INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

2025, Vol. 20(1), 119–129
e-ISSN: 2956-7971, License CC-BY 4.0

DOI: https://doi.org/10.14597/infraeco.2025.008

USE OF BUMBLEBEES AND COLORED COVER MATERIALS IN GOOD AGRICULTURAL PRACTICES

Atılgan ATILGAN [1], Dilara DURAK [1], Burak SALTUK [1]

ABSTRACT

Greenhouse activities are increasing in the Mediterranean region and constitute a large portion of agriculture. Climatic conditions can be controlled in greenhouse activities. Wind, one of the most important parameters, is less effective inside the greenhouse than outside through natural means. The study was conducted in experimental greenhouses on the Alanya Alaaddin Keykubat University campus. Three experimental greenhouses were 3x12 m in size. The first greenhouse featured a transparent cover material (CG), the second utilized a blue cover material (BG), and the third was equipped with a blue cover material and inhabited by bumblebees (BBG). Following these treatments, parameters such as plant width, length, weight, stem diameter, total yield, marketable yield, average fruit weight, and leaf chlorophyll content were determined. It was determined that the BBG greenhouse achieved the highest yield, plant height, and fruit equivalent diameter values. Furthermore, the BBG variant achieved the lowest fruit firmness values. This is thought to be due to its faster development and faster maturity compared to other greenhouses. Therefore, it has been determined that both the blue color and bumblebees positively affect tomato plant development parameters in the BBG greenhouse. Therefore, we believe that implementing good agricultural practices to achieve higher yields is a better step for both the environment and health.

***Keywords**: greenhouse, cover material, bumblebees, colour*

INTRODUCTION

Greenhouse farming activities are highly developed in our country, especially in the Mediterranean region. It is possible to control climate conditions and environmental factors through greenhouse cultivation. Factors such as light, humidity, carbon dioxide, temperature, and ventilation can be controlled (Atılgan et al., 2019). Wind speeds inside greenhouses are relatively lower than in open areas due to structural barriers and limited ventilation openings (Boulard and Draoui, 1995; Khaoua et al., 2006; Li et al.,

[1]*Alanya Alaaddin Keykubat University, Alanya, Türkiye*

2024). The majority of plant species used for food production require pollination (Klein et al., 2007; FAO, 2018). Pollination occurs in various ways. Plants self-pollinate, pollinate by other insects present in the environment, or pollination by the wind. The use of insects is a necessary natural method for plants that cannot self-pollinate due to low wind speeds in greenhouses. Bumblebees are the most commonly used insects. These bees pollinate by vibrating their wings and moving pollen (Kwon and Saeed, 2003). Bumblebees have the advantage of having longer tongues compared to other pollinator bees. Furthermore, because they are heavier and hairier than other species, they are less affected by cold winter temperatures and their performance declines less than other species (Velthuis and Van Doorn, 2006). There are many species of bumblebees. The most preferred species in cultivation is *Bombus terrestris*. The main factor in this species' popularity is its commercial abundance. These bees are traded worldwide in countries using advanced greenhouse techniques, such as the Netherlands, Israel, Belgium, and New Zealand. Similarly, with the increasing use of greenhouse farming in recent years, a demand for the use of bumblebees has begun to emerge in Turkey (Karaman and Yılmaz, 2007).

The number of colonies considered for pollination in the growing region varies depending on the plant species and climate. On average, 1-4 colonies are used for every 0.4 hectares (Topal et al., 2018). The lifespan of these bees placed in greenhouses is approximately two months for a 0.15-0.2 hectare greenhouse area. This lifespan and pollination performance vary depending on many factors, including the plant species, the location of the hive within the greenhouse, the presence and abundance of different insect and parasite species, the use of pesticides, and the environmental conditions within the greenhouse. Furthermore, the amount of sunlight affects the growth, development, and mobility of colonies (Gürel et al., 2011). Bumblebees are used as pollinators for many plants, especially eggplant, tomatoes, and peppers. Each plant's colony needs also vary. For example, the cherry tomato crop requires at least twice as many colonies per hectare as the beef tomato crop because it has a large number of flowers (Velthuis and Van Doorn, 2006).

