Journal of Postharvest Technology
2021, **09**(4): 59-66
www.jpht.in

RESEARCHARTICLE

The effect of protective netting on fruit diameter, quality classification, black spotted and discoloring fruit ratios of Granny Smith Challenger

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Received: 09.09.2021 Accepted: 11.10.2021

ABSTRACT

The aim of this study was to determine the effects of protective nets with different light transmittance on fruit diameter, fruit quality classification, black spot and discoloring fruit ratios of Granny Smith Challenger apple cultivar. In the study, control, 15%, 20%, 35% and 50% shading levels were selected as applications. In the study, in the classification made by considering the fruit diameter, the fruit were generally in the I. class, while the lowest fruit rate was recorded in IV. class. With the shade treatment, an increase in the fruit rate of I. class and a decrease in the rate of fruit of IV. class occurred. With 35% shade treatment, I. class fruit rate was 98% and there was no fruit in IV class with this treatment. Shade treatment increased both the rate of extra quality fruit and the rate of cull fruit. There was an increase in black spot disease with shading and the disease density increased in parallel with the shading level. In the study, it was determined that the shade treatment was effective on the discoloring fruit ratio, which varies depending on the year. In both years, the highest discoloring fruit ratio was obtained with control treatment. The rate of discoloring fruit decreased in parallel with the shading level. As a results, with this study, it was revealed that shade treatment positively affect fruit size, quality and discoloring fruit ratio, but it increased the rate of black spot. It can be suggested that protective netting with a shading level of 35% can be used to increase the quality of fruit.

Keywords: *Malus comminus*, fruit quality, fruit size, black scap

Citation: Ozturk, A., Aydın, E., Ozturk, B., and Aglar, E. 2021. The effect of the protective netting on fruit diameter, fruit quality classification, black spotted and discoloring fruit ratios of Granny Smith Challenger. *Journal of Postharvest Technology*, **9**(4): 59-66.

INTRODUCTION

Turkey ranks first in world apple production while it is not in the position which deserves in exports due to low yield and quality and deficiencies in the marketing infrastructure. With the yield, quality and technology-oriented production, which are the requirements of the modern production, Turkey can increase the amount of exports. For this reason, it has become a necessity to produce the quality fruit rather than high yields in the apple industry (Kaçal, 2009). Fruit color and size are the most important factors that determine the quality of apples, which are evaluated with their external appearance in marketing (Hirst and Flowers, 2000). In apples, problems such as insufficient coloration, sunburn, hail, bird and mechanical damage negatively affect the

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ISSN2348-4330

external quality. Extreme climatic events that occur with global climate change have caused significant economic losses in the fruit growing sector by affecting yield and quality (Hansen et al., 2006; Howden et al., 2007; Bal et al., 2014). As a promising alternative to the solution of these problems, protective net, which have the potential to offer safer and higher quality fruit to producers by protecting the fruit from negative effects such as excessive radiation, hail, and wind, is one of the new technology, which is accepted and used in apple production in worldwide (Siddiqui, 2017; Widmer, 2001; Leite et al., 2002; Stamps, 2009) and its use in horticultural cultivation is increasing day by day (Shahak et al., 2004). The protective nets prevent external damage in fruit while they can affect all quality characteristics of apples positively or negatively. The characteristics of the protective nets to be used vary depending on the cultivar and region. In this sense, the choosing the ideal protective net type is of great importance in terms of yield and quality. In studies conducted with different apple cultivars in countries such as the USA, Brazil, South Africa, and Israel, it has been determined that there are differences in the effects of the protective nets on fruit quality, and the some have a negative effect, and the others have no effect (Chen et al., 1998; Guerrero et al., 2002; Shahak et al., 2008). As the main reason for this situation is the difference in region and cultivar, it is extremely important to determine the most suitable protective net and use it later by making trials before using commercial shading covers in each region and apple cultivar. This study, which we planned with this in mind, was carried out to determine the effects of the use of the protective nets with different light transmittance on the commercial quality characteristics of Granny Smith Challenger apple cultivar.

