ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Hortorum Cultus, 19(5) 2020, 37–43
https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 DOI: 10.24326/asphc.2020.5.4
ORIGINAL PAPER
Accepted: 16.09.2019

THE EFFECT OF PHOTOSYNTHETIC ACTIVE RADIATION ON YIELD AND QUALITY TRAITS IN 'TOMBUL' AND 'PALAZ' HAZELNUT CULTIVARS

Yasemin Şen[1], Saim Zeki Bostan[2]✉

[1] Institute of Science, Department of Horticulture, Ordu University, 52200 Ordu, Turkey
[2] Faculty of Agriculture, Department of Horticulture, Ordu University, 52200 Ordu, Turkey

ABSTRACT

This study was carried out to determine the changes in yield and some quality characteristics of 'Tombul' and 'Palaz' hazelnut cultivars according to orchards varied in terms of photosynthetic active radiation. The study was carried out in three orchards with full day sun lighted (100% PAR), half day sun lighted (66.34% PAR) and shady (49.93% PAR) in the Fatsa district of Ordu province (Turkey) in 2016. The experiment was designed in random blocks and three replicates. As a results, it was determined that lighting conditions of the orchards have a significant effect on yield and quality traits in both cultivars. As the sun lighting decreased, yield and good kernel rates decreased; blank nut ratio increased. In addition, the oil content was decreased as the lighting in the orchards increased but it was found to be significant only in 'Tombul' hazelnut cultivar. As a result, it may be recommended to take into consideration the natural lighting conditions of the orchards in the new plantations, not to plantation the orchard in places that do not have any sunlight and to apply the cultural practices in existing orchards to get enough light.

Key words: *Corylus avellana*, kernel, sunlight, nut, PAR, yield

INTRODUCTION

Turkey, situated in a region that includes Near-East and the Mediterranean area is known as the homeland of many cultured species and varieties, and with that has largely constituted the source of the breeding studies.

Although there are 12 known species of the genus *Corylus* of the family *Betulaceae*, only *Corylus avellana*, *C. colurna* and *C. maxima* are important in terms of fruit growing and economic [Özçağıran et al. 2014].

The hazelnut is widespread, especially in temperate climates on the World. Turkey is a leading country of the world hazelnut production that has the 70% of the world hazelnut production, and the other important producer countries are Italy, USA, Georgia, Azerbaijan, China, Iran and Spain. Hazelnut belongs to moist and mild climate. Coastal side of The Black Sea Region in Turkey has the most appropriate climatic circumstances for hazelnut cultivation. And hazelnut orchards can be located 1000 m higher than sea level and 60 km inside from the seaside [Balık et al. 2016].

In order to obtain high yield in hazelnut, it is necessary to make cultural and technical practices at an adequate and sufficient level and to detect ecological parameters to be able to obtain sufficient results from these practices. One of the most important reasons for the year-to-year fluctuations in hazelnut production is the adverse climate conditions [Bostan 2006].

The duration and intensity of lightning are factors that influences growth and development. Numerous

✉ szbostan@hotmail.com

studies have shown that flower bud formation does not occur if the light level in fruit trees is less than 10–30% of the surrounding full light. Light also has an effect on the mechanism of hormones. The number of branches and leaves in the light field direction is higher than the less light side [Kaşka and Paydaş Kargı 2007].

It has been determined that approximately 3.5 times more flower bud is formed in the areas where the light is exposed compared to the branches growing in the shade. Shading reduces the potential of reproduction by disrupting vegetative development indirectly [Hampson et al. 1996].

The yield and the quality of hazelnut differs depending on grown areas. This situation can be a resulted of environmental conditions. So, after determining more environmental variables for the most suitable hazelnut growth, potential hazelnut cultivation areas should be determined to improve the yield and the quality of hazelnut [Aydinoglu 2010].

Hazelnut groves in Turkey has not been a lot of attention to climate factors in choosing the locations. Especially in recent years, the negative effects of global climate changes have started to be observed in hazelnut agriculture.

