INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

No III/1/2019, POLISH ACADEMY OF SCIENCES, Cracow Branch, pp. 219-234
Commission of Technical Rural Infrastructure

DOI: https://doi.org/10.14597/INFRAECO.2019.3.1.016

EFFECTS OF GREENHOUSE COVERING MATERIALS OF DIFFERENT COLORS ON PLANT DEVELOPMENT IN GREENHOUSE CULTIVATION: RADISH (*RAPHANUS SATIVUS VAR L.*) CASE

Zeynep Hansa Eğilmez, Atılgan Atılgan
Isparta University of Applied Sciences – Turkey

Abstract

This thesis was carried out in four greenhouses with arc roofs with a base area of 6 m^2 and a side height of 2 m in the experimental area of Isparta University of Applied Sciences, Agricultural Research and Application Center. For this purpose, greenhouse with LED lighting (LED), Red-colored (RG) greenhouse, Blue-colored greenhouse (BG) and greenhouses with transparent covering material (TrG) were used as materials. The study was conducted between February and May 2019. In this study, the effects of different color cover material on the development parameters of radish were determined by measuring the temperature, humidity and solar energy values of the greenhouse. In order to do these measurements, sensors are placed in the greenhouses. Solar energy measurements were taken between 10:00-16:00 hours considering sunshine time. Temperature and humidity measurements were recorded for 24 hours. When the values obtained from TrG, BG, RG and LED greenhouses were examined, it was determined that the highest temperature value of the radish plant in the LED greenhouse during the growing period. Average greenhouse indoor temperature values were found to be between 13°C and 16°C in LED greenhouse, between 6.5°C and 15°C in COG, between 6°C and 14°C in BG and between 6.5°C and 12.2°C in RG. Solar energy values are between 26 and 1053 Wm^{-2} in LED greenhouse, 21.1 and 856.6 Wm^{-2} in TrG, 17.9-680.3 Wm^{-2} in BG

and 14.3-633.1 Wm^{-2} in RG has been determined. In order to examine the growth parameters of radish plant, root weight, height, stem length, length of green parts and root diameter were examined. Root weight was higher in LED greenhouse, plant root length and length of green parts were higher in RG, plant root diameter and weight of green parts were higher in TrG. As a result, it was concluded that the development of radish plant is the worst in the BG in terms of both temperature and radiation energy values. In particular, it was determined that the radish plant in BG appears to be different from the other greenhouse plants. When the development of radish is taken into consideration in four greenhouses, it is concluded that TrG can be recommended for plant root weight, root diameter and green component weight and RG can be recommended for height and stem length. When the developments in the BG were considered, it was concluded that the application of blue color is not suitable for the cultivation of radish.

Key Words: Greenhouse, radish, LED lighting colored cover material, Solar energy

INTRODUCTION

Designing greenhouses in a modern way is based on being economic, maximization of solar radiation permeability and minimization of heat loss, and a modern greenhouse is comprised of its construction, cover material, heating system, cooling and ventilation systems, plant growing environment, shading system, irrigation and fertilization systems and control system (Swinkels et al. 2001). Selection must be made based on various characteristics in order to benefit from cover material or greenhouse structure economically. These characteristics are light transmittance, resistance to wind, snow and hail loads, insulation value, thermal transmittance, UV transmittance, resistance to wear and tear, sensitivity to staining, modification of material specifications by chemical effects, condensation specification and material sizes (Waaijenberg 1989). Since photosynthetic active radiation (PAR) is critical for plants, modifications of solar radiation that enters to the internal space of a greenhouse provide many advantages. Such modifications made be made by using specific coating materials. Greenhouse cover materials that are in various colours, such as red and blue etc., may make a positive effect on the diffraction and diffusion of light (Öztürk 2008). Quality of the light used affects the productivity of plants. High ultraviolet rays increase flowering in plants, while white light is effective in increasing phototropism, and red LED light is effective in increasing photosynthesis (Kasım and Kasım 2016, Tunçbilek 2019).

Studies have been conducted on usage of LED light for growing plants for more than twenty years (Bula et al. 1991, Batra et al. 1992). First studies

included only red LEDs since it was determined that they ensure absorption of chlorophyll (600 nm) at maximum level and furthermore, it was determined that an amount of blue light is required to improve spinach, radish and sorghum growth and development (Britz and Sager 1990, Yorio et al. 2001). When these studies were performed, the blue LEDs were 3% to 4% efficient, while the red LEDs were 15% to 18% efficient (Massa et al. 2006). Therefore, the aim of these studies was to determine the minimum amount of blue light required for normal growth and development in plants (Kim et al. 2005).

This study was conducted to reveal the growth effects of cover materials in blue, red and transparent colours on radish plant in the greenhouse, as well as LED lights. In the study, LED lighting and greenhouse cover material coloured by transparent (control), blue and red powder paint were used as materials. In this study, we aimed to detect the effects of greenhouse cover material in various colours and effects of LED lights on the growth of radish plant in the greenhouse.

