KSÜ Tarım ve Doğa Derg 22(Ek Sayı 2): 342-346, 2019
KSU J. Agric Nat 22(Suppl 2): 342-346, 2019
DOI:10.18016/ksutarimdoga.vi.552218

Physiological Effects of Photoselective Nets in Strawberry Plant

Servet ARAS[1], Ahmet EŞİTKEN[2]
[1]Yozgat Bozok University, Faculty of Agriculture, Department of Horticulture, 66200, Yozgat, Turkey, [2]Selcuk University, Faculty of Agriculture, Department of Horticulture, 42030, Konya, Turkey
[1]https://orcid.org/0000-0002-0347-6552, [2]https://orcid.org/0000-0002-6140-7782
✉: servet.aras@bozok.edu.tr

ABSTRACT
The sunlight manipulation can be utilized to promote the desired plant physiology by using photoselective nets. In our study, we tested different colored nets to determine the physiological responses of the strawberry plant. The study was conducted in 2016 at Selcuk University in Turkey. A strawberry (*Fragaria* × *ananassa* Duch.) cv Kabarla was used in the study planted in 7 L pots. Before the shading treatment, all plants were grown outdoors. For the shading experiment, sunlight was declined by red, green and black nets allowing 40% shade with covering from July until September of 2016 (during 2 months). At the end of the experiment, some physiological and microclimate properties were evaluated. The green net showed the highest SPAD value (39.79), while the lowest value was obtained in red net (34.99). The photoselective nets increased anthocyanin compared to control. Stomatal conductance in the red colored net decreased by approximately 38% when compared to full sunlight. The lowest soil temperature was observed under green colored net. Colored nets increased air temperature compared to control. As a result, the mitigative effect of the photoselective nets against radiation could be used to decrease the malignant effects of environmental stresses such as drought, excessive solar radiation, salinity.

Research Article

Article History
Received : 11.04.2019
Accepted : 24.07.2019

Keywords
Photoselective net
Physiology
Shading
Strawberry

Fotoselektif Netlerin Çilek Bitkilerine Fizyolojik Etkileri

ÖZET
Güneş ışığından faydalanma fotoselektif fileler aracılığıyla bitki fizyolojisini istenilen doğrultuda değiştirmek amacıyla kullanılabilir. Çalışmamızda farklı renkteki fileleri çilek bitkisinin fizyolojik tepkilerini belirleme amacıyla denenmiştir. Çalışma 2016 yılında Selçuk Üniversitesinde kurulmuştur. Kabarla çilek çeşidi çalışma için seçilmiş ve Mayıs ayında 7 litrelik saksılara dikilmiştir. Denemeye başlamadan önce bütün bitkiler dışarıda yetiştirilmiş ve düzenli sulanmıştır. Gölge uygulaması için, güneş ışığı %40' lık gölgelemeye sahip kırmızı, yeşil ve siyah filelerle azaltılmış ve Temmuz-Eylül ayları arasında (2 ay) gölgelenmiştir. Çalışmanın sonunda bazı fizyolojik ve mikroklima özellikleri değerlendirilmiştir. Yeşil file en yüksek SPAD değerine (39.79) sahipken kırmızı file en düşük değere (34.99) sahip olmuştur. Fotoselektif netler bitkilerin antosiyanin içeriğini kontrole kıyasla artırmıştır. Stoma iletkenliği kırmızı filede tam güneş ışığına kıyasla %38 azalmıştır. En düşük toprak sıcaklığı yeşil filede belirlenmiştir. Renkli fileler hava sıcaklığını kontrol grubuna göre artırmıştır. Sonuç olarak, fotoselektif filelerin radyasyona karşı faydalı etkisi kuraklık, aşırı ışık radyasyonu, tuzluluk gibi çevresel streslerin zararlı etkilerini azaltmada kullanılabilir.

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 11.04.2019
Kabul Tarihi : 24.07.2019

Anahtar Kelimeler
Fotoselektif file,
Fizyoloji,
Gölgeleme,
Çilek

To Cite : Aras S, Eşitken S 2019. Physiological Effects Of Photoselective Nets in Strawberry Plant. KSU J. Agric Nat 22(Suppl 2): 342-346. DOI: 10.18016/ ksutarimdoga.vi.552218.