MATERIALS AND METHODS

The study was carried out at a commercial apple orchard belonging to the Aksa Company (41º13ˈ42ˈˈ N and 36º31ˈ46ˈˈ E, altitude 6 m). Apple trees (*Malus* × *domestica* Borkh.) were 5-year old 'Granny Smith Challenger' cultivar grafted on M9 rootstock, and were planted with south-north orientation and 0.9 m × 3.5 m spacing (≈ 3150 tree/ ha), and trained to the Vertical Axis System. The research was performed in two consecutive growing seasons (2015 and 2016). The soil of the land where the study was conducted had a slightly alkaline (pH = 7.5), medium calcareous (12.4%), salt-free (0.071%), low organic matter level (1.96%) and a clayey-loamy structure with a saturation value of 66%. The cultural practices such as irrigation, pruning, fertilization, weed control and disease-pest control were carried out regularly.

The experiment was designed according to the randomized blocks with 3 replications. Twenty trees were used for each treatment in each block. In the study, 5 different treatments were determined as control (unnetting), 15%, 20%, 35% and 50% shading levels. In each block, the protective nettings with a width of 7.0 m and a height of 4.0 m were covered over the trees belonging to each treatment. In order for the treatments not to affect each other, the distance of 7.0 m was left as a buffer area between them. The trees of the control treatment were not covered with any nettings. The protective nettings (ChromatiNet, Green-tek, Australia) produced for each shading level were materials, which were 1 year old, dark green, made of the high density polyethylene and reinforced with UV additives that was resistant to sun. Each protective netting was drawn to the experiment trees when the petals on the flowers fell (on 2 May in 2015, on 25 April in 2016). The covers were removed from the trees after harvest. The following measurements were made on the harvested fruits.

Fruit groups according to their diameters (%)

According to the treatments, these 100 fruits taken randomly for each replication were I. (> 70.01 mm), II. (65.01-70.00 mm), III. (60.01-65.00 mm), and IV. (<60.00 mm) grouped and their percentage in the total fruit was determined (Dumanoğlu et al., 2009).

Marketable fruit ratio (%)

According to the treatments, considering the defects of 100 randomly selected fruit for each replication, marketable fruit groups were divided into extra, 1st, 2nd, and discarded classes according to the Turkish Standards Institute (TSE) Apple Standard

(Anonymous, 2007). While creating marketable fruit classes, taking into account the quality class tolerances; 5% of the I. class fruit were included in the extra class, 10% of the II. class fruit were included in the I. class, 10% of the discarded group fruit were included in the II. class and the remaining fruit were included in the non-marketable discarded fruit group.

Black spotted fruit ratio (%)

According to the treatments, those with black spot disease symptoms on the peel of the fruit found in the trees in each replication were counted and the amount in the total fruit was determined as a percentage (%).

Discoloring fruit ratio (%)

For discoloring, it was defined as discoloring by counting the fruit with green skin color ranging from clear yellow to dark brown in all fruit in the trees in each replication (Schrader ve Zhang, 2003) and the ratio of these fruit in the total number of fruit of the tree (%) was determined.

Data analysis

Whether the data was normally distributed was checked by Kolmogrov-Smirnov Test. Homogeneity control of variances was confirmed by Levene's test. After the variance analysis of the data was made, Duncan's multiple range test was used to check whether there were significant differences ($p<0.05$) between treatments. The statistical analyses were performed by using SPSS 21.0 software (IBM-SPSS Inc, Chicago, IL, USA).

RESULTS AND DISCUSSION

Fruit diameter

Fruit size, which may vary depending on the genetic structure of the cultivar and environmental conditions (Naor et al., 2008), is one of the most important criteria determining consumer preferences. Fruit size in apples is linearly related to the number of the fruit per tree (Elfving and Schechter, 1993) and the percentage exposed to full sunlight of the trees (Robinson et al., 1983). Protective nets, which have the potential to change the ecological conditions in the orchard, can affect fruit yield and size with its effect on net photosynthesis and the number of the flowers in the truss. It was reported that with the use of the shading nets, the number of the flowers in the truss decreased by 18.4% in 'Gala' and 'Fuji apple cultivars (Do Amarante et al., 2011), and fruit set decreased in 'Hi Early' (Middleton ve MacWaters, 2000).