MATERIAL AND METHOD

Research was conducted in the research greenhouses available in the land of Research and Practice Farm, Faculty of Agricultural Sciences and Technologies, Isparta University of Applied Sciences (greenhouses with LED lighting, and blue (BG), red (RG) and transparent (TrG) coloured plastic greenhouses) between February 10, 2019 and May 2, 2019. Temperature, humidity and solar energy measurement values were obtained daily between aforementioned dates. Study was conducted in four plastic arc roof greenhouses in the width of 3 m, length of 6 m, side wall height of 2 m and roof ridge height of 2.8 m. Structure determination of the test area soil was performed by Bouyoucos hydrometer method (Bouyoucos 1962). Clayey-loamy soil was used as growth medium in research greenhouses. radish was used as plant material in the test.

On February 10, 2019, radish seeds were planted in the greenhouse with an intra-row spacing of 10 cm and row spacing of 40 cm after implementation of tillage works in order to control weeds in the greenhouse. In the research, 36 months old (UV+IR+EVA+LD) reinforced PE was used as the greenhouse material. In the study, cover materials in 3 different colours and with the same specifications were used in LED, TrG, RG and BG greenhouses. All sides of red and blue cover materials were painted equally by spraying powder paint. Radish plants that were planed into the greenhouse were irrigated by providing equal amount of water to the entire area of the whole growing environment in the greenhouse in consideration of the field capacity of soil. Water and fertilizer required by plants were applied on the root area by fertigation via drip irrigation (4 Lh^{-1}) system installed in the greenhouse. In each irrigation, water was continued to be supplied until the soil reached sufficient field capacity. During our study,

we observed that certain nutrients (macro and micro elements) were required by plants, and we applied required amount of element mixtures by manure tank in order to remove such defects. Solar energy in the greenhouse was measured by 4 units of PCE-SPM 1 solar energy sensor. Solar energy, temperature and humidity sensors are installed at a height of 1.5 m from the ground in the middle of the greenhouse. In the study, temperatures and humidity values of internal and external environments were measured by HOBO devices installed both inside and outside the greenhouses.

RESULTS

Internal average temperature values of greenhouses with cover materials in different colours and values measured in the LED lighting greenhouse were compared between February and May, 2019. Solar energy, temperature and humidity values of the radish plant in the growth period of first 11 days are given in Figure 1 respectively. The temperature value that the radish plant requires at that date is determined as 12°C to 15°C (Anonymous 2019a, Eğilmez 2019). We determined that suitable temperature values of greenhouses, on which four different practices were conducted within the scope of the research, were provided by factors other than BG and TrG during daytime. When the average temperature values are analysed, it is seen that TrG is higher than other greenhouses and the temperature values of other greenhouses are closer to each other. Daytime temperature values were 14°C, 20°C, 12°C and 11°C (LED, TrG, RG and BG respectively). We observed that the temperature suggested for the germination period of radish plant was achieved in LED, RG and BG greenhouses. We determined that the daytime average temperature in the TrG exceeded several degrees the recommended value required during radish germination period. Researchers determined that the radish plant requires low temperature in order to switch from vegetative development to generative development, that it would not flowering with average night temperature value reached to approximately 4-10 °C in initial 4-8 weeks in particular, and that it would not produce any fruits and seeds (Anonymous 2009). In the greenhouses where the research was conducted, average night temperature values were determined as 7.4°C, 14.1°C, 6.7°C and 6.1°C in the greenhouses of LED, TrG, RG and BG respectively. When we analysed solar energy values measured in the specified date, we determined that these values were listed as LED>TrG>RG>BG from higher to lower respectively. Researchers determine that the minimum intensity required for plants to perform direct solar photosynthesis received by leaves has a value that ranges between 80 and 110 Wm^{-2}. However, it was reported that this value must not be below 500 Wm^{-2} in order to allow the plant to perform photosynthesis on all of its leaves completely (Anonymous 2017, Tunçbilek 2019). We determined that, in relative

date, the highest solar energy values were obtained between 12:00 and 15:00 pm, and that it exceeded the value of 500 Wm^{-2} in TrG and LED greenhouse.

