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# Effects of Covering Materials With Different Spectral Properties dn Morphological Development and Physiological Parameters of Tomato and Pepper Seedlings

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**Abstract**
This study was conducted to determine the effects of covering materials with different spectral properties on the morphological development and physiological parameters of tomato and pepper seedlings. Five different light spectra (Yellow, Mixed, Red, Blue, and White) were applied within the scope of the experiment. Parameters including plant height, plant and root fresh weight, stem diameter, SPAD (chlorophyll content), and leaf color parameters (l*, a*, b*) were analyzed. The data obtained were subjected to analysis of variance (ANOVA) according to a completely randomized design, and the differences between treatments were determined using the LSD multiple comparison test (P<0.05). In the tomato experiment, significant differences (P<0.01) were detected among treatments for almost all examined parameters. The highest plant height (70.74 cm) and total plant weight (32.21 g) were obtained under the mixed light treatment, while red light also yielded high plant weight (31.05 g). Physiologically, red light was the most effective treatment for promoting chlorophyll synthesis, providing the highest SPAD values (45.41). In the pepper experiment, no statistically significant differences were observed in plant height (P>0.05), whereas leaf color characteristics and SPAD values were significantly affected by light quality (P<0.01). Specifically, leaf lightness (l*) decreased under blue light while chlorophyll density increased. The results revealed that tomato seedlings are more sensitive to the light spectrum than pepper seedlings. Red light was found to be effective in increasing vegetative growth, while blue light improved quality parameters. These findings are strategically important for creating species-specific "light recipes" and optimizing seedling quality in modern greenhouse cultivation.

**Keywords:** Chlorophyll, Morphology, Light spectrum, LSD Test, Pepper, Tomato



## INTRODUCTION

Agricultural production is a strategically important sector due to its role in meeting the nutritional needs of humans and animals, providing raw materials for agriculture-based industries, and contributing directly and indirectly to employment and exports. The amount of agricultural production directly impacts the national income of countries around the world and contributes to their development. Among agricultural products, vegetables occupy an important position in terms of both area and production volume.

The total vegetable production area in the world is 60 million hectares, with a production volume of 1.15 billion tons (FAO, 2024). Among the leading countries in world vegetable production, China ranks first with 600 million tons. India ranks second with 130 million tons, and Turkey ranks third with 33 million tons. The most widely produced vegetables are tomatoes, onions, cabbage, cucumbers, peppers, carrots, and potatoes. China is the world's leading producer of tomatoes, India is the world's leading producer of potatoes, and Turkey is the world's leading producer of peppers.

Both tomatoes (*Solanum lycopersicum* L.) and peppers (*Capsicum annuum* L.) belong to the Solanaceae family and are strategically important to global agricultural production for fresh consumption and industrial processing. Seed selection is one of the main factors determining high yield and profitability, as it is the basic production material for both products. In modern vegetable cultivation, starting production with healthy seedlings resistant to stress conditions from these seeds is the basic condition for achieving high yield and quality. The seedling stage directly affects the plant's performance throughout its entire life cycle and is therefore the most critical phase.



Horticulture is primarily practiced in southern regions of the world and in Turkey, where a Mediterranean climate prevails. The production of vegetable seedlings under cover is concentrated in these regions. Due to the low number of frost and cloudy days and the long hours of sunlight, greenhouse cultivation continues to grow in these regions. As of 2024, it is estimated that the global greenhouse production area is approximately 5 million hectares, with an annual production exceeding 400 million tons (Anonymous, 2024). China ranks first among countries, followed by Spain, Turkey, and the Netherlands. China produces around 200 million tons of vegetables, such as tomatoes, cucumbers, and peppers, on about 2.5 million hectares of greenhouse production area. Spain, which ranks second, has a total production area of about 70,000 hectares and produces about 15 million tons of vegetables, including tomatoes, peppers, and cucumbers. Turkey ranks third in vegetable production, producing approximately 8 million tons of vegetables (tomatoes, peppers, cucumbers, and eggplants) on approximately 776,000 decares of land (TUİK, 2024). The top-ranking countries have favorable climates and technologies suitable for effective greenhouse cultivation. As technologies have changed and developed, hard plastic cover materials have emerged as the preferred option for protected cultivation, replacing the plastic covers used in the past (Eerenstein, 2015). The additives in these materials and their light transmission capacities can directly affect production. Light is the necessary energy source in protected cultivation and plays an active role in the physiological and morphological changes of plants (Ciolkosz, 2008).

