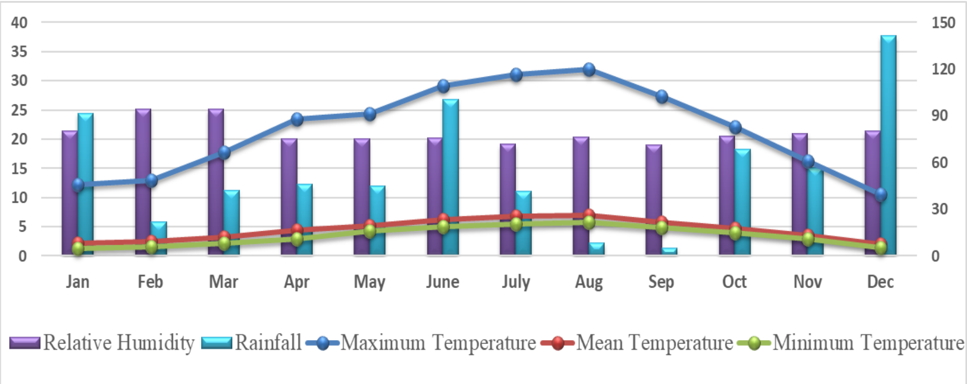

Figure 1. Climate Parameters of the kiwi orchard in 2018

2.2. Method

In March 2018, before flowering, twelve Hayward kiwi vines (six 25- and 12-year-old each) were selected in the garden. In each vine, one branches of each orientation (north, south, east and west) were selected and marked. Harvest time was determined according to kiwifruit harvesting criteria (Guroo et al., 2017). 10 fruit samples from each selected branch were separately picked at different orientations (North, South, East and West) of vine. All harvested fruits were directly transported to the laboratory. Physical and chemical analyses were performed within 24 h to find the effects of canopy orientation and vine age.

Physical measurement of the fruit

Fruit weight measurements (g) were taken on a digital scale (Desis H2C-30) with an accuracy of 1 g. Length (mm), width (mm), thickness (mm) was measured using a digital caliper (Mitutoyo 500-182-30, Japan) with an accuracy of 0.01 mm. Fruit firmness measurements were made using a 7.9-mm tip with a Tartes hand-held penetrometer 02 (İzmir, Turkey).

Chemical analysis of the fruit

The pH, soluble solid contents (SSC) and titratable acidity (TA) were measured using kiwifruit juice extracted from each sample. For SSC, a few drops of juice from three replicates were dripped onto the measurement point on an Atago digital handheld refractometer (Atago Co. Ld., Japan) at 20 °C and given as percent value (%). The pH and TA were measured potentiometrically using a pH meter (Hanna, HI 2020 Edge). pH measurements were made directly using the kiwifruit juice, while 10 mL of pure water was added to 10 mL of juice for TA measurement. The tip of the pH meter was immersed in the resulting mixture and titrated by adding 0.1 N NaOH until the pH reached 7.8–8.2.

The TA was calculated using the formula:

$$TA\ (\%) = NaOH\ (\text{spend amount}) \times N \times F \times E \times 100$$

TA: citric acid per 100 mL juice
N: normality of sodium hydroxide
F: the sodium hydroxide factor used
E: equivalent value of citric acid

To figure out the amount of dry matter, fruit samples cut into small pieces, weighed, and placed in a Pedri dishes. The samples were dried for 17–20 h at 70 °C until a constant weight was reached. Dry matter content (DMC) was calculated as the ratio of dry to fresh mass and expressed as percentage.

2.3. Statistical analyses

The experiment was set up in a randomized block design with three replicates with two branches in each direction. Statistical evaluations of the results were performed using analysis of variance with Minitab version 13.0 (S0064 Minitab Release 13, License No: wcp 1331.00197). Minitab means were separated using the Tukey's test with a *p* value less than 0.05. Angle transformation was used for percentage findings.