UV light is a necessary component for bumblebees' vision quality and movement. Therefore, the transmission rate of UV light also affects their behavior. The amount of UV light transmitted varies depending on the greenhouse cover material. While 80% of UV light passes through glass cover, less UV light passes through plastic covers such as polyvinylchloride (PVC) and polycarbonate (PC). Therefore, bumblebees cannot perform as well under plastic cover as they do under glass greenhouses. It has also been observed that bees are reluctant to leave their hives when using PVC and PC cover materials (Peitsch et al., 1992; Gürel et al., 2011). It is anticipated that this negative situation can be eliminated by coloring the commonly used and more economical plastic cover material. While bees cannot see red, they can see yellow, green, blue, and UV light. This is because each ommatidium contains four cells that respond to yellow-green light, two cells that respond most to blue light, and two permanent vision cells that respond best to ultraviolet light (Gülperçin, 2015). Observations of the frequency of visits to colorful flowers under natural conditions indicate that bumblebees have a particular preference for blue (Gumbert, 2000).

Light is one of the most important factors affecting plant growth stages, such as seed germination, bud opening, and the development of vegetative parts of plants. Light is one of the environmental factors that plays a crucial role in plant growth and development, affecting plants at various levels from seed germination to plant death. In situations where solar energy is insufficient for plant production and in growing cabinets lacking sunlight, the use of artificial light sources is becoming more common (Bayhan and Avcı, 2019).

The light spectrum in the growth medium greatly affects plant development and plant physiology (Hogewoning et al., 2010). For example, blue light plays a role in a wide variety of plant processes, including phototropism, photomorphogenesis, stomatal opening, and leaf photosynthetic function (Whitelam and Halliday, 2007; Hogewoning et al., 2010). In an experiment conducted on tomato plants by Xu et al. (2012) using blue, white, and red LED lamps, the plants showed greater disease resistance under blue light illumination. Additionally, increased fruit yield and higher quality crops were obtained. The aim of this study was to determine the effects of bumblebees and colored cover material on tomato plant development parameters. For this purpose, two greenhouses were painted blue, and bumblebees were placed in one of the painted greenhouses. By comparing these two painted greenhouses with the control greenhouse, the effects of both the blue color and bumblebees on tomato plants were determined.

MATERIALS AND METHODS

General Characteristics of the Study Area

The research was conducted in 2023-2024 in the Biosystems Engineering trial greenhouses at Alanya Alaaddin Keykubat University. There were three trial greenhouses, each measuring 3 x 12 m. Two of these greenhouses were covered with transparent polyethylene sheeting and painted blue. A bumblebee was placed inside one of the blue greenhouses, and the study was completed using transparent polyethylene (control) sheeting in the other greenhouse.

Climate Characteristics

Located in the Mediterranean region of southern Turkey, Antalya-Alanya experiences a typical Mediterranean climate, with hot, dry summers and mild, rainy winters. Winters are generally summer-like. The district's average annual temperature is around 23 °C. The warmest month of the year is July, with an average temperature of approximately 33 °C. January, the coldest month, averages 12 °C. According to precipitation data, the region receives the most precipitation in December, with an average of 118 mm (118 mm). The lowest annual precipitation is measured in August, with 11 mm (11 mm). These climate characteristics have been found suitable for tomato cultivation during the winter months. Bumblebees can cultivate fields at altitudes up to 1,500 meters. They are also capable of surviving in areas with annual rainfall of less than 339 mm and more than 10,000 mm. The Mediterranean Alanya region is not subject to the low temperatures that affect bumblebees' performance. Therefore, the Alanya region is suitable for tomato cultivation between November and June.

Greenhouse Growing Media and Biological Materials

Tomato seedlings were planted in three rows in each greenhouse. The greenhouses used in the trials were constructed of iron pipe profiles. The greenhouse cover material used in the trials was soft plastic sheeting (PE) with a 3-year warranty (UV+LD+IR+EVA).

The blue greenhouses were constructed by powder-coating the transparent cover material on the inside. The greenhouse windows were covered with netting to prevent bumblebees from escaping.
Greenhouse 1: Transparent cover material (CG)
Greenhouse 2: Blue cover material (BG)
Greenhouse 3: Blue cover material + Bumblebee (BBG)

Soil preparation and seedling planting

After tilling the soil to control weeds in the research greenhouses, tomato seedlings were planted in three rows, with a distance of 50 cm between rows and 70 cm between rows. A total of 90 tomatoes were planted, 30 per greenhouse.