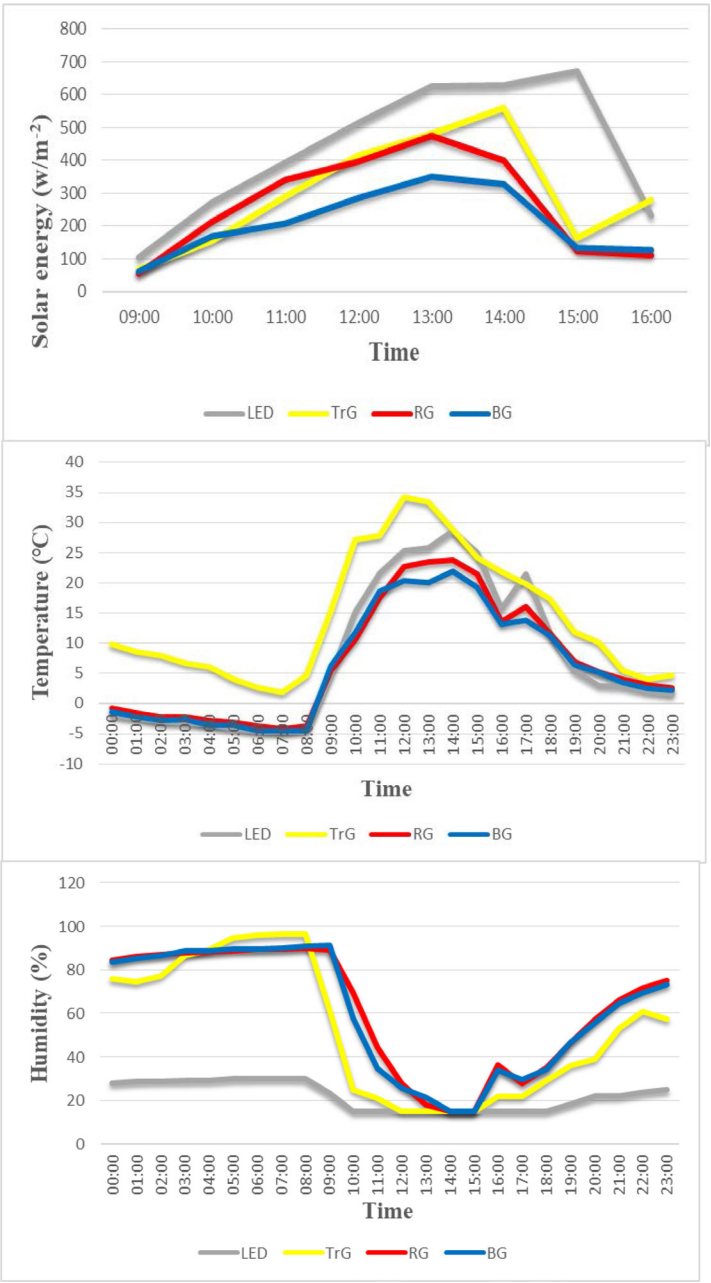

Figure 1. Solar energy, temperature, humidity values in greenhouses (21.02.2019)

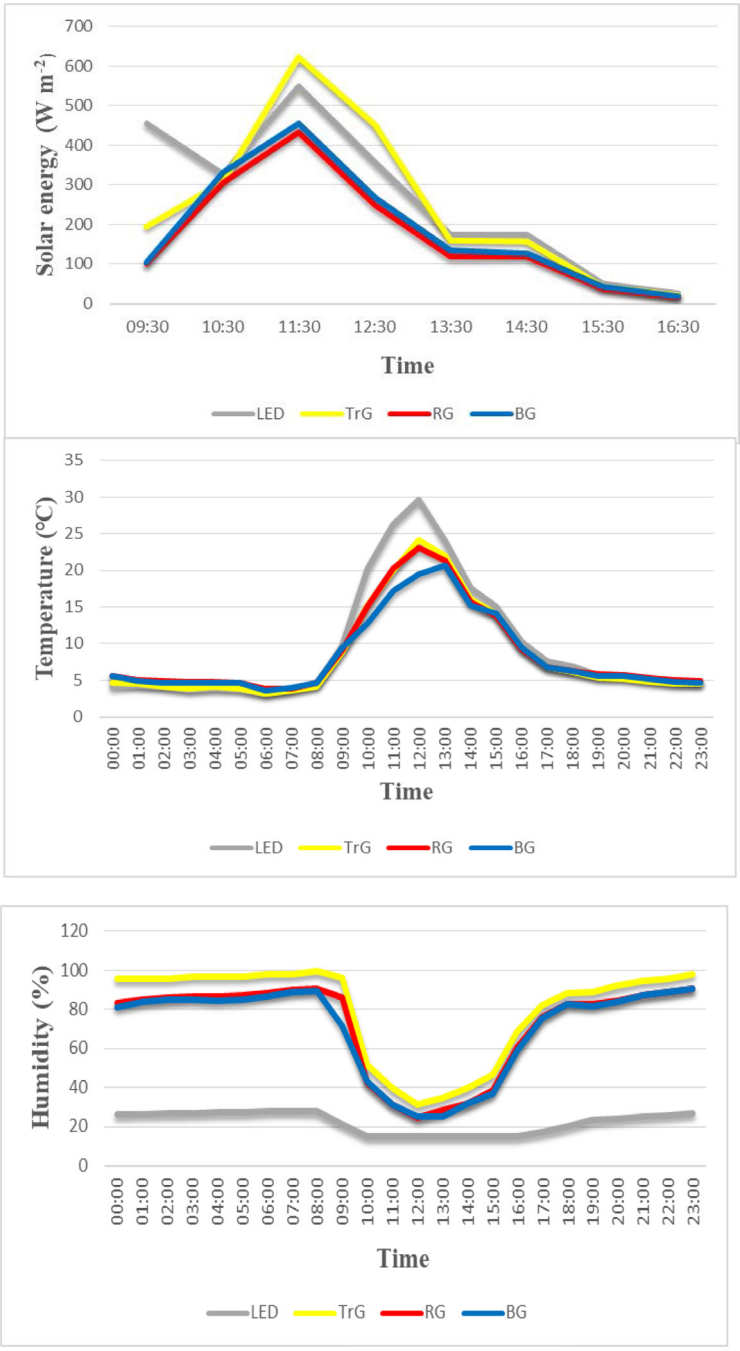

Figure 2. Solar energy, temperature, humidity values in greenhouses (03.03.2019)