In this study, it is aimed to determine the yield and quality characteristics of 'Tombul' and 'Palaz' hazelnut cultivars with different sunlight conditions in Ordu province of Turkey.

MATERIAL AND METHODS

The study was carried out in Fatsa district of Ordu province of Turkey in 2016. In the study, 'Tombul' and 'Palaz' hazelnut cultivars, which are the most important commercial cultivars of the region, were used. In the commercial orchards, the numbers of stem per ocak (multi-stem bush form system) were 6. The distance between the ocaks is 3.5 m. These orchards were established approximately 100 years ago. The distance of the orchards to the coast is approximately 2 km. The orchards had slightly acidic soil and non-saline soil, and for organic matter were good level.

The orchards selected based on daylight they received. In order to determine the total photosynthetic active radiations (PAR) levels, the device which can measure the temperature, humidity and PAR values together (Hobo U12 Temp/RH/2 External Data Logger and APOGEE Quantum-PAR-Sensor) were placed to the center of experimental plants on poles at a height of 3–4 m above the ground. Temperature, humidity and photosynthesis of active radiation (PAR) values were recorded during 89 days between the dates of 13.05.2016–9.08.2016.

The hazelnuts were harvested by hand on August 10, 2016. After harvesting, hazelnuts with clusters were exposed to sun for 2 days to pre-drying, and then the separated from the husk by hand and dried them on the sunlight during 5 days.

The analyses for yield (g/stem), yield efficiency (g/cm^2), good kernel ratio (%), small nut ratio (%), blank nut ratio (%) and defective kernel ratio (total ratios of poor filled, doubles, black tips, decays, shrivels, moldy, insect injury – %) was done using all fruits in a stem. The sampling for analyses of nuts per husk, nut weight (g), nut size (means of nut length, width and height – mm), shell thickness (mm), kernel weight (g), kernel size (means of nut length, width and height – mm), kernel percent (%), internal cavity (mm), blanching ratio (%), protein ratio (%), oil ratio (%) and vitamin E (mg/kg kernel oil) was done using 30 samples selected randomly from a stem.

In the cold press oil extraction device, hazelnut oil was obtained by pressing the hazelnuts. The obtained extract was dissolved in 2 ml of heptane: tetrahydrofuran (THF; 95: 5 v/v) prior to injection and filtered through a 45 mm filter. Analyzes were performed using the Agilent HPLC system (1260 Infinity). α-tocopherol was identified by a DAD detector at a wavelength of 292 nm. Phenomenex Luna silica column (250 × 4.6 mm id, 5µm in particle size) was used for separation and the mobile phase (heptane: THF, 95: 5) was passed through the column with isocratic flow at 25°C at a flow rate of 1.2 ml/min completed. The results are expressed in µg tocopherol/g dry matter, calculated from standard curves prepared using standard substances [Balz et al. 1992].

For crude protein analysis 0.5 g of each sample was weighed and placed in Kjeldahl tubes. The tube was poured into the tube as catalyst (K_2SO_4 : $CuSO_4$) and 12 ml of concentrated sulfuric acid was added and the protein device (Gerhardt Vap40) was burned for 1 h at 420°C until the color was completely clear. After the gas was exhausted, the flask was cooled

to about 40°C. After combustion, the sample placed in the distillation unit was distilled with boric acid (3% H_3BO_3) and sodium hydroxide (33%) solutions. The collected distillate was then titrated with 0.2 N hydrochloric acid solution. The amount of protein was calculated according to the following formula [AOAC 2000a]:

$$\text{protein (\%)} = (V \times S \times N \times 100 \times 5.30)/m$$

V: HCl used for titration (ml),
m: sample amount (g),
S: 0.014,
N: normality of HCl solution.