INTRODUCTION

The sunlight management has been an important study to maintain optimum fruit production and quality in orchard systems. Optimizing of sunlight use can be performed with some cultural practices such as pruning, training system, orchard design, with regard to improve the quantity of light (the amount of photosynthetically active radiation, PAR) (Corelli-Grappadelli and Lakso, 2007; Bastias and Corelli-Grappadelli, 2012). Moreover, growers use protective netting to reduce the light quantity for prevention of fruit sunburn, reduction in soil water and diminishing hail damages (McCaskill et al., 2016; Kalcsits et al., 2017; Mupambi et al., 2018). Besides, light quality (spectral composition of sunlight) dramatically influence plant growth and physiology was less studied in fruits. Light quality controls many regulations such as stomatal activity, flower induction, fruit development, increase in plant growth and biomass (Smith, 1994; Matsuda et al., 2004). These responses as a result of light quality are mediated by many pigment-based photoreceptors such as cryptochromes, phototropins (Batschauer, 1998; Wang and Folta, 2013).

Light quality management can be performed by utilizing photo selective (colored) nets to promote physiological responses and plant growth, so these nets can alter both quantity and quality of solar radiation (Martins et al., 2008; Bastias and Corelli-Grappadelli, 2012; Oliveira et al., 2016). Photoselective nets change the spectrum of transmitted light, with the blue and red nets exhibiting peaks in the blue-green (400-540 nm) region and in the red region (590 nm), respectively (Oren-Shamir et al., 2001).In addition, the colored nets increases the relative content of scattered vs. direct light and absorbs infra-red radiation (Shahak et al., 2004). The effect of color type of nets on plants is similar to that of the color of light reflecting the same behavior on plants. For instance, red net provides the benefits by the greater availability of the red radiation (above 590 nm) (Henrique et al., 2011). Red shade nets decrease blue, green, and yellow waves and add waves in the red and far-red spectral range (Pinto and Bertolucci, 2014; Stagnari et al., 2018).

Photoselective nets leads to morphological and physiological alterations in plants (Bassett et al., 2006). Growth changes due to the presence of white, red-white, red-black and green-black colored nets were reported for apple (Solomakhin and Blanke, 2008). Light modification under red and white photoselective net provided better apple fruit yield and quality compared to blue, grey and black once (Shahak et al., 2008). Bastias et al. (2011) reported that net photosynthesis in apple was significantly higher under 46.3% blue and 56.3% grey nets compared to 12.5% pearl net. Moreover, increase in chlorophyll content has been reported in basil plant as an effect of the green colored net (Stagnari et al., 2018).

Many researches related with nettings have focused on shade percentages of the nets and black, white and dark green colored shade nets are widely utilized types. However, as far as we know, detailed information about use of colored net is currently limited. To gain insights into different colored nets, finding out the responses of plants under photoselective shade nets have a significance. Furthermore, the physiological changes in plant by light quality via photoselective nets has been studied in many fruits such as apple (Solomakhin and Blanke, 2008), orange (Zhou et al., 2018), avocado (Tinyane et al., 2018), less studied in strawberry. Therefore, it is still unknown the effects of photoselective nets on the physiology of strawberry plant. Accordingly, here we identified physiological impacts of colored nets on strawberry plant.

MATERIAL and METHOD

The experiment was performed in 2016 in a greenhouse of Department of Horticulture at Selcuk University in Turkey. Strawberry (*Fragaria* × *ananassa* Duch.) cv Kabarla was chosen for the study. The experiment was designed as randomized plot design with three replications, three plants each. The plants were planted in 7 L pots containing soil, substrate and perlite (1:3:1; v/v/v) in May of 2016. Before the shading treatment, all plants were grown outdoors. For the shading experiment, sunlight was declined by red, green and black nets allowing 40% shade with covering from July until September (during 2 months) of 2016. Nets placed over a metal tunnel were1.5 m high, and each group was separated from the other plots.

SPAD and anthocyanin measurements

Relative chlorophyll (Chl) was measured as SPAD value with a Minolta SPAD-502 chlorophyll meter. Relative anthocyanin content of the leaves was measured with Anthocyanin Content Meter (ACM-200 plus).

Stomatal conductance and leaf temperature

Stomatal conductivity and leaf temperature were measured with a leaf porometer (Li-COR).