3. Results

3.1. Effect of fruit canopy orientation on fruit quality parameters

Fruit weight was significantly affected by canopy orientation and the heaviest fruits were taken from the south side of the canopy (Table 1). Fruit wide and length was significantly higher (50.39 mm and 70.46 mm respectively) of the south oriented fruits compared to the other orientation. Fruit thickness was increased in east oriented fruits, but it was not statistically different from south oriented fruits. A south-facing side can be light-saturated, while the north-facing side of the vine is still limited by light, resulting in unequal fruit quality. Titratable acidity and fruit pH was increased in north orientation while the other orientation obtained similar values for these parameters. Titratable acidity generally declined as sunlight exposure increased as with Cabernet Sauvignon (Bergqvist et al., 2001), clusters on the north side of the canopy keeping greater acidity at the same exposure level than clusters on the south. Juice pH declined as exposure increased on the north side of the canopy, while sunlight had insignificant effect on juice pH for clusters on the south. The highest dry matter was recorded in fruits harvested from the south orientation and this was statistically important. No significant differences were found for pH of fruit between the orientation for 25 years old kiwi vines. In general aspects, fruit set is heavier on the south and east side of the 25 years old vines (Figure 2).

Table 1. Fruit quality parameters of 25 years old kiwi vines recorded at different orientation.

	Fruit Weight (g)	Fruit Wide (mm)	Fruit Thickness (mm)	Fruit length (mm)	Fruit Firmness (kg cm^{-2})	TA (%)	SSC (%)	pH^{ns}	DMC (%)
South	93.84a	50.39a	49.33ab	70.46a	4.03b	1.64c	10.23a	3.07	16.23a
North	79.70b	44.56b	44.22c	66.14b	7.51a	1.78a	9.82ab	3.20	14.82b
East	81.25b	46.90ab	51.35a	67.23b	5.37b	1.62c	9.66b	3.12	14.60b
West	85.91b	45.23b	47.43bc	66.55b	4.39b	1.70b	9.48b	3.15	14.55b

* The letters show statistical differences between values in each column (P≤0.05); ns (not significant)

Figure 2. Fruits on different orientation of 25 years old vine canopy.

12 years old kiwi vines fruits were the heavier on the South orientation than other orientation like as 25 years old vines. Fruits width of the east side of vine significantly bigger than on north side fruits while fruit length was significantly longer on the south oriented fruits. No significant differences were found in fruit thickness between the 12 years old vine's fruits (Table 2). The highest fruit firmness was measured in the north side of the canopy and the lowest was on the south side. Fruit juice SSC ranged between 9.19% and 9.53% but could not affected by canopy orientation. Fruits from east side have higher dry matter content than fruits from the other fruiting zone. The effect of canopy orientation was statistically significant on fruit titratable acidity content and pH value (Table 2).

Table 2. Fruit quality parameters of 12 years old kiwi vines recorded in different orientation.

	Fruit Weight (g)	Fruit Diameter (mm)	Fruit Thickness^{ns} (mm)	Fruit length (mm)	Fruit Firmness (kg cm^{-2})	TA (%)	SSC^{ns} (%)	pH^{ns}	DMC (%)
South	88.21a	50.78ab	45.83	70.37a	6.34c	1.63bc	9.53	3.02b	21.75a
North	68.50c	47.32b	45.29	58.41b	8.07a	1.71a	9.53	3.11a	18.48b
East	80.24b	51.98a	44.66	66.56ab	7.32ab	1.60c	9.50	3.03b	20.62a
West	77.20b	48.56ab	45.05	58.55b	7.10bc	1.65b	9.19	3.07ab	20.18ab

* The letters indicate statistical differences between values in each column (P≤0.05). ** ns: not significant

3.2. Effect of vine age on fruit quality in different orientation

Vine age was significantly affected the fruit weight on south, north and west orientation of canopy (Figure 1). 25 years old kiwi vines had the heavier fruits when compare with 12 years old vines and difference was statistically important. However, the fruits of the 25-year-old vines had the longest fruit in the south side canopy of vine, it was not different from fruits of 12 years old vines. Fruit firmness is another quality factor that influenced by vine age; and the highest fruit firmness were measured at fruits of 12 years old vines on each side of canopy (Figure 1). The firmness of fruit was slightly greater on north side of both age group vines. Dry matter content was significantly higher all orientation of the canopy for fruits of the 25 years old vines (Figure 3). Among the age groups of vines, 25 years old registered highest dry matter content. Soluble dry matter contents and pH of fruits did not show a significant difference according to plant age and branch position.