In protected cultivation, high-transparency materials are used for coverage to ensure sufficient light penetration into greenhouses (Çetin, 2020). The spectral properties of these materials can be modified to manipulate the light composition that reaches the plants. According to the literature, blue light (400-500 nm) has been shown to promote chloroplast development and stomatal movements, resulting in plants that are more compact and dark green in color. In contrast, red light (600-700 nm) has been observed to trigger stem elongation and an increase in biomass by altering the balance of phytochromes (Havan et al., 2024; Folta et al., 2003; Quyang et al., 2015; Matsuo et al., 2019). However, different vegetable species' (e.g., tomato and pepper) morphological and physiological responses to the same light spectrum can vary significantly depending on their genetic makeup and photomorphogenetic adaptation strategies. Çetin (2020) studied the effect of different colored cover materials on the development of tomato plants under greenhouse conditions. He reported that using blue material positively affected yield, fruit weight, and green plant growth. They also reported that red-colored coverings reduced the temperature and radiation energy values of tomato plants. In their studies examining the effect of LED lighting on the growth and development of tomato seedlings, Brazaityte and colleagues (2010) reported that seedlings developed better under high-powered lighting devices with blue, red, and far-red LEDs supplemented with UV (380 nm) light. They also found that orange (622 nm), yellow (595 nm), and green (520 nm) light sources were not suitable for tomato seedling growth. In their study investigating the effects of different colored cover materials on plant growth in greenhouse lettuce cultivation, Tunçbilek (2019) conducted research in three greenhouses: a control greenhouse, a blue-covered greenhouse, and a red-covered greenhouse. Each greenhouse had a base area of 6 $m^2$. The researcher reported higher yield values, such as leaf count, head diameter, and weight, in the control greenhouse and found that colored greenhouse cover materials resulted in bitterness or bolting in lettuce. Stutte et al. (2009) studied potatoes, radishes, and lettuce and found that blue light (400–500 nm) promotes higher biomass and leaf area. However, they reported that different red (660, 670, 680, and 690 nm) and blue (430, 440, 460, and 475 nm) wavelengths may not have the same effect depending on the plant variety. Brown et al. (1995) reported that, in peppers (*Capsicum annuum* L.), combining infrared (735 nm) and red (660 nm) light resulted in greater increases in stem biomass and plant height than red light alone. Havan and colleagues (2024) examined the effects of different wavelengths of LED lighting (red, blue, green, and a white-daylight mixture) on the quality of tomato seedlings. They reported that blue light inhibited tomato seedling development, while red light promoted growth and increased seedling height. The study also found that decreasing the proportion of blue light in tomato seedlings significantly increased plant weight and height. Bayhan and Avcı (2019) conducted a study to determine the effects of different LED lighting systems (blue, red, yellow, and combinations of these colors) on the growth and yield of greenhouse-cultivated lettuce. They found that the three-color combination produced the highest total plant weight, while the blue+yellow combination produced the lowest. The researchers also reported that the highest yield per unit area was obtained with the three-color combination and the lowest yield was obtained with the blue-yellow combination.

This study aims to compare the effects of cover materials with different spectral properties on the morphological development and physiological parameters of tomato and pepper seedlings. Morphological development includes plant height, weight, and diameter, while physiological parameters include SPAD and color values. The findings are expected to contribute to the field by reducing the cost of growing high-quality seedlings under cover and by developing species-specific, optimized light sources.

## Materials and Methods

This study was conducted in March 2025 in the plant growth chamber located in the Horticulture Department at Dicle University's Faculty of Agriculture. White LED lamps were used to light the cabinet. The amount of light reaching the plants was measured in photosynthetically active radiation (PAR), which defines light wavelengths in the visible range of 400–700 nm. Conditions of 16 hours of light and 8 hours of darkness were created inside the cabinet. The cabin temperature was maintained at 25 ± 1/20 ± 1 °C (day/night) using two air conditioners and time-controlled relays. The humidity level in the cabinet was maintained at 65-70%.

### Plant Materials and Growing Sites

The experiment used Falcon variety tomato (*Solanum lycopersicum* L.) and Üçburun variety pepper (*Capsicum annuum* L.) seeds. The seeds were sown in trays at a 2:1 peat: perlite potting mix ratio. After sowing the seeds, the trays were watered, placed in trays with a depth of 10 cm, and covered with different transparent materials. The trays used in the experiment were designed with 48 cells, and the experiment was set up with two trays (two replicates) for each cover material application. 

### Application of Cover Materials in Different Colors

The experiment used five different transparent, light-transmitting plastic cover materials. The materials were red, yellow, blue, white, orange and mixed colors. The covers were cut to cover the entire tub, and their thicknesses were measured as 0,38 mm. To ensure that the observed differences were solely due to the color of the cover, the light intensity and photoperiod were kept constant in all applications. The amount of light reaching under the transparent covers was measured with a PAR meter. The amounts of light obtained were as follows: red: 410 PAR; yellow: 454 PAR, blue 401 PAR, white 465 PAR, orange 421 PAR and mixed colors 401PAR.

From the time of sowing, the amount of water required by the plants was controlled according to the soil's moisture content. Seventeen days after sowing, the plants were fertilized with a 1:2 ratio of Hoagland nutrient solution. Since no diseases or pests were observed, no spraying was performed. The experiment ended 35 days after sowing.

### Morphological and Physiological Measurements and Observations Taken

After the experiment was completed, the following measurements and observations were taken:

<u>Morphological measurements:</u>

- Plant height (cm)

- Root length (cm)

- Root collar diameter (mm)

- Plant fresh weight (g)

- Root fresh weight (g)

Physiological measurements:

SPAD-502 Chlorophyll Meter to measure leaf chlorophyll content and digital colorimeter devices to measure leaf color (l*, a*, b*) content.

**Statistical analyses**

Data were subjected to analysis of variance (ANOVA) using statistical software. The Least Significant Difference (LSD) test was used for mean separation at a significance level of $P<0.05$. The coefficient of variation (CV%) was calculated to evaluate the precision of the experimental trials.