Irrigation and Fertilization

Drip irrigation (4 $dm^3 \cdot h^{-1}$) was used as the irrigation method. Fertigation was applied to the root zone using drip irrigation pipes installed in the greenhouses, providing the plants with the necessary water and fertilizer. The dripper spacing was 40 cm. Irrigation was carried out once or twice a week, depending on irrigation water needs, to avoid disturbing the bees.

Determining Plant Evapotranspiration in Greenhouses

The FAO-24 evaporation cup method (Doorenbos and Pruitt, 1977) has been reported to provide good results in calculating ET0 in greenhouses under Mediterranean climate conditions with a Kpan (cup coefficient) of 0.79 (Fernandez et al., 2010). Tomato evapotranspiration was calculated using the following equation:

$$ET_0 = Kp \times Eo \tag{1}$$

where:
ET_0 – Reference evapotranspiration ($mm \cdot day^{-1}$)
Kpan – Pan coefficient (0.79 for greenhouses)
Eo – Pan evaporation ($mm \cdot day^{-1}$)
ETc – ETo x Kc
ETc – Evapotranspiration for tomatoes
Kc – Crop coefficient

Equivalent diameter measurement (mm) was calculated usung the following equation:

$$D_p = [L \cdot \frac{(W+T)^2}{4}]^{\frac{1}{3}} \tag{2}$$

where:
Dp = Equivalent mean diameter (mm)
L = Length (mm)
W = Width (mm)
T = Thickness (mm)

Determining the number and location of bumblebees in the greenhouse

The hive was placed in the center of the greenhouse to avoid hindering soil cultivation, prevent movement within the greenhouse, and allow the bees to enter and exit easily. The bees were placed in the greenhouse during the flowering period of the tomato plants. The behavior of the bumblebees was studied through observation in the greenhouses where they were located. Photographic monitoring was carried out at regular intervals.

RESULTS AND DISCUSSION

The results obtained during the study were expressed in three different groups. The first group was the greenhouse with blue cover material and bumblebees (BBG), the second group was the greenhouse with blue cover material (BG), and the final group was the control greenhouse with transparent cover material (CG). For this purpose, five plant samples were selected for each greenhouse to represent the average for spad values. Ten spad measurements were taken from each selected plant, as shown in Fig. 1, and the averages were calculated. Based on the data obtained, chlorophyll levels in plant leaves were compared in the greenhouse studies. The average of spad measurements taken from five plants in the blue greenhouse was 42.10, for the BBG 40.23, and finally, the average spad measurement in the CG was 42.66. Considering the data, it was observed that the highest spad value was in the control greenhouse, followed by the blue greenhouse, and finally the blue bee greenhouse. Based on other measured parameter values and observations, it was determined that tomatoes developed and harvested earlier in the BBG, followed by the BG, and finally the control greenhouse. Since the BG development was higher than the control greenhouse during the period when the samples were taken, the decrease in the spad value is thought to be due to the larger leaves and faster development of tomato seedlings.

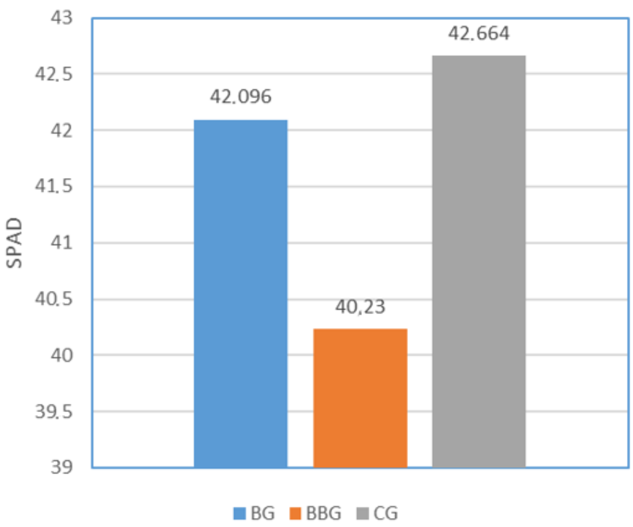

Figure 1. Chlorophyll levels in tomato plant leaves in greenhouses.