The oil ratio was determined using a soxhlet device [AOAC 2000b]. The glass containers of the apparatus were dried in the oven and brought to constant weight and the beakers to be n-hexane were dried and then tared. The temperature of the device is set to 130ºC, which is suitable for n-hexane. The milled 5 g nuts were placed in the cartridge. The cartridges were placed in the soxhlet extraction device. 60 ml of n-hexane was placed in each beaker. The first step of the device took 30 min to immerse. The second step, washing, lasted 150 min. Final phase recovery was completed in 30 min. After recovery, the samples were placed in an oven at 105 ±2°C. The oven was left for 1 h. The samples taken from the oven were cooled in a desiccator and then weighed to 0.001 g of sensitive precision balance. After taking the total weight of the beaker, percent of crude oil was calculated with the following formula:

$$\text{oil (\%)} = (A2-A1)/m \times 100$$

A1: weight of the beaker for constant weighing (g),
A2: total quantity in the last weighing per beaker (g),
m: sample weight (g).

The experiment was designed in randomized complete blocks and 3 replications. In each orchard, 3 ocaks for 'Tombul' and 'Palaz' cultivars were determined. Statistical analysis was performed in the JMP13 program. LSD test was used to compare the differences between means.

RESULTS AND DISCUSSION

According to the data from the device, information about the sunlight conditions of the orchards was obtained. According to this information, the highest PAR and humidity value were measured in full day sun lighted orchard (Tab. 1).

As a result of analysis of variance in 'Tombul' cultivar, yield, good kernel ratio, blank nuts ratio, internal cavity and oil content; in 'Palaz' cultivar, yield, good kernel ratio, blank nuts ratio, defective kernel ratio, shell thickness and protein content were significant according to the lighting conditions of the orchards (Tabs 2 and 3).

In 'Tombul' hazelnut, according to lighting of orchards, the highest yield and good kernel ratio, the lowest blank nut ratio were obtained in full day sun lighted, half day sun lighted and shady orchards, respectively; the lowest internal cavity size in full day sun lighted; the highest oil content in half day sun lighted and shady orchards were determined (Tabs 2 and 3).

In 'Palaz' hazelnut, according to lighting of orchards, the highest yield and good kernel ratio, the lowest blank nut ratio and defective kernel ratio in full day sun lighted, half day sun lighted and shady orchards, respectively; the thinnest shell thickness and the highest protein content were determined in full day sun lighted orchards (Tabs 2 and 3).

In the study, the highest yield was determined in full day sun lighted, half day sun lighted and shady orchards, respectively in both cultivars, and the yield decreased as the lighting decreased. The yield in the full

Table 1. The average temperature, humidity and PAR values of the research orchards

Orchards	Temperature (°C)	Humidity (%)	PAR (µmol)
Full day sun lighted	21.07	85.23	434.87
Half day sun lighted	21.33	84.22	297.21
Shady	21.32	82.82	217.14

Table 2. The average pomological values of 'Tombul' and 'Palaz' hazelnut cultivars that were compared to orchards

Traits	'Tombul'			'Palaz'		
	orchards			orchards		
	full day sun lighted	half day sun lighted	shady	full day sun lighted	half day sun lighted	shady
Yield (g/stem)	**86.80 a***	**51.60 ab**	**36.07 b**	**85.90 a***	**69.77 ab**	**31.00 b**
Yield efficiency (g/cm^2)	7.87	6.50	5.90	7.80	6.47	5.37
Nuts per husk	3.23	3.10	3.08	3.23	2.78	3.15
Good kernel ratio (%)	**75.53 a****	**58.87 b**	**56.67 b**	**75.80 a***	**51.47 b**	**51.13 b**
Small nut ratio (%)	6.10	3.87	1.87	6.07	2.93	4.53
Blank nut ratio (%)	**15.00 b****	**31.07 a**	**36.07 a**	**12.53 b***	**22.80 a**	**30.27 a**
Defective kernel ratio (%)	3.37	6.20	5.40	**5.60 b***	**15.33 ab**	**21.53 a**
Nut weight (g)	1.79	1.85	1.64	1.82	1.78	1.59
Nut size (mm)	16.53	17.40	15.87	11.50	16.90	15.73
Shell thickness (mm)	1.20	1.28	1.20	**1.21 b***	**1.38 a**	**1.27 ab**
Kernel weight (g)	0.94	1.12	0.95	0.97	0.96	0.98
Kernel size (mm)	13.47	13.07	12.87	14.00	13.07	12.93
Kernel percent (%)	53.30	59.93	58.00	53.43	53.90	62.00
Internal cavity (mm)	**3.83 b***	**5.73 a**	**3.97 b**	4.50	5.33	4.50
Blanching ratio (%)	98.00	97.33	98.00	92.00	91.67	89.33