**FINDINGS AND DISCUSSION**

The statistical results obtained from the measurements and observations made at the end of the study are presented in Tables 1 and 2. Analysis of variance (ANOVA) revealed that different cover applications had varying effects on the morphological and physiological characteristics of tomato and pepper seedlings.

Table 1 shows the physiological and morphological changes in tomato seedlings grown under different colored cover materials. Statistical analyses showed significant differences ($P < 0.01$) between treatments for almost all parameters in tomatoes. Tomato seedlings exhibited a much more pronounced statistical response to spectral changes than pepper seedlings did.

The red cover produced the greatest plant height and growth (70.74 cm), followed by the yellow cover (55.70 cm) and the mixed-color cover (50.85 cm). The lowest growth was observed with the blue cover (42.25 cm), followed by the white cover (43.68 cm) and the orange cover (45.12 cm). The red cover's stimulating effect on plant height can be explained by phytochrome activity and cell elongation. However, the effect of different cover materials on root length was not statistically significant. The highest root fresh weight was found in the mixed-color cover material (7.91 g), and the lowest weights were found in the yellow (5.21 g), red (5.12 g), blue (5.45 g), and orange (5.80 g) cover materials. Examining the plant weight parameter, which is effective in biomass

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accumulation, revealed the highest weights in the mixed-color (32.21 g) and red (31.05 g) cover materials and the lowest weights in the yellow (24.73 g) and blue (22.18 g) cover materials. The effect of different cover materials on the root collar diameter was not statistically significant. Regarding chlorophyll content (SPAD), the highest SPAD content was detected in the red cover material (45.41), while the lowest was detected in the mixed cover material (31.02). These results support the specific effect of blue light on chloroplast development. Among plant color parameters, the highest l* brightness value was found in white (50.04) and orange (48.50) cover materials, while the lowest value was found in yellow (41.08) cover material. Regarding the a* redness parameter, the highest content was found in white (-10.02) and orange (-12.14) materials, while the content was low in all other materials. For the b* yellowness parameter, the highest content was found in orange (32.10), blue (31.15), yellow (30.48), and white (30.29) cover materials. The lowest b* content was found in the red cover material (26.11).

**Table 1**: Results obtained in tomato seedlings

| **Parameter** | **Yellow** | **Mixed** | **Red** | **White** | **Blue** | **Orange** | **P-Value** | **LSD** | **CV%** |
|---|---|---|---|---|---|---|---|---|---|
| **Plant Height (cm)** | 55.70 b | 50.85 b | 70.74 a | 43.68 c | 42.25 c | 45.12 c | **<0.001** | 6.12 | 8.4 |
| **Root Length (cm)** | 19.66a | 21.92a | 23.54a | 16.27a | 18.40a | 19.10a | **0.082** | N.İ | 15.3 |
| **Root Weight (g)** | 5.21 b | 7.91 a | 5.12 b | 6.78 ab | 5.45 b | 5.80 b | **0.045** | 1.85 | 18.1 |
| **Plant Weight (g)** | 24.73 b | 32.21 a | 31.05 a | 26.40 ab | 22.18 b | 28.15 ab | **0.005** | 4.76 | 12.5 |
| **Root Diameter (mm)** | 4.45a | 3.58a | 4.43a | 4.12a | 2.84a | 4.30a | **0.185** | N.İ | 21.0 |
| **SPAD** | 33.78 bc | 31.02 c | 45.41 a | 35.28 bc | 36.12 b | 34.22 bc | **<0.001** | 4.23 | 7.8 |
| **l*** | 41.08 c | 44.08 b | 45.50 b | 50.04 a | 47.12 ab | 48.50 a | **0.001** | 2.95 | 4.5 |
| **a*** | -19.56 b | -19.34 b | -18.06 b | -10.02 a | -15.42 b | -12.14 a | **<0.001** | 3.44 | 14.2 |
| **b*** | 30.48 a | 28.32 ab | 26.11 b | 30.29 a | 31.15 a | 32.10 a | **0.012** | 2.88 | 6.7 |

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Table 2 shows the physiological and morphological changes observed in pepper seedlings grown under different colored cover materials. The statistical analysis results indicate significant differences ($P < 0.01$) between the treatments for most pepper parameters.

Regarding plant height and development, the greatest height was measured under the red cover (42.15 cm), while the least development was observed under the white cover (33.00 cm). The stimulating effect of the red cover on plant height can be explained by phytochrome activity and cell elongation. However, the effect of different cover materials on root length was not statistically significant. The highest root fresh weight was found in white cover materials (6.66 g), while the lowest root fresh weights were found in blue cover materials (4.18 g). Examining the plant fresh weight parameter, which is effective in biomass accumulation, revealed that the highest weight was in the red cover materials (11.20 g), while the lowest weights were in the blue (6.95 g) and white (6.85 g) cover materials. Examining the root collar diameter of the plant revealed that the red covering material had the highest diameter (3.82 mm), while the white covering material had the lowest diameter (1.51 mm). Regarding the chlorophyll content (SPAD) parameter, the highest SPAD content was found in the red cover material (37.90), and the lowest was found in the blue cover material (25.12). The highest l* brightness value was found in the white cover material (48.60), and the lowest was found in the yellow (43.43) and mixed (44.12) cover materials. Regarding the a* redness parameter, the highest content was detected in the yellow color material

(-6.51), while the lowest content was detected in the white (-20.30) and blue (-20.89) materials. For the b* yellowness parameter, the highest content was found in the white cover material (33.30), while the lowest content was found in the yellow (29.80), mixed (28.10), and red (29.45) cover materials.