The average plant heights taken from 10 plants randomly from each greenhouse are given in Fig. 2. When the data were averaged for each greenhouse, the height values were determined as 151 cm for the blue greenhouse, 155.1 cm for the blue bee greenhouse, and 116.4 cm for the control greenhouse. No significant difference was observed between the average plant height measured in the blue bee greenhouse and the blue greenhouse, and higher results were obtained compared to the control greenhouse. In an experiment conducted by Demirsoy (2016) with different color light sources on tomatoes, peppers, and eggplants, it was determined that seedling root length, root dry weight, leaf dry weight, total plant dry weight, leaf thickness, plant height, growth rate, and yield amount reached the highest values in plants grown with blue light application in all examined species, and they were found to be recommendable. In their color study on tomato plants, Çetin and Atılgan (2020) found that higher height measurements were obtained in the greenhouse using blue greenhouse cover material than in the control greenhouse. Since similar results were obtained in our study and the parallelism of the data was taken into account, it is thought that development will be achieved earlier by using this blue color cover material.

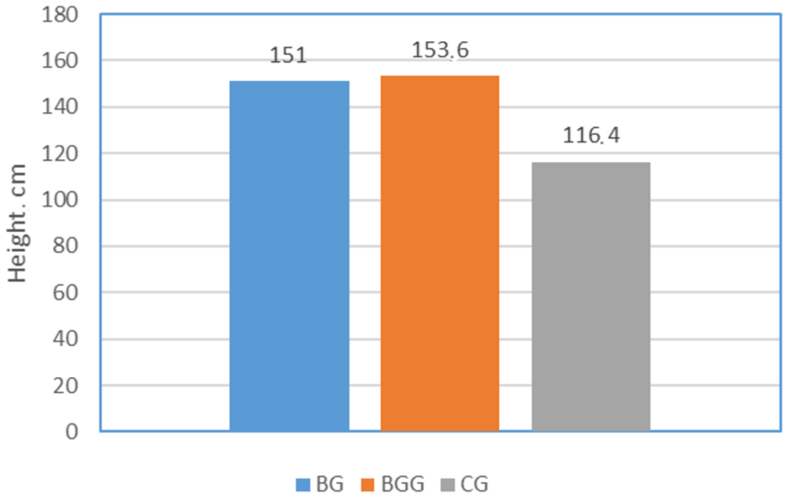

Figure 2. Plant height values obtained during the growth and development of tomato plants.

Data were collected for plant stem diameter from each greenhouse.. The average values for the plant stem diameters were determined as 10.5 mm in the blue greenhouse, 10.8 mm in the blue bumblebee greenhouse, and 9.3 mm in the control greenhouse (Fig. 3). As with the height measurements, the lowest average plant diameters were measured in the control greenhouse. This is believed to be due to the blue cover material increasing photosynthesis rates.

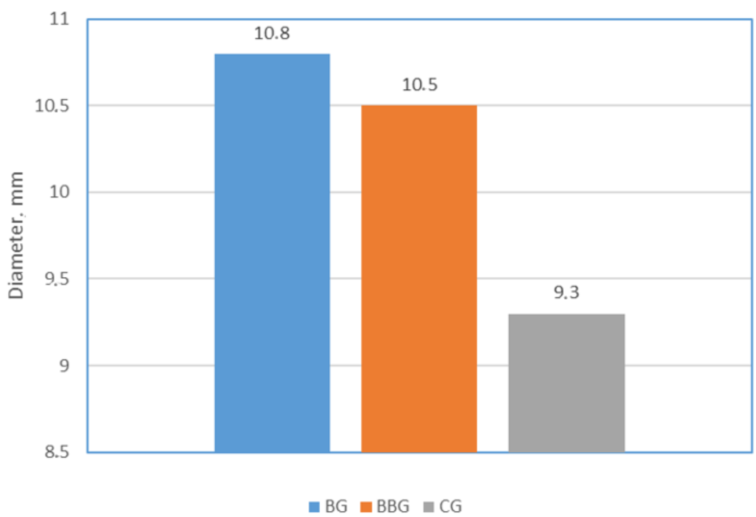

Figure 3. Stem diameter values of tomato plants in greenhouses.

The values obtained from plant samples taken from each experimental greenhouse were calculated according to Equation 2, and the equivalent diameter values are shown in Fig. 4. When the average of the equivalent average diameters was also calculated, the largest equivalent average diameter was measured as 63.03 mm from the blue-bee greenhouse. The equivalent average diameter values were then measured and calculated as 62.75 mm from the blue greenhouse and 62.7 mm from the control greenhouse, respectively. Based on these data, it is thought that the greenhouse with the largest fruit size was the blue bumblebee greenhouse. This is due to the blue cover material, which increases plant photosynthesis rates, and the bumblebees' contribution to pollination, leading to earlier fruit production and earlier plant development.