* significant at $P < 0.05$ probability level, ** significant at $P < 0.01$ probability level

'Tombul'	LSD(0.05)	'Palaz'	LSD(0.05)
Yield	35.57	Yield	39.21
Good kernel ratio	8.58	Good kernel ratio	9.38
Blank nut ratio	11.00	Blank nut ratio	9.07
Internal cavity	1.28	Defective kernel ratio	10.37
		Shell thickness	0.12

day sun lighted orchard was higher 58.44% compared to shady orchard and 40.55% compared to half day sun lighted orchard in 'Tombul' hazelnut cultivar. The yield in the full day sun lighted orchard was higher 63.91% compared to shady orchard and 18.78% compared to half day sun lighted orchard in 'Palaz' hazelnut cultivar (Tab. 2). In a study in 'Tonda Romana' hazelnut cultivar conducted in Italy, the effect of light penetration on the yield of different planting in the high density filbert planting was investigated, and it was stated that inside the tree, where the shading was more intense, catkin formation was reduced and the vegetative growth was lower than that in the control trees, the reasons of the yield reduction were caused by the thinning of the productive zone and by the competition of leaves for light between trees, the light deficiency on artificially shaded trees have caused to reduction of the vegetative and the reproductive activity, and it is necessary guarantee a sufficient light exposure also inside the trees sited at large spacings, seemingly well illuminated, with appropriate techniques. Therefore, it was recommended that must intervene by eliminating the trees in excess or with pruning or practices tending to reduce the total tree growth [Tombesi 1977]. On the other hand, the all pruning periods significantly increased the yield [Roversi and Malvicini

2014]. According to Hampson et al. [1996], shade was more detrimental to yield than flowering: yield per tree dropped by >80%, from 2.9 to 3.4 kg in full sun to 0.6 to 0.9 kg in 92% shade in 'Ennis' and 'Barcelona' hazelnuts, therefore, but improving light penetration into the canopy would probably increase orchard productivity. Azarenko et al. [1997] found that the yield, density of catkin and total female flowers were reduced by shading, therefore, the light environment within a hazelnut canopy must be managed to optimize yields, nut quality and flowering. Me et al. [2005] determined that the free vase system enabled better light interception especially in the outer part of the canopy at greater heights from the soil surface, the use of the double hedge system could be recommended only for the first ten years after planting, as after this period it is necessary to cut one of two plants to avoid excessive tree growth and to permit better illumination, and fruit set was significantly higher in the case of vase. Moreover, the light infiltration showed an influence on yield, and clusters drop and blanks was higher in the shaded part of the canopy [Valentini et al. 2009]. Also in 'Palaz' hazelnut cultivar, as the number of plants in the unit area increased, the yield per hectare was increased but the yield per plant decreased [Beyhan 2007]. As it can be seen, also in previous studies, it is concluded that light has a significant effect on the yield and low light conditions decrease the yield.