**Table 2:** Results obtained in pepper seedlings

| Parameter | Yellow | Mixed | Red | White | Blue | Orange | P-Value | LSD | CV% |
|---|---|---|---|---|---|---|---|---|---|
| **Plant Height (cm)** | 36.41 b | 35.12 b | 42.15 a | 33.00 c | 34.21 bc | 34.85 bc | **0.002** | 3.54 | 9.1 |
| **Root Length (cm)** | 12.87a | 13.10a | 14.20a | 15.42a | 13.06a | 14.20a | **0.134** | N.İ | 12.4 |
| **Root Weight (g)** | 5.06 b | 4.92 b | 5.34 b | 6.66 a | 4.18 c | 5.10 b | **0.008** | 1.12 | 19.3 |
| **Plant Weight (g)** | 8.42 c | 9.85 b | 11.20 a | 6.85 d | 6.95 d | 10.12 ab | **<0.001** | 1.45 | 15.6 |
| **Root Diameter (mm)** | 1.85 c | 2.15 b | 3.82 a | 1.51 d | 1.64 cd | 2.05 bc | **<0.001** | 0.32 | 11.2 |
| **SPAD** | 32.00 b | 28.45 c | 37.90 a | 30.12 bc | 25.12 d | 29.56 c | **<0.001** | 2.85 | 8.1 |
| **l*** | 43.43 d | 44.12 d | 45.20 c | 48.60 a | 46.50 b | 47.20 ab | **<0.001** | 1.42 | 3.2 |
| **a*** | -6.51 a | -15.42 c | -14.10 c | -20.30 d | -20.89 d | -13.12 b | **<0.001** | 1.95 | 10.5 |
| **b*** | 29.80 c | 28.10 c | 29.45 c | 33.30 a | 32.41 ab | 31.50 b | **<0.001** | 1.65 | 5.3 |

The highest plant heights in tomato and pepper seedlings were observed under red cover materials (Figure 1). The lowest plant heights were observed under blue cover materials for tomatoes and under white and blue cover materials for pepper seedlings. Çetin (2020) reported in their study on the effects of different colored greenhouse cover materials on tomato (*Solanum lycopersicum*) growth that plant heights under red and blue cover materials were higher than in the control group (white). Havan et al. (2024) reported that tomato seedlings grown under red LED lamps had the greatest height, while those grown under blue LED lamps had the least height. The researchers also reported that blue light inhibits plant growth. Blue light has been shown to suppress gibberellin and auxin levels by inhibiting the photoreceptor cry1, which limits plant height (Folta et al., 2003). It has been reported that elongation in plants exposed to red light is due to increased gibberellin synthesis (Quyang et al., 2015) and that elongation suppression caused by blue light is due to increased expression of genes that block gibberellin synthesis (Matsuo et al., 2019). Claypool and Lieth (2020) reported that pepper seedlings exposed to green light experienced no negative growth effects, and their height was similar to that of seedlings exposed to red light. Köksal et al. (2013) investigated the effects of red LED diodes on tomatoes. They stated that red and orange diodes created differences in the vegetative parts of the plant. Their study showed that using red-orange LED lights during the cultivation of tomato plants resulted in differences in plant height, number of leaves, number of flowers, and biomass weight. Ultimately, the researchers indicated the feasibility of using red-orange LED lights in the cultivation of tomato plants.