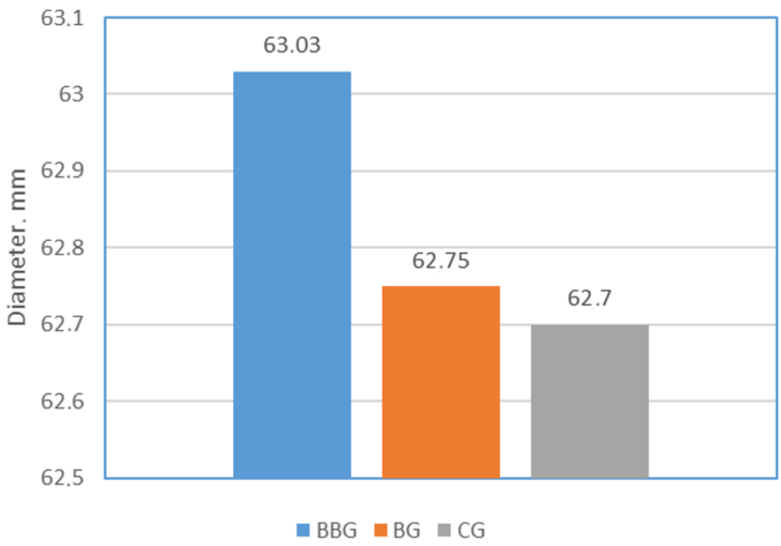

Figure 4. Equivalent average diameter values of tomato plants in greenhouses.

The hardness measurements of tomato plants are shown in Fig. 5. The average hardness value obtained from measurements in the greenhouse using blue-colored cover material was 5.99 kg·cm^{-2}. The average hardness value of tomato plants in the blue-colored greenhouse with bumblebees was measured as 5.85 kg·cm^{-2}. In the control greenhouse, where the greenhouse cover material was polyethylene, the hardness value of tomato plants was 5.96 kg·cm^{-2}. As can be seen from the measurements, the highest hardness value for tomato plants was measured in the greenhouse with blue cover material, 5.99 kg·cm^{-2}. It is estimated that the blue-colored greenhouse with bumblebees has an impact on growth and development in tomato plants, causing earlier ripening (determined by color, shape, and hardness), preventing water loss, and ensuring uniform growth, resulting in lower hardness values.

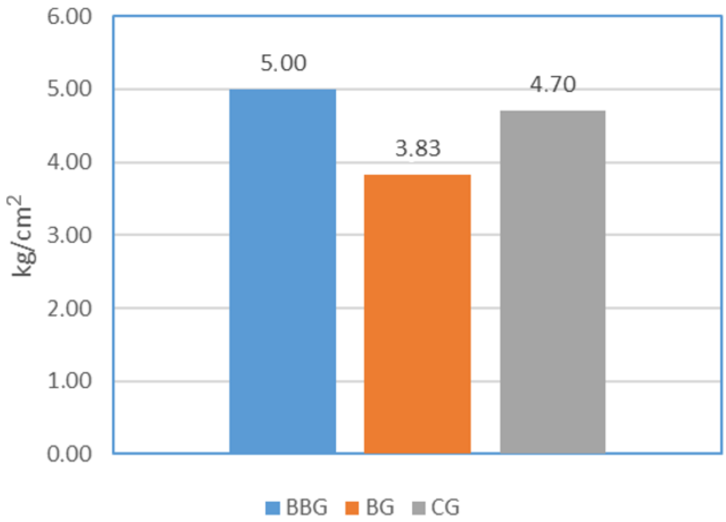

Figure 5. Fruit hardness values of tomato plants in greenhouses

Harvest values for the resulting tomato plants are shown in Fig. 6. According to the results, the highest yield, 44.66 tons·ha^{-1}, was obtained from the greenhouse with blue and bumblebees (Fig. 6). These values were then measured as 39.86 tons·ha^{-1} from the blue greenhouse and 35.56 tons·ha^{-1} from the control greenhouse, respectively. Based on the literature review, it is thought that the higher yield in greenhouses BG and BBG compared to the control greenhouse is due to higher photosynthetic rates, which in turn promotes earlier plant development and more flowering while still young. Comparing the data obtained from the blue and bumblebee greenhouses with other greenhouses, a noticeable increase in yield was observed due to both light and bee pollination support. Observations within the greenhouse throughout the flowering period revealed consistent bee activity. The increased yield is believed to be due to the blue cover material supporting both bee activity and plant growth.