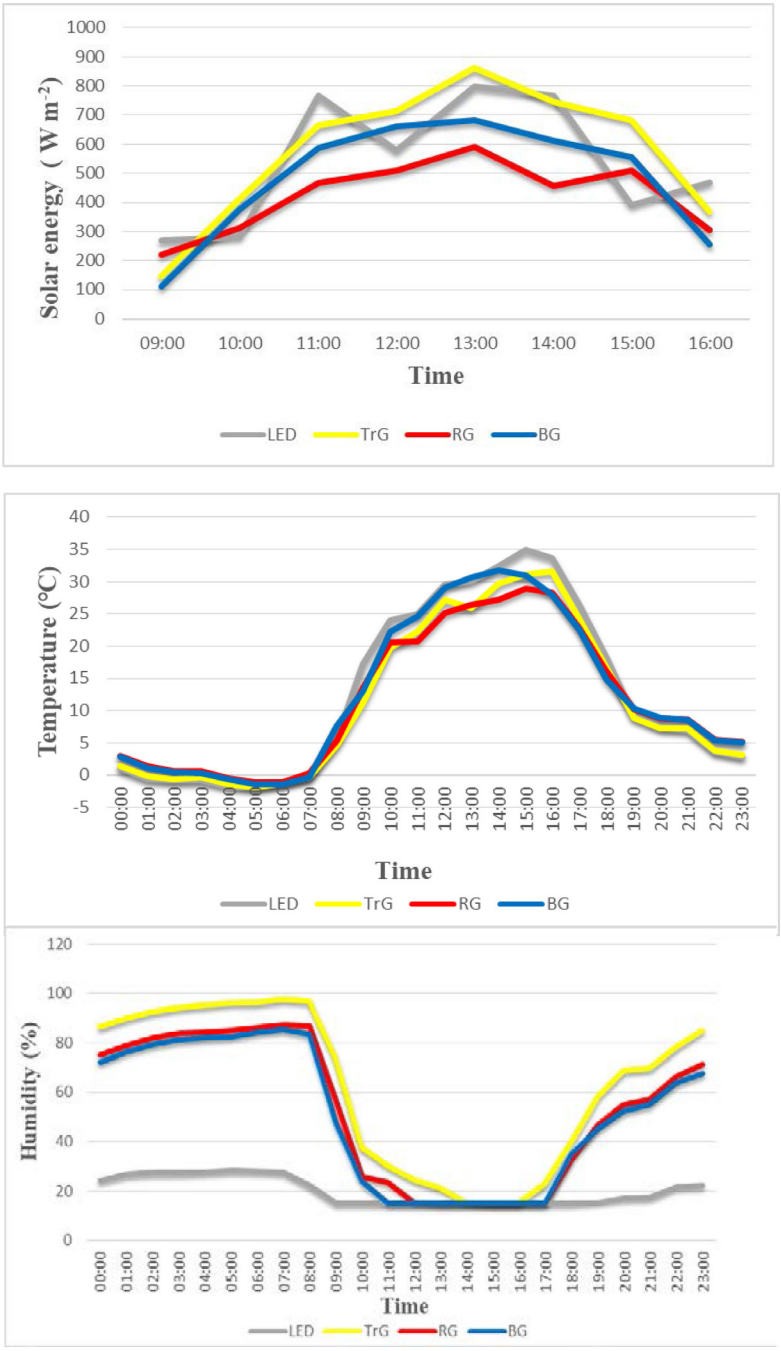

Figure 3. Solar energy, temperature, humidity values in greenhouses (27.03.2019)