Leaf relative water content (LRWC)

Leaf relative water content (LRWC) was determined by the procedure of Smart and Bingham (1974). Fresh weights (FW) of leaves were determined and then leaves were placed in distilled water to rehydrate. After 5 hours, turgid weights (TW) were determined. Afterward, leaves were oven-dried and dry weights (DW) were determined. LRWC was calculated using the equation as:

LRWC(%) = ((FW-DW)/(TW-DW))× 100

Soil temperature, air temperature and air humidity

Soil temperature was measured by using soil termometer. Air temperature and air humidity of phyllosphere (on the leaf surface) under the fotoselective nets and above the un-shaded control plants were recorded by using mobile data logger at the time when the soil temperature was recorded.

Statistical analyses

Data were analyzed with the statistical software package SPSS (20.0) compared by the Duncan' s test at 5%.

RESULTS

The red, green and black shade nets as compared to full sunlight significantly influenced physiology of strawberry plant and the air temperature and humidity. Thus, the results demonstrated significant differences among colored nets in quality of light. SPAD readings showed that chlorophyll content in leaves slightly changed after installation of the photoselective nets. The highest SPAD value was measured in green net treatment (39.79) (Table 1). The highest anthocyanin was obtained from black net (12.13) and while the lowest value was in full sunlight (9.72). Red net (150.36 mmol $m^{-2}s^{-1}$) leaded a remarkable decrease in stomatal conductivity compared to control (241.83 mmol $m^{-2}s^{-1}$). Stomatal conductance in the red colored net decreased approximately 38% when compared to full sunlight. The leaf temperature was not affected significantly. Plants growing under intense radiation had higher LRWC than plants in shaded conditions. Colored nets considerably decreased water loss compared to control.

The lowest soil temperature (23.06 °C) was observed under green colored net (Table 2). Colored nets increased air temperature compared to control. The highest air humidity was seen in control (35.33%), while black and red nets had the highest values (30.66 and 31.00%, respectively).

Table 1. Effects of colored nets on the plant physiology

	SPAD	Anthocyanin	Stomatal Conductance	Leaf Temperature	LRWC
Control	35.84 b	9.72 b	241.83 a	32.16	68.00 b
Red Net	34.99 b	11.17 ab	150.36 b	32.30	81.57 a
Green Net	39.79 a	10.63 ab	230.26 a	32.43	83.57 a
Black Net	35.83 b	12.13 a	244.76 a	32.03	83.89 a

Means separation within column by Duncan's multiple range test. $p<0.05$

Table 2. Effects of colored nets on the microclimate conditions

	Soil Temperature (°C)	Air Temperature (°C)	Air Humidity (%)
Control	24.75 a	31.90 b	35.33 a
Red Net	24.66 a	32.73 a	31.00 c
Green Net	23.06 b	32.46 a	33.66 b
Black Net	23.56 ab	32.76 a	30.66 c

Means separation within column by Duncan's multiple range test. $p<0.05$

DISCUSSION

Strawberry is an important berry fruit distributed worldwide. In the current study, we utilized different colored nets at moderate shade level (40%) in order to reveal plant responses against different light quality. Alterations in plant responses with different color screens were observed compared to the cultivation in full sunlight. It is evident that the photoselective nets affected both physiological and environmental factors. Thus, it can be inferred that the plant of 'Kabarla' strawberry is sensitive to light quality, and physiologically reacts with regard to coloring. Furthermore, we speculated that colored net affected the plants as reflecting the effects of own color in the spectrum of light.

Increase in chlorophyll content an adaptation of plant to shade conditions in order to receive more light amounts under limited light (Stagnari et al., 2018). Li and Syvertsen(2006) reported that citrus trees grown under red net exhibited the lowest chlorophyll contentthan citrus trees grown under other types of shade nets. In the current study, shading had a significant effect on leaf relative chlorophyll content (SPAD). The green net enhanced SPAD value compared with full sunlight and red and black nets. Similar to chlorophyll content, photoselective nets significantly increased the relative leaf anthocyanin content compared with control. Plants accumulate anthocyanins as an adaptive response to capture more light. Plants also produce anthocyanin to alleviate photooxidative damages in leaves (Gould et al., 1995). In a previous experiment, the anthocyanin content of *Polygonum hydropiper* plant increased under red light (Miura and Iwata, 1981). The light receptors such as phytochrome (red light) may play roles in anthocyanin synthesis (Mizuno et al., 2009).