The highest good kernel ratio in both cultivars was obtained in the full day sun lighted orchard, followed by half day sun lighted and shady orchards. The effect of the natural lighting conditions on the good kernel ratio was positive. In the orchard with full-day sunlight, the good kernel ratio was more than 20% in 'Tombul' and more than 30% in 'Palaz' compared to other orchards (Tab. 2). In a study in which the effect of different altitudes and directions on the yield and quality characteristics of the 'Tombul' hazelnut cultivar was investigated, the rate of good kernel was higher in the orchards in the south direction, although it was not statistically significant compared to the factors investigated [Çalış 2010]; on the other hand, the increase or decrease in the number of plants in the unit area in 'Palaz' hazelnut cultivar did not affect this ratio and it was determined that it varied according to years [Beyhan 2007]. Although these studies are not exactly the same as the methodological study, the results support indirect our study.

The lowest blank nut ratio in both cultivars was determined in full-day sun lighted, half day sun lighted and shady orchards, respectively. In the orchard with full-day sunlight, the blank nut ratio was 58% less in 'Tombul' and 51% in 'Palaz' compared to other orchards (Tab. 2). As the light levels of the orchards increased, the rate of blank nut decreased. The blank nut ratios were approximately halved in 92% shade compared to full sun for 'Ennis' and 'Barcelona' hazelnut cultivars, the highest ratio was in Barcelona hazelnut cultivar and the defects vary according to cultivars and years [Hampson et al. 1996]; on the contrary, Valentini et al. [2009] stated that clusters drop and blanks were higher in the shaded part of the canopy in 'Tonda Gentile delle Langhe' hazelnut cultivar. As can be seen, two different results were found in the literature and the result of our study is similar to result of the second study.

According to the sunlight conditions of the orchards, the defective kernel rate was significant only in the 'Palaz' cultivar. However, the lowest rate for both cultivars was determined in full day sun lighted orchard. In 'Palaz' hazelnut cultivar, defective kernel ratio in the full day sun lighted orchard was lower 63.47% less compared to half day sun lighted and 73.99% compared to shady orchard (Tab. 2). It is observed that shading in the orchards of 'Tonda Romana' hazelnut cultivar in different planting system increases the rate of defective kernel rates [Tombesi 1977, Hampson et al. 1996, Azarenko et al. 1997]. As it can be seen, in previous studies, as in our study, it has been determined that less sunlight environment increases the defective kernel ratio.

The shell thickness is a highly variable trait and thinnest shell is usually a trait preferred in the hazelnut trade of kernels [Lagerstedt 1975], but extremely thin-shelled hazelnuts are not very desired due to the cracking in the shell and the formation of a black tip inside. In our study, this value was found to be statistically significant only in the 'Palaz' cultivar, and the highest value was determined in half day sun lighted orchard (Tab. 2). Karadeniz and Küp [1997] found that the shell thickness values of 'Tombul' hazelnut cultivar in the orchards of north and west were higher than in the east and south directions. Çalış [2010] determined that this trait did not show a significant change compared to the orchards of the same cultivar. In our study, it is thought that the change in this characteristic

Table 3. The average chemical values of 'Tombul' and 'Palaz' hazelnut cultivars that were compared to orchards

Chemical traits	'Tombul' orchards			'Palaz' orchards		
	full day sun lighted	half day sun lighted	shady	full day sun lighted	half day sun lighted	shady
Protein ratio (%)	14.02	13.62	13.49	**15.41 a***	**12.51 b**	**12.39 b**
Oil ratio (%)	**49.53 b****	**56.80 a**	**56.80 a**	57.87	64.07	66.67
Vitamin E (mg/kg kernel oil)	338.333	320.100	357.267	338.467	267.967	270.300

* significant at $P < 0.05$ probability level, ** significant at $P < 0.01$ probability level

'Tombul'	LSD(0.05)	'Palaz'	LSD(0.05)
Oil ratio	3.94	Protein ratio	0.88

may change under the influence of many factors rather than a single factor.