The decrease in yield with shading nets allows to obtain large and high quality fruit without the need for thinning. In the study, in the classification made by considering the fruit diameters, the fruit were generally in the I. class, while the lowest fruit rate was recorded in the IV. class. It was observed that the fruit ratios of the I. II. III and IV classes were 89%, 6.3%, 3.3% and 1.3%, respectively. However, it was determined that these rates differed between the treatments and with protective net treatments, an increase in the fruit rate of the I. class and a decrease in the fruit rate of the IV. class. In fact, the rate of I class fruit was recorded as 98% with 35% protective net treatments, it was determined that there were no IV class fruit with this treatment. With these results, it can be said that shading treatments increase the size of the fruit (Table 1).

This can be explained by increasing the net photosynthesis and decreasing the number of fruits per tree due to the positive role in stomatal conductivity, plant gas exchange, and plant-water relations of the protective nets (Sharkey and Raschke, 1981), which cause the light intensity and temperature (1-3 °C) reduction (Iglesias and Alegre, 2006).

Table 1: Effect of different shading levels on fruit diameter groups of 'Granny Smith Challenger' apple cultivar

Treatments	Fruit groups according to their diameters (%)			
	I	II	III	IV
			2015	
Control	89.0 d	6.3 a	3.3 a	1.3 a
% 15	91.0 c	6.3 a	2.7 a	0.7 ab
% 20	95.0 b	3.7 b	1.0 b	0.3 ab
% 35	98.0 a	1.7 c	0.3 b	0.0 b
% 50	96.0 b	2.3 c	1.0 b	0.3 ab
			2016	
Control	87.0 d	6.0 ab	4.7 a	2.3 a
% 15	90.0 c	7.0 a	1.7 b	1.0 b
% 20	93.0 b	5.0 b	1.7 b	0.3 b
% 35	95.7 a	3.3 c	1.0 b	0.0 b
% 50	93.0 b	5.3 b	1.0 b	0.3 b

*Means in the same column followed by the different letter are statistically different at P < 0.

Table 2: Effect of different shading levels on marketable fruit ratio of 'Granny Smith Challenger' apple cultivar

Treatments	Marketable fruit ratio (%)			
	Extra	I	II	Cull
			2015	
Control	55.56 d*	31.90 a	9.60 a	2.95 d
% 15	69.93 c	18.70 b	7.60 b	3.80 d
% 20	75.63 b	12.50 c	5.80 c	6.10 c
% 35	82.33 a	6.20 d	3.00 d	8.50 b
% 50	68.53 c	10.80 c	9.40 a	11.30 a
			2016	
Control	46.73 e	35.30 a	13.80 a	4.20 c
% 15	66.13 c	22.80 a	8.50 c	2.60 d
% 20	73.66 b	13.80 d	8.60 c	3.95 d
% 35	80.43 a	8.20 e	3.00 d	8.40 b
% 50	63.76 d	16.00 c	11.20 b	9.05 a

*Means in the same column followed by the different letter are statistically different at P < 0.05.

Quality classification

In apples, fruit are classified as Extra, I. and II. quality by considering the criteria such as fruit color, size and intact. Producers and consumers often prefer visually appealing extra-quality fruit with good color and no flaws. The light quality affects fruit quality characteristics such as size, color and firmness (Shahak et al., 2004, 2008; Rajapakse and Shahak, 2007). Protective nets, which affect light intensity and quality, temperature, humidity and soil temperature in the orchard, can have an impact on fruit

quality characteristics (Bastías and Corelli-Grappadelli, 2012; Iglesias and Alegre, 2006; Kalcsits et al., 2017). In the study, the marketable fruit groups were divided into extra, 1st, 2nd and discarded classes according to the Turkish Standards Institute (TSE) Apple Standard (Anonymous, 2007). Considering the year 2015, the rate of the extra quality fruit varied between 56% (control) and 82% (35% shade application) while shading treatments increased the rate of the extra quality fruit. However, it was determined that the rate of the cull fruit increased with shading treatments. In fact, the cull fruit rate was 3% in the control treatment while this rate was recorded as 11% with 50% protective net treatment. Again, it was observed that 1st and 2nd quality fruit ratios were higher in the control treatment (Table 2).The protective nets offer an alternative as a traditional approach to protect apples from mechanical injury from sunburn, hail and wind, and abiotic factors that limit tree growth, yield, and quality (Mditshwa et al. 2019). The protective nets prevent external damage in fruit while they can affect all quality characteristics of apples positively or negatively. In studies conducted with different apple cultivars in countries such as the USA, Brazil, South Africa, and Israel, it has been determined that there are differences in the effects of the shading covers on fruit quality, some have a negative effect, and some have no effect (Chen et al., 1998; Guerrero et al., 2002; Shahak et al., 2008).