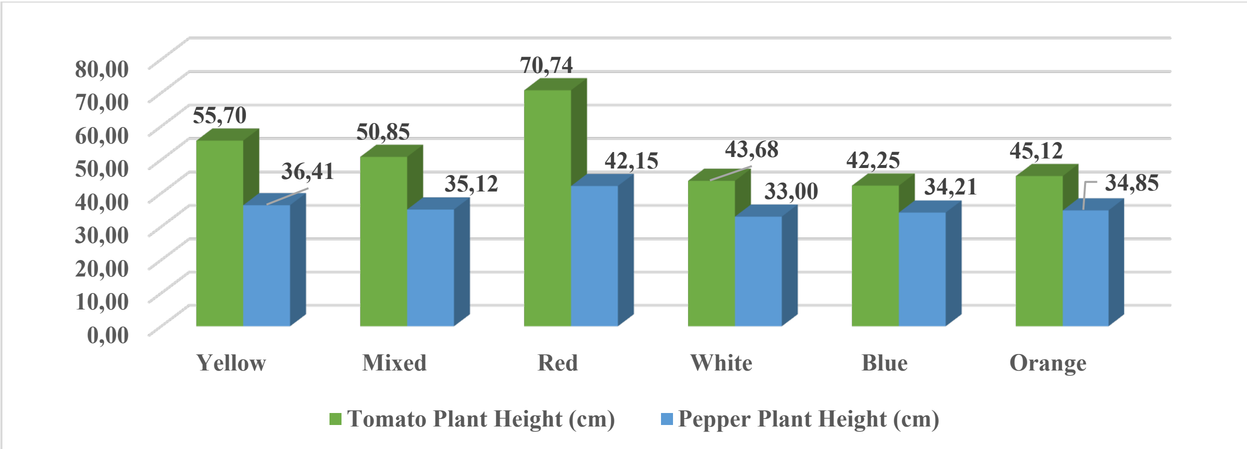


**Figure 1:** Effect of different cover materials on tomato and pepper plant height

The root length parameter was not found to be statistically significant for tomato and pepper seedlings under different cover materials (Figure 2). In an investigation conducted by Kaya (2022) on the effects of different LED lighting wavelengths on the growth, quality attributes, and mineral compositions of tomato (*Lycopersicon esculentum* L.) seedlings, it was reported that variations in light quality and intensity had a statistically non-significant impact on root length. This observation is consistent with the findings of our study.



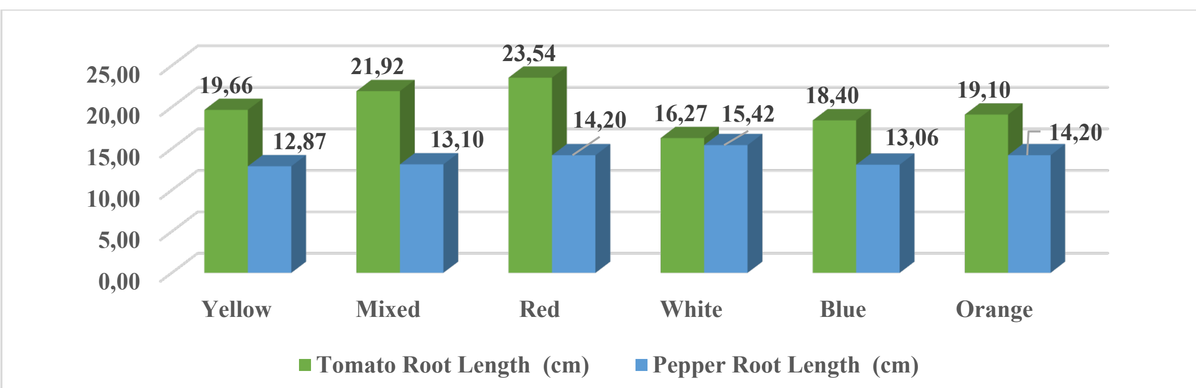


**Figure 2:** Effect of different cover materials on the root length of tomato and pepper plants

The highest root weight was observed in mixed-color cover materials for tomatoes and white-colored materials for peppers (Figure 3). The lowest root weight was observed in red light for tomatoes and in blue materials for peppers. Havan et al. (2024) reported that the effects of different LED lights on the fresh weight of tomato seedlings' roots were statistically insignificant.

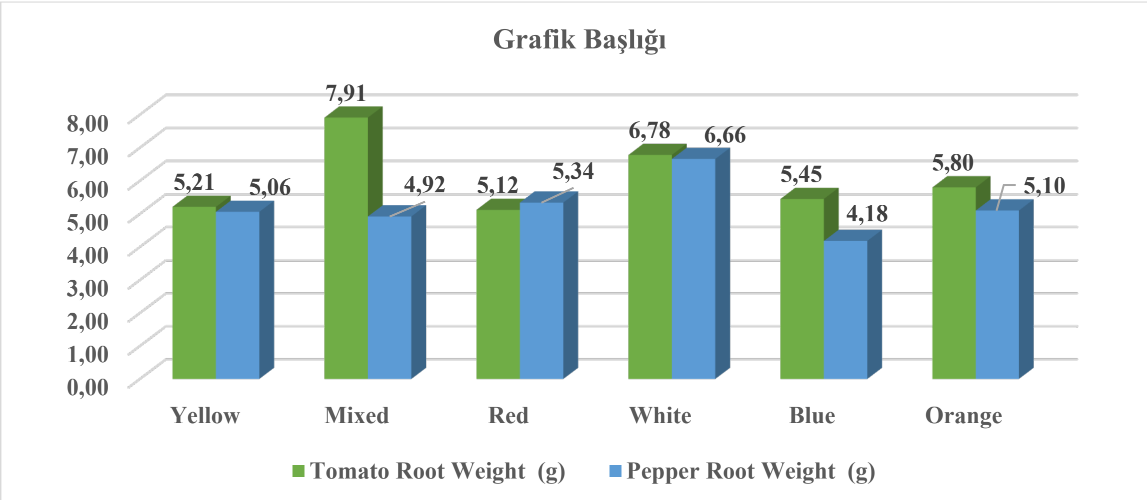


**Figure 3:** Effect of Different Cover Materials on Root Weight of Tomato and Pepper Plants

Examining the plant weights revealed that tomato plants had the highest weight under mixed and red cover materials, while pepper plants had the highest weight under red cover materials (Figure 4). The lowest plant fresh weights were found under blue cover materials for tomatoes and under white and blue cover materials for peppers. Havan et al. (2024) reported finding the highest plant fresh weights in tomato seedlings grown under red LED lamps and the lowest in seedlings grown under blue LED lights. These results are consistent with those of our study. Pinho et al. (2007) studied lettuce plant development under LED diode covers (red, orange, blue, and yellow). They reported that diodes could be used for plant development and that red diodes increased plant weight and yellow diodes promoted development.