It is desirable that the nuts are full and have a small internal cavity, especially after drying [Lagerstedt 1975]. Although this trait varies according to many factors, it is generally thought to be heritable and also the value of the internal cavity increases as the shell becomes thinner [Çetiner et al. 1984]. In our study, the size of the internal cavity was statistically significant only in 'Tombul' hazelnut cultivar, and the highest values were obtained in half day sun lighted orchard as in the shell thickness (Tab. 2).

The blanching percentage was found to be significant only in 'Palaz' cultivar, while the lowest ratio was determined in full day sun lighted, and the highest ratios were in half day sun lighted and shady orchards with lower sunlight levels (Tab. 2). The blanching percentage, which is an important trait in hazelnuts consumed as kernel and has a moderate heritability (48%) [Mehlenbacher and Smith 1988, Thompson et al. 1996], may vary depending on genotypes, years, ecological conditions and blanching temperature/time [Bostan and İslam 1999]. In our study, it is thought that this feature may change in many factors.

Protein ratio can vary significantly according to genotypes, years and regions [Şahin et al. 1990]. In our study, the effect of the sunlight of the orchards on the protein content ratio was found significant only in 'Palaz' cultivar, but the highest rate in both cultivars was determined in the sunlight full day. In addition to the factors mentioned above, nutrition and maintenance conditions and sunlight are thought to be effective on protein content (Tab. 3).

The oil content, which is an important trait in obtaining many processed products, has a significant effect on the quality of the products; as the moisture ratio increases, the oil content of the samples decreases and this ratio can vary significantly according to genotypes, regions and years [Şahin et al. 1990]. In our study, the oil ratio was found to be significant only in 'Tombul' hazelnut cultivar (Tab. 3). This ratio was determined as the lowest in full day sun lighted orchard. In other words, as the sunlight level in the orchards increased, the oil content decreased. In addition to the factors mentioned in the literature on oil ratio, it is thought that the sunlight conditions of the orchards are also effective.

CONCLUSIONS

As a result, it can be said that low level of sunlight conditions in the orchards reduced the yield. The yield efficiency and nut number per husk increased in the light environment. The good kernel ratio decreased in low level of sunlight conditions. The defective kernel and blank nut ratio were decreased as the sunlight levels of the orchards increased. The protein ratio was increased as the sunlight levels of the orchards increased. The fat ratio was decreased as the sunlight levels of the orchards increased, other pomological character-

istics of the samples could be affected by more than one factor. It should be taken into consideration of the light environment of the orchards for new plantations.

ACKNOWLEDGEMENTS

This study is a part of the MSc Thesis of Yasemin Şen. The authors would like to thank the Ordu University Scientific Research Projects Coordination Unit (ODUBAP) for its financial support to the project (Project Number: TF-1621).

REFERENCES

AOAC (2000a). Official methods of analysis of AOAC international (protein by Kjeldahl nitrogen-method 920.152).

AOAC (2000b). The total fat content was determined in accordance with the method of the Association of Official Analytical Chemists methods total fat by Soxhlet extraction (method 920.39C).

Aydinoglu, A.C. (2010). Examining environmental condition on the growth areas of Turkish hazelnut (*Corylus colurna* L.). Afr. J. Biotechnol., 9(39), 6492–6502. DOI: 10.5897/AJB10.400

Azarenko, A.N., McCluskey, R.L., Hampson, C.R. (1997). Time of shading influences, yield, nut quality and flowering. Acta Hortic., 445, 179–183. DOI: 10.17660/ActaHortic.1997.445.24

Balık, H.İ., Kayalak Balık, S., Beyhan, N., Erdoğan, V. (2016). Hazelnut Cultivars. Trabzon Commodity Exchange, pp. 96.

Balz, M., Schulte, E., Thier, H.P. (1992). Trennung von Tocopherolen und Tocotrienolen durch HPLC. Eur. J. Lip. Sci. Technol., 94, 209–213 [in German]. DOI: 10.1002/lipi.19920940604

Beyhan, N. (2007). Effects of planting density on yield and quality characteristics of hazelnut (cv. 'Palaz') in a hedgerow training system. Can. J. Plant Sci., 87, 595–597. DOI: 10.4141/P05-064

Bostan, S.Z., İslam, A. (1999). Determination of interrelationships among the percentages of pellicle removal and the other important fruit quality characteristics in hazelnuts by path analysis. Turkey III. National Horticultural Congress, 14–17 September, 238–242 [in Turkish].