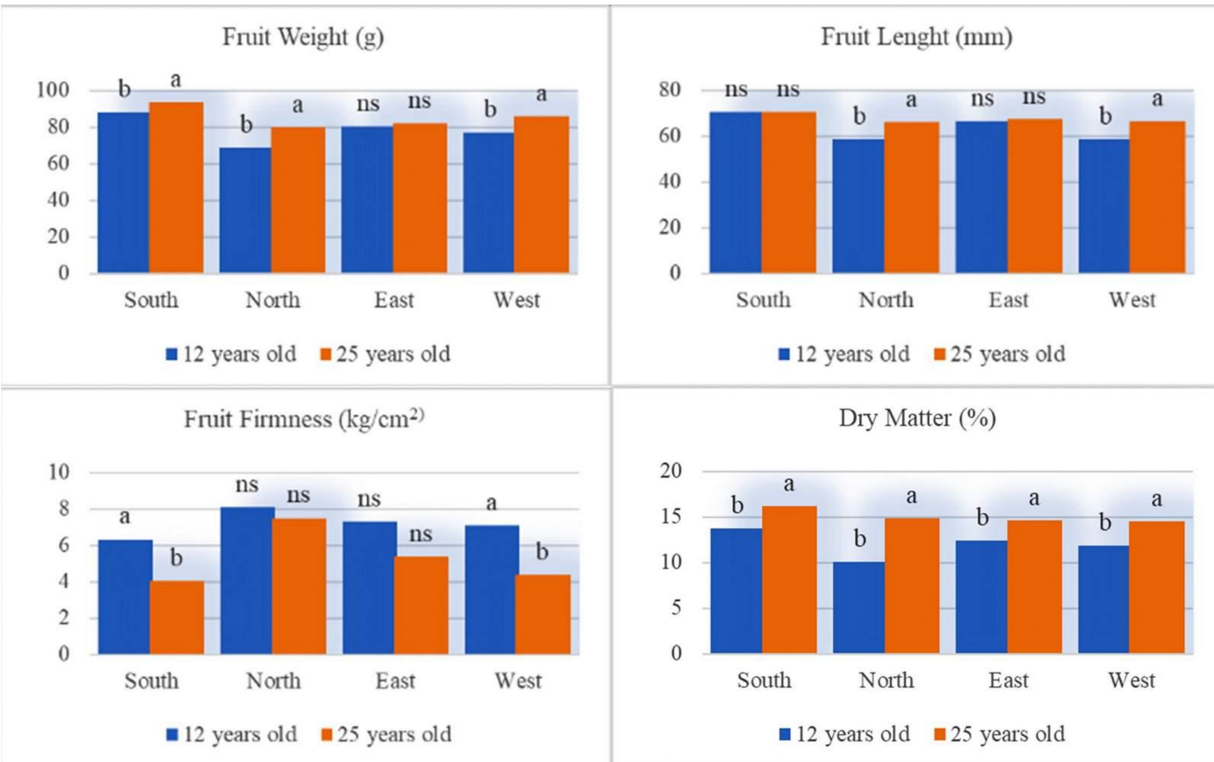

Figure 3. Vine old effects on fruit weight, length, dry matter content, and fruit firmness (P<0.05)