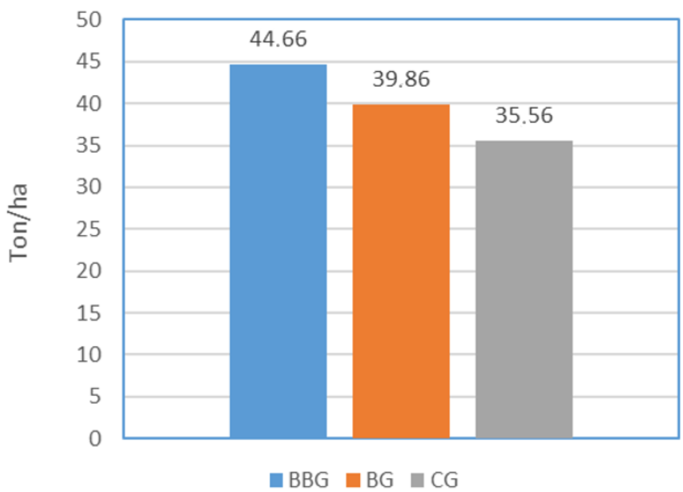

Figure 6. Harvest values of tomato plants in greenhouses.

CONCLUSION

The results of the study were compared with the values in the control greenhouse for tomato development parameters in both the blue and blue bumblebee greenhouses. In this context, the values obtained were found to be higher than those in the control greenhouses for tomato plant stem diameter, equivalent fruit diameter, plant height, and yield in greenhouses BBG and BG. Considering fruit firmness values, only the blue greenhouse was found to be higher than the control greenhouse. Similarly, for spad values, only the control greenhouse values were found to be higher than the other greenhouses. Consequently, it is believed that using the blue cover material and bumblebees will yield better results in both plant height and yield and will positively impact growth.

ACKNOWLEGEMENT

This article was derived by the Scientific Research Project Unit of Alanya Alaaddin Keykubat University, supported by project number 2023-02-11-MAP01. We would like to thank Alanya Alaaddin Keykubat University, Scientific Research Project Unit for their support of our work.

REFERENCES

1. Atılgan, A., Yucel, A., Aktas, H., Tunçbilek, F. (2019). *Investigation of Heating and Cooling Degree-Hour Values in Greenhouses with Different Color Cover Materials: The Case of Lettuce Plant*. Infrastruktura i Ekologia Terenów Wiejskich. 16/III(1): 235–252.
2. Boulard, T., Draoui, B. (1995). *Natural ventilation of a greenhouse with continuous roof vents: Measurements and data analysis*. Journal of Agricultural Engineering Research. 61(1): 27–36.
3. Khaoua, S.A.O., Bournet, P.E., Migeon, C., Chave, M., Boulard, T. (2006). *Analysis of greenhouse ventilation efficiency based on opening configurations and wind speeds*. Biosystems Engineering. 93(3): 365–374.
4. Li, Y., Zhang, X., Wang, L., Gao, J. (2024). *Study on the Natural Ventilation Model of a Single-Span Plastic Greenhouse in a High-Altitude Area*. Agronomy. 14(9), 2166.
5. Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences. 274(1608): 303–313.
6. Food and Agriculture Organization of the United Nations. (2018). Pollinators vital to our food supply under threat. FAO. https://www.fao.org/newsroom/detail/Pollinators-vital-to-our-food-supply-under-threat/en
7. Kwon, Y.J. Saeed, S. (2003). *Effect of Temperature on the Foraging Activity of Bombus Terrestris L. (Hymenoptera: Apidae) On Greenhouse Hot Pepper (Capsicum annuum L.).* Appl. Entomol. Zool., 38(3): 275–280.
8. Velthuis, H. H., Van Doorn, A. (2006). *A Century of Advances in Bumblebee Domestication and The Economic and Environmental*

Aspects of Its Commercialization for Pollination. Apidologie. 37(4): 421–451.