Plants subjected to drought stress demonstrate a decrease in stomatal conductance as a defense mechanism to avoid water loss. In the current experiment, significant alterations in stomatal conductance were observed when comparing strawberry plant grown under the photoselective nets in relation to full sunlight plant. The stomatal conductance tended to be lower under red and green net and evaluation among different colored nets demonstrated that red net effectively decreased leaf stomatal conductance when compared to full sunlight. Moreover, there was no significant differences in stomatal conductance were found between control and black nets. In a study of Goins et al. (1997) it was reported that photosynthesis decreased under red LEDs may be associated with lower stomatal conductivity. There was no statistical difference in leaf temperature among shading treatments due to using the same shading level above plants and the leaf temperature was not affected by color of net.

The increase in LRWC caused by photoselective nets was observed in our study. Protection of water loss is a result of lower levels of irradiance leaded by shade treatment. There was no significant difference in leaf relative water content occurred among photoselective nets.

Photoselective nets reduced soil temperature. The rankings of the treatments based on the soil temperature were as follows: green < black <red ≅control. Similar results as decreasing soil temperature were obtained in apple trees under blue and red nets (Kalcsits et al., 2017). Many studies reported that nets reduced canopy temperature. However, in our experiment air temperature above the leaves increased under nets. The current study was built semi-opened and well-ventilated conditions. Therefore, the air temperature and humidity were mainly affected by the external climatic conditions as reported in the study of Zhou et al. (2018).

In the current experiment, green net leaded higher chlorophyll content, while black net had the highest anthocyanin content among colored nets. In addition, red net showed the lowest stomatal conductance value. Different colored nets possessed distinct properties on plants, thus the color of net should be chosen according to their behaviors on plants. Farmers should decide the color of net on their purpose depending environmental conditions such as drought condition.

CONCLUSION

We suggest that different colored nets lead distinct physiological responses and modified light quality leading to protection of water loss, higher air temperature and lower air humidity on phyllosphere as compared to the unshaded plants. As a result, the mitigative effects of the photoselective nets against radiation could be used to decrease the malignant effects of environmental stresses. When we consider which photoselective net was the most useful for strawberry plant, many factors should be taken into account. For instance, the red net should be the most suitable for strawberry production under water-limited conditions through decreasing stomatal conductance. However, the data wwere preliminary and more research is required for understanding the physiological mechanisms underlying changes in the plant responses and for evaluating the results with other fruit species.

REFERENCES

Bassett C, Wisniewski M, Artlip T, Norelli J2006. Global analysis of genes regulated by low temperature and photoperiod in peach bark. Journal of the American Society for Horticultural Science,131(4):551-563.

Bastias RM, Corelli-Grappadelli L 2012. Light quality management in fruit orchards: physiological and technological aspects. Chilean Journal of Agricultural Research, 72(4): 574.

Bastias RM, Losciale P, Chieco C, Rossi F, Corelli-Grappadelli L2011. Physiological aspects affected by photoselective nets in apples: preliminary studies. Acta Horticulturae, 907: 217–220.

Batschauer A1998. Photoreceptors of higher plants. Planta, 206:479-492.

Corelli-Grappadelli L, LaksoAN2007. Is maximizing orchard light interception always the best choice? Acta Horticulturae, 732:507-518.

Goins GD, Yorio NC, Sanwo MM, Brown CS 1997. Photomorphogenesis, photosynthesis, and seed yield of wheat plants grown under red light-emitting diodes (LEDs) with and without supplemental blue lighting. Journal of Experimental Botany, 48(7): 1407-1413.

Gould KS, Kuhn DN, Lee DW, Oberbauer SF 1995. Why leaves are sometimes red.Nature, 378: 241-242.

Henrique PC, AlvesJD, DeunerS, GoulartPFP, Livramentoe DE2011. Aspectos fisiológicos do desenvolvimento de mudas de café cultivadas sob telas de diferentes colorações. Pesquisa Agropecuaria Brasileira,46:458-465.

Kalcsits L, Musacchi S, Layne DR, Schmidt T, Mupambi G, Serra S, Mendoza M, Asteggiano L, Jarolmasjed S, Sankaran S, Khot LR, Espinoza CZ 2017. Above and below-ground environmental changes associated with the use of photoselective protective netting to reduce sunburn in apple. Agricultural and Forest Meteorology, 237: 9-17.

Li KT, SyvertsenJ2006. Young tree growth and leaf function of citrus seedlings under colored shade netting. HorstScience,41(4):1022.

