Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL
Volume 8, Issue 1, 2025, Pages 190–202
Available online at https://aasj.journals.ekb.eg
DOI: https://dx.doi.org/10.21608/aasj.2025.381284.1192

Optimizing barley growth conditions using colored greenhouse covers and IoT-based environmental monitoring

AbdElkareem M. M. M.*, Mahmoud R. K.

Faculty of Agricultural Engineering, Al-Azhar University, Assiut, Egypt

Abstract

This study investigated the impact of colored greenhouse covers and IoT integration on optimizing environmental conditions for barley cultivation. The primary objective was to evaluate how different cover colors (blue, white, red, green) alter microclimatic parameters (temperature, humidity, light) and influence barley growth, supported by IoT-enabled monitoring systems. Four identical greenhouses in Assiut, Egypt, equipped with automated irrigation and IoT sensors, were tested under varying cover colors. Environmental data (temperature, humidity, wind speed) and plant metrics (biomass, length, Light intensity) were collected and analyzed. Results revealed significant color-specific effects: red covers retained the highest internal temperatures (30.45°C) and humidity (66.5%), suitable for crops requiring warm, humid conditions. Green covers maintained cooler temperatures (29°C) and lower humidity (58.5%), ideal for moderate climates. Blue covers promoted advanced vegetative growth (160 mm plant length by day 10) due to enhanced chlorophyll-a activation, while red covers favored early-stage growth (100 mm by day 5) via stem elongation. An analysis of light intensity showed red and blue covers transmitted optimal light levels (27,000–37,800 lux), aligning with barley’s photosynthetic needs, whereas green covers underperformed (10,600–28,300 lux). IoT systems enabled real-time monitoring, confirming that wind speed inversely affected internal temperatures. The study concludes that selecting cover colors based on crop-specific requirements and integrating IoT technologies can significantly enhance growth efficiency and resource management in controlled environments.

Keywords: Colored covers, IoT integration, barley cultivation, spectral light manipulation.

*Corresponding author: AbdElkareem M. M. M.,
E-mail address: mahmoudmansourabdelkareem@gmail.com

1. Introduction

Optimizing environmental conditions in protected cultivation systems remains critical for enhancing crop productivity, particularly in arid regions like Egypt. This study explores the combined effects of colored greenhouse covers (blue, white, red, green) and IoT-based monitoring systems on microclimate regulation and barley growth. Prior research underscores the role of spectral light manipulation in plant development: Gmizo *et al.* (2012) demonstrated how colored films alter tomato growth, while Alhelal *et al.* (2024) linked red shading nets to elevated humidity in strawberry cultivation. However, limited attention has been given to cereal crops like barley, especially when integrated with IoT technologies for real-time environmental tracking. This research addresses this gap by evaluating how color-induced light modifications and automated IoT based systems synergistically influence barley biomass, plant morphology, and photosynthetic efficiency. The urgency of this work stems from the need to develop cost-effective, scalable solutions for smallholder farmers in water-scarce regions, where climate variability threatens food security. Key objectives include assessing the thermal and spectral properties of "colored covers", quantifying their impact on barley growth stages, and validating the reliability of IoT-driven data collection. Terms such as colored covers (light-filtering materials modifying spectral transmission) and IoT integration (wireless sensor networks for environmental monitoring) are central to this investigation. Conducted in Assiut Governorate, Egypt (27.19°N, 31.18°E) during February–March 2024, the study employed four identical greenhouses equipped with automated irrigation and DHT11 sensors. Methodologically, a randomized experimental design compared growth metrics under different covers, with data analyzed through descriptive statistics. External variables like wind speed were monitored to contextualize microclimate fluctuations. By merging spectral engineering with digital agriculture, this work advances precision farming strategies, offering actionable insights for optimizing cover selection and IoT adoption resource-limited environments.

2. Materials and methods

2.1 Specification of the greenhouse

The greenhouses that constructed, developed and tested in Assiut Governorate, Egypt. Latitude 27.19°N and longitude 31.18°E, Experiments were carried out during the period from 29^{th} of February to 15^{th} of March 2024 A. D. Four identical greenhouse systems (Blue, White, Red, and Green (BWRG)) with the same construction properties were involved in this study, as shown in Figure (1). The greenhouses were identical in all aspects except for the covering color. Each structure was oriented east-west, with dimensions of 1.2 m (length) × 0.8 m (width) × 0.8 m (base height). The gable roof reached a peak height of 1.00 m at the center, supported by a triangular truss structure. The side walls measured 0.8 m in height, and the net floor area was 0.96 m^2. Figure (2) provides a detailed schematic of the greenhouse design.