9. Topal, E., Yücel, B., Altunoğlu, E., Acar, A.A., Kösoğlu, M., Tekintaş, F.E. (2018). *The Effect of Honeybee and Bumblebee Pollination and Natural Pollinators on Cherry Fruit Set and Quality*, J. of AARI, 28(2): 62–75.
10. Gürel, F., Gösterit, A., Karslı, B.A. (2011). *Sera Koşullarının Bombus Terrestris L. Kolonilerinin Tozlaşma Performansına Etkileri*. Batı Akdeniz Tarımsal Araştırma Enstitüsü Derim Dergisi, 28(1): 47–55.
11. Peitsch, D., Fietz, A., Hertel, H., de Souza, J., Ventura, D.F., Menzel, R. (1992). *The Spectral Input Systems of Hymenopteran Insects and Their Receptor Based Colour Vision*. J. Comp. Physiol. A., 170: 23–40.
12. Gülperçin, N. (2015). *Böceklerin Gözünden Dünya*. Balıkesir Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 17(1): 53–58.
13. Gumbert, A. (2000). *Color Choices by Bumble Bees (Bombus terrestris): Innate Preferences and Generalization After Learning*. Behav Ecol Sociobiol. 48: 36–43.
14. Bayhan, Y., Avcı, Z. (2019). *Determining the Effects of Led Lighting Systems in Greenhouse Vegetable Growing on the Growth and Yield of Plants*. European Journal of Science and Technology. 17: 86–95.
15. Hogewoning, S.W., Trouwborst, G., Maljaars, Poorter, H., van Ieperen, W., Harbinson. J. (2010). *Blue Light Dose–Responses of Leaf Photosynthesis, Morphology, and Chemical Composition of Cucumis Sativusgrown Under Different Combinations of Red and Blue Light*, Journal of Experimental Botany, 61(11): 3107–3117.
16. Whitelam, G., Halliday, K. (2007). *Light And Plant Development*. Blackwell Publishing Ltd, 9600 Garsington Road, Oxford. ISBN: 978-1-4051-4538-1.
17. Xu, H.L., Xu, Q., Li, F., Feng, Y., Qin, F., Fang, W. (2012). *Applications of Xerophytophysiology in Plant Production-LED Blue Light As A Stimulus Improved the Tomato Crop*. Scientia Horticulturae, 148, 190–196.
18. Doorenbos, J., Pruitt, W. O. (1977). *Guidelines for Predicting Crop Water Requirements,* Irrigation and drainage paper 24. Land and Water Development Division FAO Rome 24: 144.
19. Fernández, M.D., Bonachela, S, Orgaz, F., Thompson, R., López, J.C., Granados, M.R., Gallardo, M., Fereres, E (2010). *Measurement and Estimation of Plastic Greenhouse Reference Evapotranspiration in A Mediterranean Climate*. Irrigation Science. 28(6): 497–509.
20. Demirsoy, M. (2016). *Sera Koşullarında Farklı Yapay Işık, Renk ve Kaynaklarının Domates (Lycopersicon Esculentum Mill.), Biber (Capsicum Annuum L.) ve Patlıcan (Solanum Melongena L.)'da Fide Büyüme, Gelişme, Kalite ve Dikim Sonrası Adaptasyonlarına Etkilerinin Kantitatif Yöntemlerle İncelenmesi*. Doktora tezi, Ondokuz Mayıs Üniversitesi, Samsun.
21. Çetin, E., Atılgan, A. (2020). *Sera Yetiştiriciliğinde Farklı Renklerdeki Sera Örtü Malzemelerinin Bitki Gelişimine Etkileri: Domates (Solanum Lycopersium) Örneği*. Ziraat Fakültesi Dergisi. 15(2): 199–205.

Atilgan Atilgan
ORCID: 0000-0003-2391-0317
e-mail:atilgan.atilgan@alanya.edu.tr
Department of Biosystmes Engineering
Engineering Faculty
Alanaya Alaaddin Keykubat University
Alanya, Türkiye

Dilara Durak
ORCID: 0000-0003-2518-8778
e-mail: dlrdrkk@gmail.com
Department of Biosystmes Engineering
Engineering Faculty
Alanaya Alaaddin Keykubat University
Alanya, Türkiye

Corresponding Author: Burak Saltuk
ORCID: 0000-0001-8673-9372
e-mail:burak.saltuk@alanya.edu.tr
Department of Biosystmes Engineering
Engineering Faculty
Alanaya Alaaddin Keykubat University
Alanya, Türkiye

Received: October 21, 2025
Revised: October 25, 2025
Accepted: October 29, 2025