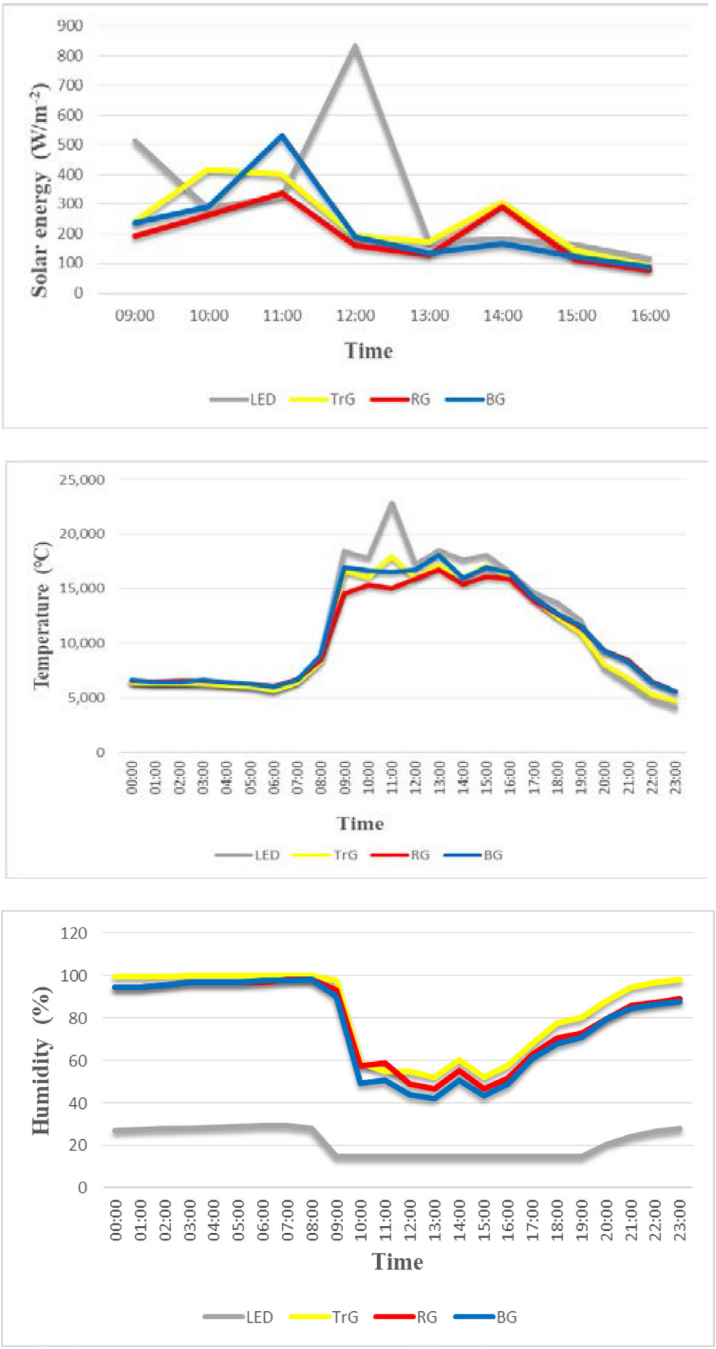

Figure 4. Solar energy, temperature, humidity values in greenhouses (11.04.2019)

We determined that average solar radiation values of LED, TrG, RG and BG were measured as 430.4, 300.5, 264.9 and 206.5 Wm-2 respectively between 10:00 am-16:00 pm. According to the reports provided by researchers, there is a linear correlation between intensity of solar energy and dry matter production, but in case effective solar energy is analysed photosynthetically, it was determined that all of the plants have a saturation point in order to perform photosynthesis, that photosynthesis ratio varies for each plant based on PAR quantity, and that plants may be subjected to heat stress, if required level of PAR is exceeded (Kürklü 1995). On 21.02.2019, the highest average daytime temperature was measured in TrG greenhouse, and the highest solar energy value was measured in LED greenhouse.

In the growth period of radish plant, which took 21 days (03.03.2019), we determined that average daytime temperature value measured in greenhouses was 16°C and that night temperature was ranging from 4°C to 15°C approximately. We determined that this value is between the normal temperature values required for the radish plant. Researchers reported that the daily average temperature of the radish plant must range from 4°C to 18°C in the post-germination growth period. In case the temperature exceeds 20°C in areas where radish plant is planted, it was determined that root development of the plant would decelerate and that spots would be observed on leaves, and in case the temperature is below 10°C, then it was determined that early jointing and vernalisation would occur. Radish plant is listed in the group of plants sensitive to vernalisation (Anonymous 2009). In the specified date, it was determined that temperature values measured at night were as 4.41°C, 4.43°C, 5.0°C and 4.49°C in LED, TrG, RG and BG respectively. Average daytime temperatures were as 13°C, 11°C, 11°C and 11°C respectively. We determined that obtained results are within the temperature values recommended by researchers. As we examined solar energy that occurred in the aforementioned date, we observed that LED, TrG, BG and RG were listed from higher to lower respectively. Average solar energy values of LED, TrG, BG and RG were measured as 263.8, 244.8, 170.5 and 184.8 Wm^{-2} between 10:00 am and 16:00 pm respectively. No time interval, in which solar radiation value exceeding 500 Wm^{-2}, was observed in the relative date. LED greenhouse reached to the highest solar radiation value. Thus, we observed that solar energy and temperature are directly proportional and that solar energy value was high as well in the greenhouse, in which daytime temperature value was the highest on 03.03.2019.

Measurement values of radish plant are provided for the growth period of 45 days (27.03.2019). It was determined that the temperature value required by or suggested for the radish plant in the post-germination growth period was ranging from 18°C to 26°C in daytime, and from 4°C to 15°C in the night. We observed that the greenhouses, in which the radish plant was produced for 45 days and which had four different cover materials within the scope of the research,

had temperature values similar to recommended temperature values in daytime. However, it was determined that temperature values measured at night were close to minimum temperature values. Researchers reported that the temperature must be above 15°C for the radish plant at night (Anonymous 2019b). Average night temperature values were 3.2°C, 3.2°C, 4.3°C and 4.2°C in LED, TrG, RG and BG respectively and average daytime temperature values were 21°C, 19°C, 18°C and 20°C in LED, TrG, RG and BG respectively. As we examined the solar energy values of radish plant in the growth period of 45 days, TrG obtained the highest value and this value was followed by LED, BG and RG respectively. In the aforementioned period, it was determined that the approximate time period when solar energy values were the highest was between the range of 13:00 and 14:00 pm. With the value of 574.78 Wm^{-2}, TrG had the highest value among relative time periods, and it was followed by LED with the value of 540.03 Wm^{-2}, by BG with the value of 478.23 Wm^{-2} and by RG with the value of 419.82 Wm^{-2}.