Martins JR, AlvarengaAA, CastroEM, PintoJEBP, Silvae APO2008. Avaliação do crescimento e do teor de óleo essencial em plantas de *Ocimum gratissimum* L. cultivadas sob malhas coloridas. The Brazilian Journal of Medicinal Plants,10:102-107.

Matsuda R, Ohashi-Kaneko K, Fujiwara K, Goto E, Kurata K 2004. Photosynthetic characteristics of rice leaves grown under red light with or without supplemental blue light. Plant and Cell Physiology, 45(12): 1870-1874.

McCaskill MR, McClymont L, Goodwin I, Green S, Partington DL2016. How hail netting reduces apple fruit surface temperature: A microclimate and modelling study. Agricultural and Forest Meteorology, 226: 148-160.

Miura H, Iwata M1981. Effect of on anthocyanin content of seedlings of benitade (*Polygonum hydropiper* L.). Journal of the Japanese Society for Horticultural Science, 50:44-52.

MizunoT, Amaki W, Watanabe H2009. Effects of monochromatic light irradiationby LED on the growth and anthocyanin contents in leaves of cabbage seedlings. In VI International Symposium on Light in Horticulture, 907: 179-184.

Mupambi G, Anthony BM, Layne DR, Musacchi S, Serra S, Schmidt T, Kalcsits LA 2018. The influence of protective netting on tree physiology and fruit quality of apple: A review. Scientia Horticulturae, 236: 60-72.

Oliveira GC, Vieira WL, Bertolli SC, Pacheco AC 2016. Photosynthetic behavior, growth and essential oil production of *Melissa officinalis* L. cultivated under colored shade nets. Chilean Journal of Agricultural Research, 76(1): 123-128.

Oren-Shamir M, Gussakovsky EE, Shpiegel E, Nissim‐Levi A, Ratner K, Ovadia R, Giller YE, Shahak Y2001. Coloured shade nets can improve the yield and quality of green decorative branches of *Pittosporum variegatum*. Journal of Horticultural Science and Biotechnology,76:353-361.

Pinto JE, Ferraz EO, Bertolucci SK, Silveira HR, SantosAR, Silva GM 2014. Produção de biomassa e óleo essencial em mil folhas cultivada sob telas coloridas. Horticultura Brasileira, 32(3): 321-326.

Shahak Y, Gussakovsky E, Gal E, Ganelevin R2004. ColorNets: Crop protection and light-quality manipulation in one technology. In VII International Symposium on Protected Cultivation in Mild Winter Climates: Production, Pest Management and Global Competition 659: 143-151.

Shahak Y, Ratner K, Giller YE, Zur N, Or E, Gussakovsky EE, Stern R, Sarig P, Raban E, Harcavi E, Doron I, Greenblat-Avron Y2008. Improving solar energyutilization, productivity and fruit quality in orchards and vineyards by photoselectivenetting. Acta Horticulturae, 772: 65–72.

Smart RE, Bingham GE1974. Rapid estimates of relative water content. Plant Physiology, 53: 258-260.

Smith H 1994. Sensing the light environment: the functions of the phytochrome family. In: Kendrick RE, Kronenberg GHM (eds). Photomorphogenesis in Plants. Springer, Dordrecht, 374–416.

Solomakhin A, Blanke MM 2008. Coloured hailnets alter light transmission, spectra and phytochrome, as well as vegetative growth, leaf chlorophyll and photosynthesis and reduce flower induction of apple. Plant Growth Regulator, 56(3): 211-218.

Stagnari F, Di Mattia C, Galieni A, SantarelliV, D'Egidio S, Pagnani G, Pisante M,2018. Light quantity and quality supplies sharply affect growth, morphological, physiological and quality traits of basil. Industrial Crops and Products, 122: 277-289.

Tinyane PP, Soundy P, Sivakumar D 2018. Growing 'Hass' avocado fruit under different coloured shade netting improves the marketable yield and affects fruit ripening. Scientia Horticulturae, 230: 43-49.

Wang Y, Folta KM 2013. Contributions of green light to plant growth and development. American Journal of Botany, 100(1): 70-78.

Zhou K, Jerszurki D, Sadka A, Shlizerman L, Rachmilevitch S, Ephrath J 2018. Effects of photoselective netting on root growth and development of young grafted orange trees under semi-arid climate. Scientia Horticulturae, 238: 272-280.