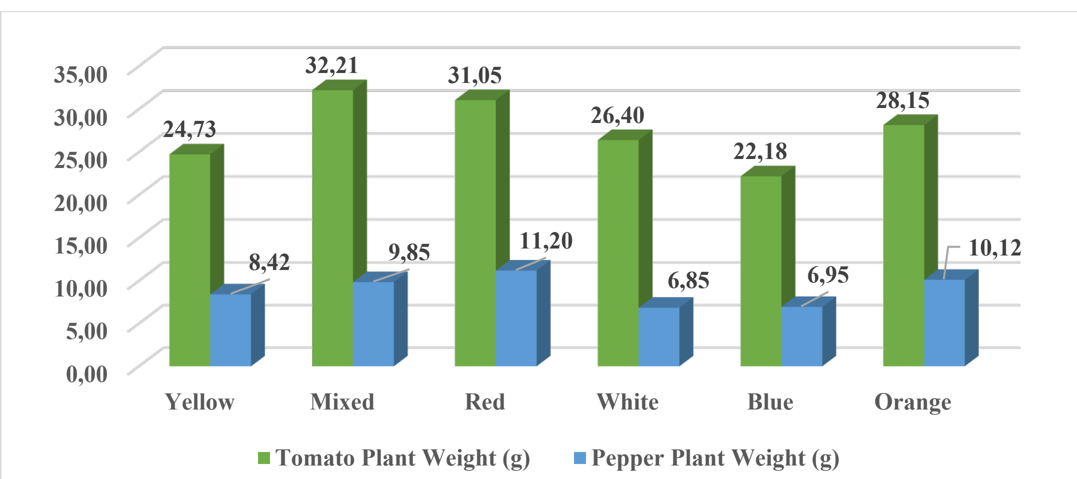


**Figure 4:** Effect of Different Cover Materials on Tomato and Pepper Plant Weight

The effect of different colors on tomato seedlings was found to be statistically insignificant in terms of the root collar diameter parameter. For pepper seedlings, the largest diameter was observed with red cover materials, and the smallest with white and blue cover materials (Figure 5). Havan et al. (2024) reported in their study on the effects of different LED lamps on tomato seedling development that the largest diameter was found under red LED lamps and the smallest under control, blue, and green LED lamps.

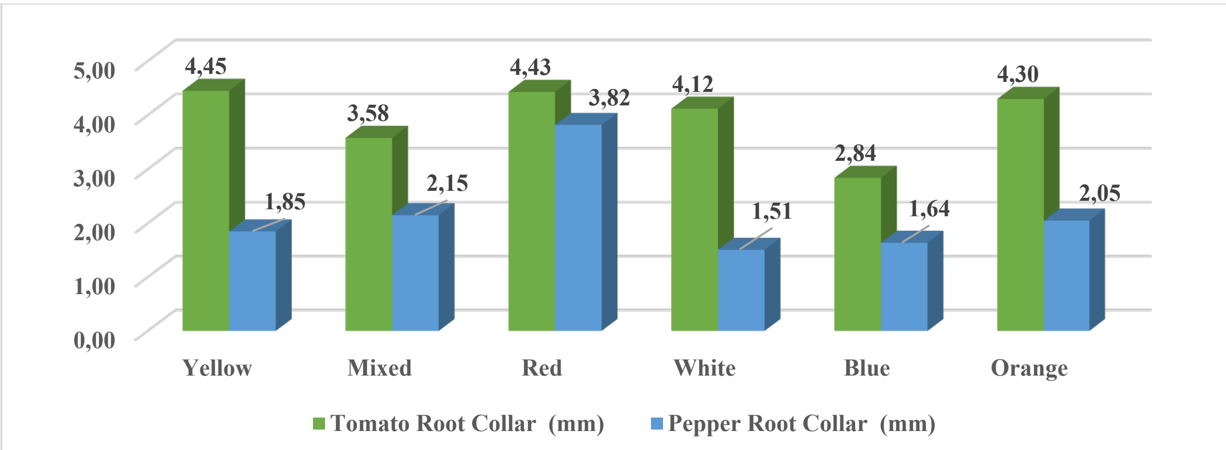


**Figure 5:** Effect of Different Cover Materials on the Root Collar of Tomato and Pepper Seedlings



Examining the effect of different cover materials on the chlorophyll content of tomato and pepper seedlings revealed that the highest content was obtained when the plants were grown under red materials. The lowest content was found in tomatoes grown under mixed-color materials and in peppers grown under blue materials (Figure 6). Havan et al. (2024) reported that the effect of different colored LED lamps on chlorophyll content in tomato seedlings was statistically insignificant. Yavari et al. (2021) reported that red light increased the net photosynthesis rate in *Arabidopsis* seedlings, while blue light had a reducing effect. A study on spinach seedlings under white, blue, red, and red-blue light applications reported that seedlings under blue, red, and red-blue lights at 300 µmol $m^{-2}$ $s^{-1}$ PPFD had lower chlorophyll content than seedlings under white light (Ohashi-Kaneko et al., 2007).