We observed that the radish plant was in the flowering period in the 60th day. On April 11, 2019, we determined that average daytime temperature values of LED, TrG, RG and BG were as 15 °C, 14 °C, 13 °C and 14 °C respectively. Researchers report that these values may be listed among temperature values that are suitable for the radish plant (Anonymous 2009).

Average daytime temperature averages measured in the harvesting period were as 22°C, 20°C, 19°C and 21°C in LED, TrG, RG and BG respectively. We determined that such values constitute the optimal temperature value for radish plant in the harvesting period. In general, we observed m^{-2} temperatures higher than the temperature values suggested in the vegetative development period of the radish plant. We considered that such situation causes leaves of the radish plant to develop rapidly, as well as deceleration of root development. In the aforementioned date, it was determined by measurements that time periods, in which solar radiation value was above 500 Wm^{-2} in greenhouses, were between 10:00 am and 15:00 pm. Therefore, LED greenhouse reached to the highest solar energy values with the longest period. In consideration of the growth process of 81 days, we examined the differences between radish plants by weight after harvesting in four experimental greenhouses, which had cover materials in different colours, and values related with the growth period in the greenhouse conditions are shown in Figure 5. Total plant root weight of TrG, RG, BG and LED was found as 86.4 g, 66 g, 54 g and 45.2 g respectively from higher to lower.

Root diameters of the radish plant was measured by compasses, and relative values are given in Figure 6. As we analysed the root diameter of the radish plant in average by greenhouse types, highest head diameter was observed in the TrG. As we listed the average plant head diameters from higher to lower in four greenhouses, we found the values of 29 cm, 27.9 cm, 27.1 cm and 24.9 cm in TrG, RG, BG and LED greenhouses respectively.

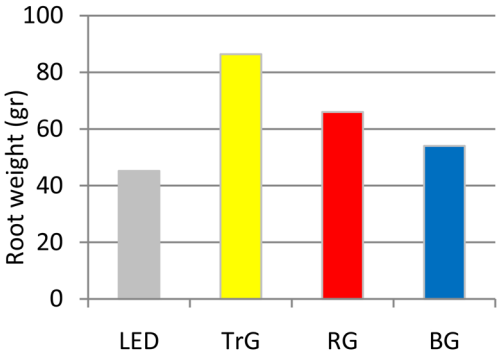

Figure 5. Average values of root weight

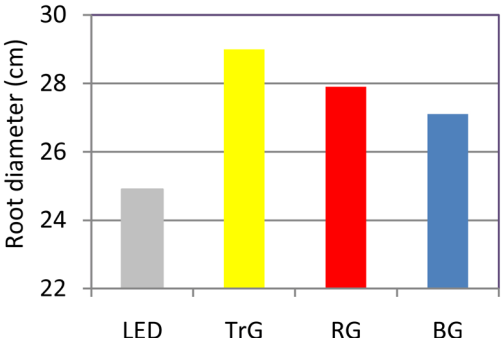

Figure 6. Average values of root diameters

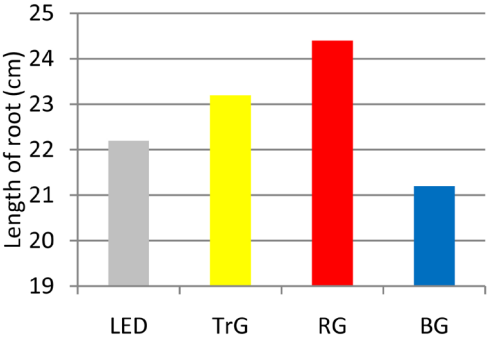

Figure 7. Average length of root

Length of root development values of the radish plant are shown in Figure 7. In the measurements we performed, we determined that the highest value in terms of plant length was obtained by RG, and that the lowest value was obtained by BG greenhouse.

As we examined the values related with the weight of green parts, we determined that the highest value was obtained by TrG, and that the lowest value was obtained by LED greenhouse. Averages of these values are as below 192.8, 150.8, 146.4, 78.3 gr (TrG, BG, RG and LED) respectively (Figure 8).