Black spotted and discoloring ratio

The presence of the black spot in apples is one of the most important factors affecting the quality negatively. Although it can be controlled with pesticides, the alternative solutions that are friendly to human health and the environment gain importance in order to control the black spot due to the effects of drugs on human health. In our study carried to determine the effect of the protective net on the fruit quality, we also evaluated the effect of the shading on black spot disease. It was determined that there was an increase in black spot disease with shading and the disease density increased in parallel with the shading ratio. The fact that the black spot ratio, which was 3.1% in the control treatment, increased depending on the level of the shading treatment and rised 12.3% with 50% shading application. Again in the study, there were differences in the ratio of black spots depending on the year. The black spot ratio was found to be lower in the second year of the study. From these data, it can be concluded that the effect of the climatic factors on the intensity of black spot disease is significant (Table 3). The reason of the increasing in black spot disease with the shading treatment can be explained by its potential to change the climatic conditions in the orchard (Stamps, 2009). Protective nets that limit the light intensity provide the opportunity to decrease the temperature in the orchard (Iglesias ve Alegre, 2006) and therefore to high humidity, which is one of the important factors in black spot disease. This may be one of the main reasons for the increase in black spot disease with shading treatment.

Table 3: Effect of different shading levels on black spotted and discoloring fruit ratio of 'Granny Smith Challenger' apple cultivar

Treatments	Black spotted fruit ratio (%)	Discoloring fruit ratio (%)
	2015	
Control	3.1 e*	24.4 a
% 15	4.3 d	20.6 b
% 20	6.4 c	15.4 c
% 35	9.4 b	6.7 d
% 50	12.3 a	0.0 e
	2016	
Control	2.7 e	32.7 a
% 15	4.0 d	22.2 b
% 20	4.9 c	17.0 c
% 35	8.2 b	8.2 d
% 50	10.5 a	0.0 e

*: Means in the same column followed by the different letter are statistically different at $P < 0.05$.

The discoloring fruit ratio, which occurs as a result of exposure of the tree to excessive light in apple, is important in terms of fruit quality and economy. Schrader et al. (2009) reported that in Washington State, apple fruit losses due to sunburn are 10%, causing a loss of approximately $100 million in the industry each year. In fruit discoloring that the enzymes, reactive oxygen species and phenolic compounds are effective, mechanical damage such as injury also plays an important role (Adams and Brown 2007). The protective net is an important tool for apple growers to improve external fruit quality and reduce the occurrence of sunburn. The use of the protective net in apple production prevents the formation of the sunburn and increases the percentage of quality fruit (Kalcsits et al., 2017). Consistent with these explanations, it was determined that the protective net treatment was effective on the discoloring fruit ratio, which varies depending on the year in the study.

The highest discoloring fruit ratio control application was achieved in both years while it was determined that a decrease in the discoloring fruit ratio occurred in parallel with the level of the shading treatment. The fact that the discoloring fruit ratio was 24.4% in the control treatment in 2015 while it decreased with the increase in the level of the shading treatment and was recorded as 0% in the 50% protective net (Table 3). These results may be explained that with the effect of the protective net on the protecting of the fruit from the excessive light (negatively affects fruit coloration of the 'Granny Smith' apple cultivar) (Fouché et al., 2010) and on the climatic events such as wind and hail, which cause mechanical damage on fruit (Shahak et al., 2004; Do Amarante et al. ., 2011). Indeed, Kalcsits et al. (2017) suggested that the ratio of the clean fruit without sunburn increased by 25% with shading treatment in the 'Honeycrisp' apple cultivar while Do Amarante et al. (2011) reported that the shading treatment reduced the incidence of sunburn by 12.1% in the 'Gala' cultivar.

CONCLUSION

As a result, it was observed that the fruit diameter and the ratio of the quality fruit increased with protective net treatment. It was determined that the ratio of the fruit with black spot disease, which causes significant losses in apples, was higher in trees with shading treatment, but the discoloring fruit ratio was lower. Producers may be advised to apply 35% protective net in apple orchards for fruit size and quality.

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