Bostan, S.Z. (2006). The importance of climate in hazelnut farming. 3. National Hazelnut Council, 10–14 October, Giresun İl Özel İdare Müdürlüğü, Giresun, 422–425 [in Turkish].

Çalış, L. (2010). Effects on yield and quality of different altitudes and vectors in 'Tombul' hazelnut cultivars grown in Perşembe district of Ordu MSc. Thesis, Ordu University, Institute of Science, Horticultural Department, Ordu, Turkey [in Turkish].

Çetiner, E., Okay, A.N., Baş, F. (1984). The pre-selection of cultivar and pollinator in round pomological hazelnut group. Sonuç Raporu. Tarım Orman ve Köy İşleri Bakanlığı, Proje ve Uygulamaları Genel Müdürlüğü, Fındık Araştırma ve Eğitim Merkezi Müdürlüğü, Giresun [in Turkish].

Hampson, C.R., Azarenko, A.N., Potter, J.R. (1996). Photosynthetic rate, flowering and yield component alteration in hazelnut in response to different light environments. J. Amer. Soc. Hort. Sci., 121(6), 1103–1111.

Karadeniz, T., Küp, M. (1997). The effects on quality hazelnut of direction. Acta Hortic., 445, 285–291. DOI: 10.17660/ActaHortic.1997.445.38

Kaşka, N., Paydaş Kargı, S. (2007). Fruit trees physiology growth and development (Translation). Nobel Kitabevi, pp. 243 [in Turkish].

Lagerstedt, H.B. (1975). Filberts. In: Advances in Fruit Breeding, Janick, J., Moore, J.N. (eds.). Purdue Univ. Press. West Lafayette, Ind., USA, 456–489.

Me, G., Valentini, N., Caviglione, M., Lovisolo, C. (2005). Effect of shade on flowering and yield for two different hazelnut training systems. Acta Hortic., 686, 187–191. DOI: https://doi.org/10.17660/ActaHortic.2005.686.25

Mehlenbacher, S.A., Smith, D.C. (1988). Heritability of ease of hazelnut pellicle removal. HortScience, 23(6), 1053–1054.

Özçağıran, R., Ünal, A., Özeker, E., İsfendiyaroğlu, M. (2014). Temperate Zone Fruits. Ege Üniversitesi Basım Evi, İzmir, pp. 262 [in Turkish].

Roversi, A., Malvicini, G.L. (2014). Effects of manual pruning on hazelnut yield and fruit quality. Acta Hortic., 1052, 175–178. DOI: 10.17660/ActaHortic.2014.1052.22

Şahin, İ., Erkut, A., Öztek, L., Üstün, Ş., Oysun, G. (1990). Researches on technological traits of hazelnut cultivars grown in the Middle and East Black Sea region. Ondokuz Mayıs Üniversitesi Yayınları, 63, Samsun, pp. 54 [in Turkish].

Thompson, M.M., Lagerstedt, H.B., Mehlenbacher, S.A. (1996). Hazelnuts. In: Fruit Breeding, Janick, J., Moore, J.N. (eds.). Vol. 3, Wiley, New York, 125–184.

Tombesi, A. (1977). Effect of light penetration on high-density filbert planting. Institute of Fruit Culture, University of Perugia, Italy. Estratto dagli Annali, Vol. 32–33, 301–310.

Valentini, N., Caviglione, M., Ponso, A., Lovisolo, C., Me, G. (2009). Physiological aspects of hazelnut trees grown in different training systems. Acta Hortic., 845, 233–238. DOI: 10.17660/ActaHortic.2009.845.32