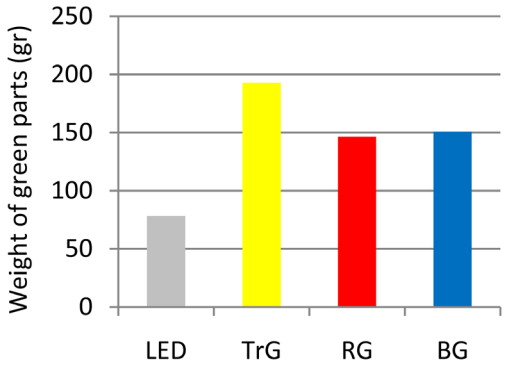

Figure 8. Average weight of green part

Measurement procedures performed on the length of green parts are shown in Figure 9. The length of green parts was measured from highest to the lowest in RG, LED, TrG and BG respectively, and their averages were obtained as 74.7 cm plant^{-1}, 72.1 cm plant^{-1}, 67.8 cm plant^{-1} and 64.7 cm plant^{-1} respectively.

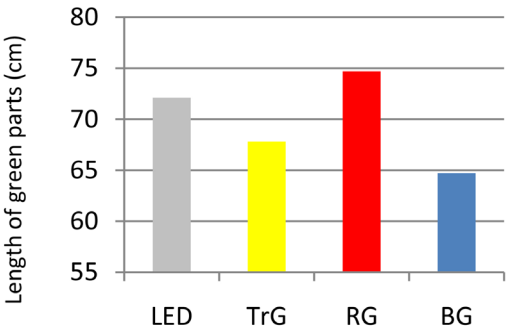

Figure 9. Average length of green part

As a result of measurements and analyses performed in the laboratory after harvesting procedures, we observed that radish plants grown in BG developed more improperly (double head and unevenness in the root area of the plant etc.) in terms of shape in comparison to plants that were grown in other greenhouses (TRG, RG and LED).

Differences between the averages of 5 variables (root diameter, root length, root weight, length of green parts and weight of green parts) measured after the harvesting of radish plant grown by LED light with cover materials in various colours (TrG, RG and BG) within the scope of greenhouse growing were analysed by using Tukey Test-one way analysis of variance. Descriptive statistics of greenhouses used in the study are given in Table 1. According to the result of the analysis of variance performed by the result of Tukey test in terms of the characteristics of root diameter, root length, root weight and weight of green parts, the difference between the averages of LED, TrG, RG and BG greenhouses was significant statistically.

Table 1. Descriptive statistics of root diameter, root length and root weight characteristics and Tukey test results

	Diameter of root (cm)	Root lenght (cm)	Root weight (gr)	Green component length (cm)	Green component weight (gr)
LED	25.0^{B}	22.2^{B}	45.4^{C}	71.6	78.4^{C}
KOS	28.7^{A}	23.2^{AB}	83.0^{A}	67.3	187.6^{A}
KS	27.8^{A}	24.4^{A}	65.9^{B}	74.8	146.9^{B}
MS	27.3^{AB}	21.5^{B}	55.2^{BC}	66.3	154.5^{B}
	**	**	**		**

*P<0.05, ** P<0.01 Capital letters indicate the results of the Tukey test. Different letters indicate that the means are different.

CONCLUSIONS

We determined that the values that were obtained when solar energy values reached to minimum-maximum levels in the dates when measurements performed were ranging from 26 Wm^{-2} and 1053 Wm^{-2} in LED, from 21.1 and 856.6 Wm^{-2} in TrG, from 17.9 Wm^{-2} and 680.3 Wm^{-2} in BG and from 14.3 Wm^{-2} and 633.1 Wm^{-2} in RG respectively. While the lowest solar energy value was found almost the same, the highest solar radiation value was obtained in the greenhouse with LED light and in the greenhouse with transparent coloured cover material. Therefore, the highest average daytime temperature values were

measured in the LED greenhouse in several growth stages. Thus, we considered that the LED greenhouse increased ambient temperature and that lighting effect made a positive impact on solar energy as well. We considered that transparent coloured other greenhouse provided higher values in comparison to BG and RG because of the fact that solar energy values were higher in the TrG since light refractions and reflections were higher in red and blue coloured greenhouses. As we examined average temperature values, we determined that temperatures ranged from 13°C to 16°C in LED greenhouse, from 6.5°C to 15°C in TrG, from 6°C to 14°C in BG, and from 6.5°C to 12.2°C in RG. The highest average internal greenhouse temperature value was observed in LED greenhouse, and it was followed by TrG, BG and RG. In greenhouses, cover material of which were painted in red and blue, particularly in RG, we considered that it had a lower internal temperature in comparison to other greenhouses since the cover material absorbs heat. Therefore, by considering that it may be beneficial for the sustainability of production, we may emphasize that usage of coloured cover material may be recommended to areas, in which temperature values are very high, in greenhouse growing particularly in the summer time. We are of the opinion that LED greenhouse may be beneficial in long daytime plants that like light, such as radish plant in particular, in areas where one may not be engaged in growing due to cold since average temperature values are measured as high. However, since the heat diffused by the LED device in the LED greenhouse may have increased transpiration in the plant, it may be considered as the reason why the dry weight of the plant is lower than the plants in other greenhouses. Also, we consider that LED causes extension of the stem length and deceleration of the root development of radish plant with the effect of high temperature following flowering period. Therefore, it may be recommended to use LED until flowering period (first 4-8 weeks). We determined that the appearance of plants grown in the greenhouse, cover material of which was painted in blue, was different than the appearance of plants grown in the other greenhouse (deformity in the root area, double – headed etc.). Therefore, considering the negative difference in the appearance of radish plants grown in BG, it is not recommended to grow radishes in BG.