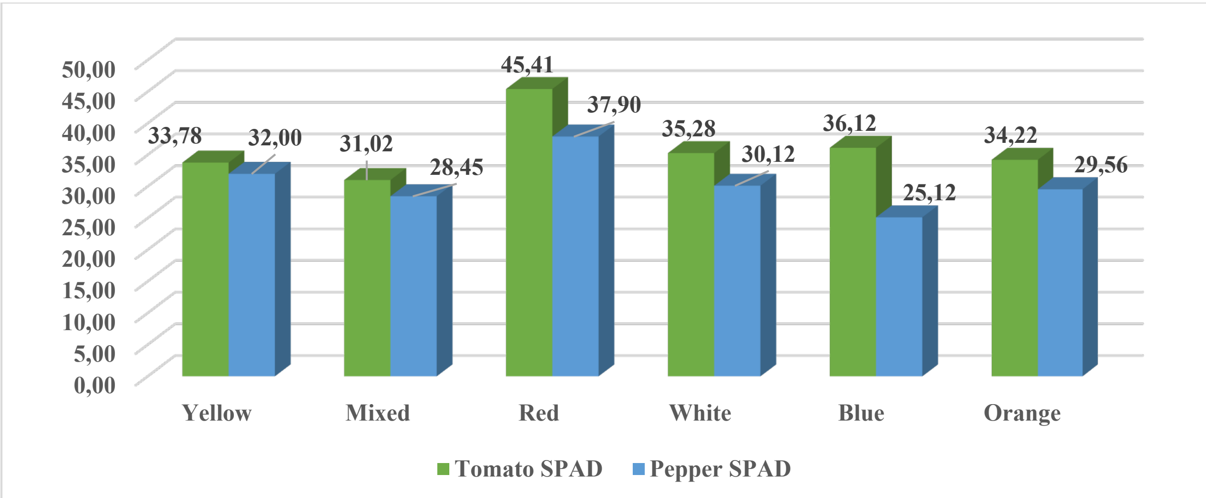


**Figure 6:** Effect of Different Cover Materials on the SPAD Content of Tomato and Pepper Leaves

Examining the color values of plant leaves revealed that the highest l* value in tomato seedlings was found with white and orange cover materials, while the lowest value was found with yellow cover material (Figure 7). Similar results were obtained in pepper seedlings: the highest l* content was found in white cover material and the lowest content was found in plants under yellow and mixed-color cover materials. Kaya (2022), in a study evaluating the effects of different LED lighting wavelengths on the growth, quality parameters, and mineral element content of tomato (*Lycopersicon esculentum* L.) seedlings, stated that the interaction between light intensity and color had a significant effect on the l* value. It was reported that the lowest l* content was observed under Red + Far-Red treatments, whereas the highest l* content was detected under Red + Blue + Far-Red lights at high intensity.

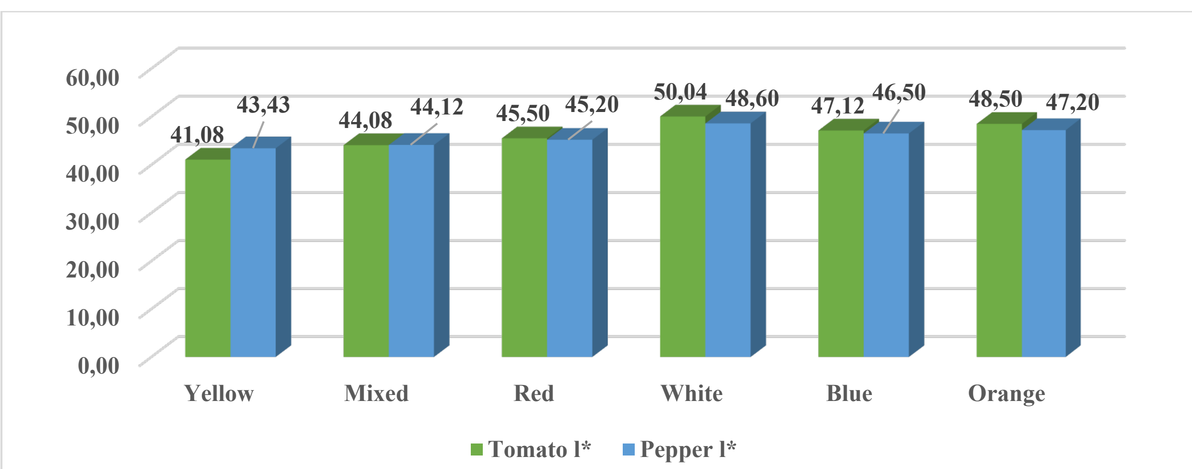


**Figure 7:** Effect of Different Cover Materials on the Color Content of Tomatoes and Peppers

Examining the color values of plant leaves revealed that the highest a* value in tomato seedlings occurred under white and orange cover materials. The lowest content was detected in plants under other cover materials. For pepper seedlings, the highest a* values were found under yellow cover materials, and the lowest values were found under white and blue cover materials (Figure 8). Kaya (2022) stated that various light color treatments significantly influenced the a* value. The author reported that the lowest a* content was detected under the Red + Blue treatment, while the highest values were obtained under Red and Red + Blue + Far-Red light conditions. Additionally, it was noted that the a* value in the Red + Blue treatment was lower than that observed under white light.