4. Discussion

In this study, fruit quality of Hayward kiwi cultivar was evaluated on the different orientation of the vine canopy. Fruit size and weight differentiation was seriously influenced by canopy orientation. Fruit length, thickness and weight was increased on the branches in the south and east side of vine. South orientation was more effective side in this study. As noted by Biasi et al., (1993), kiwifruit need exposure to light for high fruit quality. In another study suggested that increasing the radiation environment so that resulted with the higher fruit quality (Miller et al., 2001). This confirms the results for apple reported by (Gao and Li, 2016). Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted. The preliminary studies suggested that the north-south orientation is luckier than east-west row orientation (Sarlikioti et al., 2011; Maldera et al., 2021). The sunlight distribution and pattern throughout the day is changed by plant positioning, canopy orientation and density, intra row density (Trentacoste et al., 2015; Campos et al., 2017). Light distribution in canopy is important for crop photosynthesis as suggested by the modelling studies (Sarlikioti et al., 2011; Li et al., 2014). It was found that hulled almonds fruit weight was higher in the south side of east-west oriented row and hazelnut productivity was higher on south facing branches of plants (Bak et al., 2014). These results are in agreement with ours. As a contrast with our findings, Polat and Turunç (2015) could not observed any specific effects of canopy orientation on fruit weight. Fruit firmness was increased on the north oriented branches in our study. Bostan and Günay (2014) suggested that south orientation was more effective on fruit firmness. Increasing of fruit firmness in the south side is in contrast with our findings. Fruit in the south side of vine exposed to higher light levels through the growing season and fruit size increased. Generally, fruit size is negatively correlated to firmness and our result is confirm this. The position within the tree canopy has a considerable influence on the dry matter contents in fruits. Dry matter content could change between the fruits of north-and south oriented branches as presented here. South oriented branches contained higher dry matter. Kiwi fruits collected from the south canopy were heavier and had a higher soluble solids content. These findings are consistent with those reported for the apple (Nilsson et al., 2007). Excessive exposure to sunlight can reduce the anthocyanin content and sugar concentration of grains (Bergqvist et al., 2001), soluble dry matter was higher in sun-exposed fruits, while titratable acidity, pH, and fruit weight was lower in shaded or unlit fruits. In our study, fruit weight, fruit length, soluble solid content and dry matter content was higher in 25 years old vines fruits. The age of vine also affects the accumulation of dry substances and sugars varies with age (Rattan et al., 2020). Higher amount of dry substances was found in fruits of older kiwi vines as presented in aronia fruits (Andrzejewska et al., 2015). This result is thought to be caused by higher fruit temperature in the south-facing branches (Adams et al., 2001). Solids concentration of kiwi fruit was influenced by the position of the fruit on vine in earlier studies (Hopkirk et al., 1986) while this parameter is only showed difference in the 25 years old vine fruits in our study. Plant age and canopy position significantly affect the physico-chemical properties of the guava fruits (Asrey et al., 2007). 15 years old trees registered highest SSC contend when compare with the 10- and 20-years old plants. Kiwi vine age could not affect the SSC contents of fruits in our study. Canopy microclimate especially light intensity affected fruit yield and quality most. Light has been regarded as the principal energy source and one of the most important environmental factors (Dong et al., 2014). Light from the south had a comparatively higher intensity, while it was relatively lower from the north, mainly because the branches and leaves on the southern part of the canopy shaded the light from the north.

5. Conclusions

The most changeable parameters changed by the canopy orientations are fruit size and flesh firmness. In general, southern canopy fruits showed the highest values for each quality parameter and eastern canopy fruits ranked second, except for fruit firmness and titratable acidity. Our results proved a close relationship between fruit quality and fruit-bearing orientation. Fruit quality changes were attributed to the chancing levels of irradiance and ambient temperature on different orientations. Fruit quality is particularly important for commercial marketing and the kiwifruit industry. These results showed the necessity of collecting separately. The effect of fruit-bearing orientation has not been independently investigated in earlier studies; hence, these data serve as a reference for future studies and can be used to set standards for planting kiwi orchards, as well as pruning and harvesting. Fruit size and quality plays key role for commercial marketing; segregation of harvests based on fruit-bearing direction will enhance the market quality of kiwi fruits. It could present a new strategy aimed at improving the market value. Innovative mechanization would improve the performance of selective harvesting of fruits. Future studies should focus on a continuous log of fruit weight and surface temperature throughout the growth period, which will provide additional information on fruit orientation effects. The results can serve pruning and harvesting treatments and support producers to grow high-quality marketable kiwi fruit. In this context, our study is the first and supplied valuable fruit quality parameters. With some effort, producers could increase the marketing value of their products yield, thus extend the storage life of fruits. The study should be continued with investigation other climatical parameters and a suitable harvest model should be tried to be created for the vine.

Author Contributions

Conceptualization: M.S.D.; methodology: M.S.D.; software: M.S.D.; formal analysis: M.S.D. and İ.E.; writing – original draft preparation: M.S.D.; writing – review and editing: M.S.D.; visualization: M.S.D.; supervision and project administration: M.S.D. Both authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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