REFERENCES

Anonymous (2009). *Turp Yetiştiriciliği*. http://hbogm.meb.gov.tr/modulerprogramlar/kursprogramlari/ bahcecilik/moduller/turp_yetistiriciligi.pdf (date of access: 11.02.2019)

Anonymous (2017). Light and Lighting Control in Greenhouses https://www.arguscontrols.com/resources/ Light-and-Lighting-Control-in-Greenhouses.pdf (date of access: 15.02.2019).

Anonymous (2019a). Radish Cultivation. https://defteriniz.com/turp-sebze-

yetistirme/20923 (date of access: 16.05.2019).

Anonymous (2019b). Radish Cultivation. http://www.tarimsalistatistik.com/tr-TR/Sayfa/turp-yetistiriciligi (date of access: 10.02.2019).

Bula, R.J., Morrow, R.C., Tibbitts, T.W., Barta, D.J., Ignatius R.W., Martin, T.S. (1991). Light emitting diodes as a radiation source for plants. HortScience 26: 203-205.

Barta, D.J., Tibbitts, T.W., Bula, R.J., Morrow, R.C. (1992). Evaluation of light emitting diode characteristics for a space-based plant irradiation source. Advances Space Research 12: 141-149.

Britz, S.J., Sager, J.C. (1990). Photo morphogenesis and photo assimilation in soybean and sorghum grown under broad spectrum or blue deficient light sources. Plant Physiology 94: 448–454.

Bouyoucos, G.J. (1962). Hydrometer Method Improved for Making Particle Size Analyses of Soils. Agronomy Journal 54(5): 464-465.

Demiralay, İ. (1993). Toprak Fiziksel Analizleri. Atatürk Üniversitesi Yayınları No:143, Erzurum.

Eğilmez, Z.H. (2019). Sera Yetiştiriciliğinde Farklı Renklerdeki Sera Örtü Malzemelerinin Bitki Gelişimine Etkileri: Turp Örneği, Isparta Uygulamalı Bilimler Üniversitesi, Lisansüstü Eğitim Enstitüsü Yüksek Lisans Tezi, Tarımsal Yapılar ve Sulama Anabilim Dalı.

Kasım, R., Kasım, M.U. (2016). Işık Yayan Diyot (Led) Teknolojisinin Meyve Ve Sebzelerin Hasat Sonrası Dönemindeki Uygulamaları, VII. Bahçe Ürünlerinde Muhafaza Ve Pazarlama Sempozyumu, 04-07 Ekim 2016, 86-93.

Kim, H.H., Wheeler, R.M., Sager, J.C., Yorio, N.C., Goins, G.D. (2005). Light-emitting diodes as an illumination source for plants: A review of research at Kennedy Space Center. Habitation (Elmsford) 10: 71-78.

Kürklü, A. (1995). Güneş Işınımı ve Hava Sıcaklığı Açısından Bitki Çevre İlişkileri. Akdeniz Üniversitesi Ziraat Fakültesi Dergisi, 8: 225-229.

Massa, G.D., Emmerich, J.C., Morrow, R.C., Bourget, C.M., Mitchell, C.A. (2006). Plant growth lighting for space life support: A review Gravit. Space Biology, 19: 19-29.

Öztürk, H.H. (2008). Güneş Enerjisi ve Uygulamaları. Birsen Yayınevi Ltd. Şti., 277. İstanbul.

Swinkels, G.L.A.M., Sonneveld, P.J., Bot, G.P.A. (2001). Improvement of Greenhouse Insulation with Restricted Transmission Loss through Zigzag Covering Material. J. Agricultural Engineering Research, 79(1): 91-97.

Tunçbilek, F. (2019). Sera Yetiştiriciliğinde Farklı Renklerdeki Örtü Malzemelerinin Gelişim Üzerine Etkileri: Marul Örneği (YL Tezi, Isparta Uygulamalı Bilimler Üniversitesi, Lisansüstü Eğitim Enstitüsü).

Waaijenberg, D. (1989). Standard for Film-Covered Greenhouses. Engineering and Economic Aspects of Energy Saving in Protected Cultivation. Acta Horticulture 245: 78-85.

Yorio, N.C, Mackowiak, C.L., Wheeler, R.M., Sager, J.C. (1995). Vegetative growth of potato under high-pressure sodium, high-pressure sodium SON-Agro, and metal halide lamps. HortScience 30: 374-376.

Corresponding author: Prof. Dr. Atilgan Atılgan
E-mail: atilganatilgan01@gmail.com
ORCID: 0000 0003 2391 0317
Isparta University of Applied Sciences
Faculty of Agricultural Sciences and Technologies
Department of Agricultural
Str. And Irr., 32160-Çünür-Isparta-TURKEY
Phone:+90 246 2118567

Received: 17.09.2019
Accepted: 13.10.2019