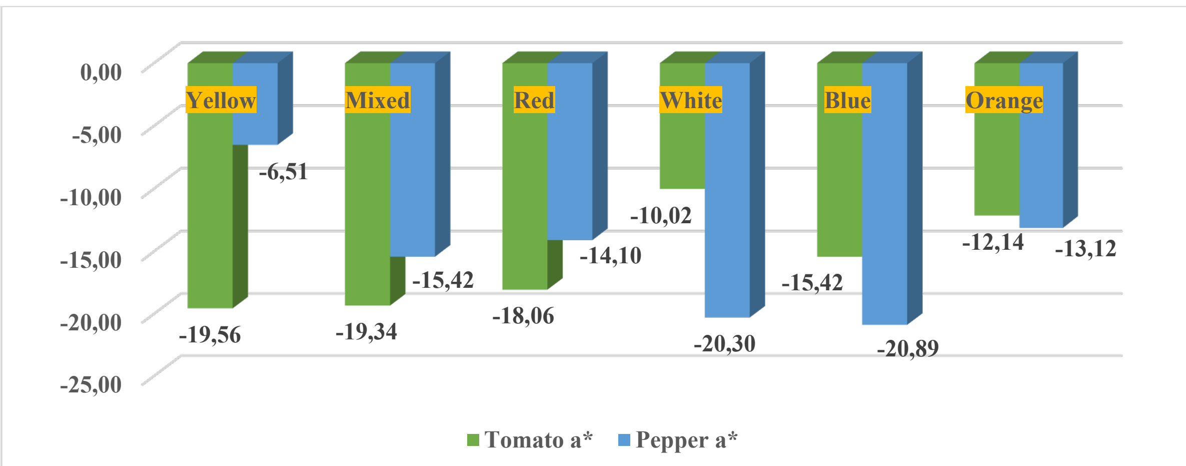


**Figure 8:** Effect of Different Cover Materials on the a* Color Content of Tomatoes and Peppers

Examining the color values of plant leaves revealed that the highest b* value in tomato seedlings occurred with yellow, white, blue, and orange cover materials, while the lowest occurred with red cover materials. For pepper seedlings, the highest content was found in plants grown under white cover, and the lowest content was found in plants grown under yellow, mixed, and red cover materials (Figure 9). Kaya (2022) reported that both light intensity and different spectral colors had a statistically significant effect on the b* content. The researcher stated that the minimum b* value was obtained under the Red + Blue light treatment, whereas the maximum content was achieved under the Red + Blue + Far-Red light condition

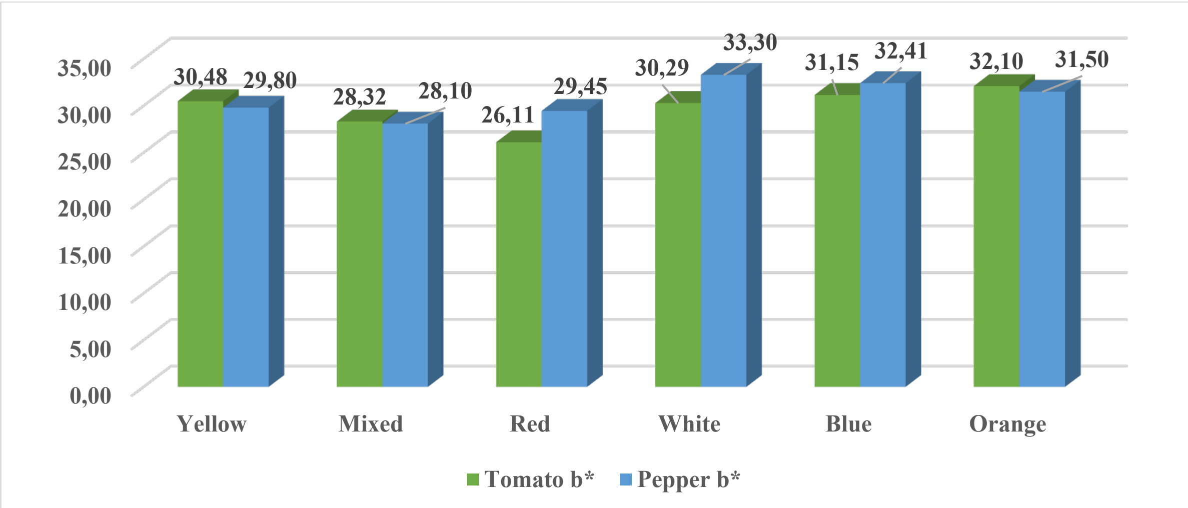


**Figure 9:** Effect of different cover materials on the b* color content of tomatoes and peppers

## CONCLUSION

The research results revealed that tomato seedlings are more sensitive to the light spectrum than pepper seedlings. Red light was found to be effective in promoting vegetative growth, while blue light was found to be effective in improving quality parameters such as chlorophyll content and color. These findings are strategically important for modern greenhouse cultivation, as they allow for the creation of plant-specific "light recipes" and the optimization of seedling quality. The red cover used in protected cultivation promotes elongation in both peppers and tomatoes. It also increases chlorophyll content and root development in peppers. Using a normal white plastic cover increases chlorophyll content in tomato plants. In peppers, it contributes to root development similarly to the red cover. This study suggests that using different cover materials rather than colored LED lamps may be a feasible option in protected cultivation.

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