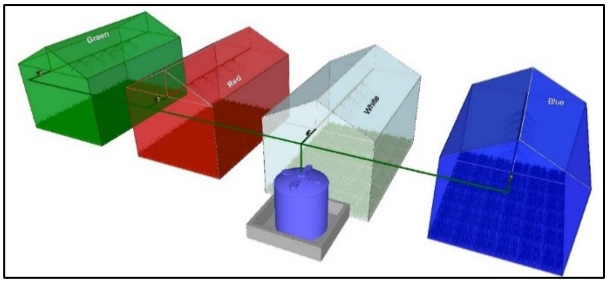

Figure (1): Four identical greenhouse systems.

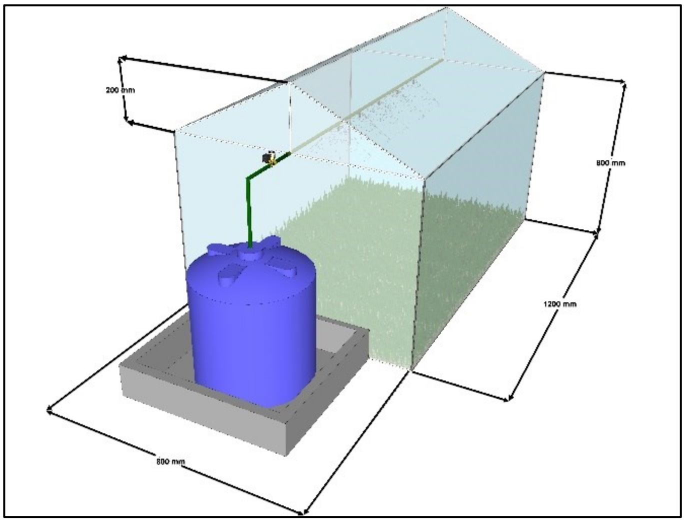

Figure (2): Detailed schematic of the greenhouse design.

2.2 Systems inside greenhouses

Table (1) illustrates the systems utilized and available within the experimental greenhouses. It identifies a smart irrigation system as the key feature, whereas no active cooling or heating systems are present. Lighting operates at standard intensity without adjustments.

2.3 Irrigation system

The irrigation system was a smart automated setup comprising two main modules: (1) hydraulic components (water pump, polyethylene pipes, and micro-sprinklers) and (2) control components (NodeMCU microcontroller, relay module, and 12V DC power supply).

Table (1): Systems inside greenhouses.

System	Description
Irrigation system	sprinkler system (smart system)
Cooling system	Non
Heating system	Non
Ventilation system	Closed system
Lighting system	Normal

Detailed technical specifications of the electronic circuit and pump parameters are provided in Table (2) and Figure (3).

2.4 Control irrigation system

The control irrigation system consists of NodeMCU, relay, and power source. Turns the relay on for 6000 milliseconds, then off for 21600000 milliseconds, repeatedly. As shown in Figure (3) and in the following code:

```
#define MOTOR_PIN 8
void setup()
{pinMode(MOTOR_PIN, OUTPUT);}
void loop()
{digitalWrite(MOTOR_PIN, HIGH);
 delay(120000);
 digitalWrite(MOTOR_PIN, LOW);
delay(21600000);}
```

Table (2): Detailed specification of the electronic circuit.

Parameter	Specification	Job	Figures
Relay Module (1 Channels - 5V)	Rating: 10A (250V AC or 30 V DC) Input (Control) Voltage: 5V DC	This relay module allows microcontrollers such as Arduino to control high-power electrical devices safely and efficiently.	
NodeMCU Based ESP8266 Development Kit (With CP2012 Chip)	Operating Voltage: 3.3V Input Voltage: 7-12V Flash Memory: 4 MB SRAM: 64 KB	Sending and receiving data	
A centrifugal water pump	Model: QB 60 Voltage: 220 V Currency:1.1 Amp Power: 0.3 Hp Flow rate: 25 L/ min. Frequency: 50 Hz Head: 13 m	Pumping the water in the irrigation system	
Micro sprinkler	Recommended spacing: 0.5 to 5 m Discharge rate: 25 to 400 l/ min. Operating pressure: 0.9 to 3.5 bar	This sprinkler was economical and easy installed it gave a fine spray of water over an area its radius reaches to 5 meters depending on the pressure	

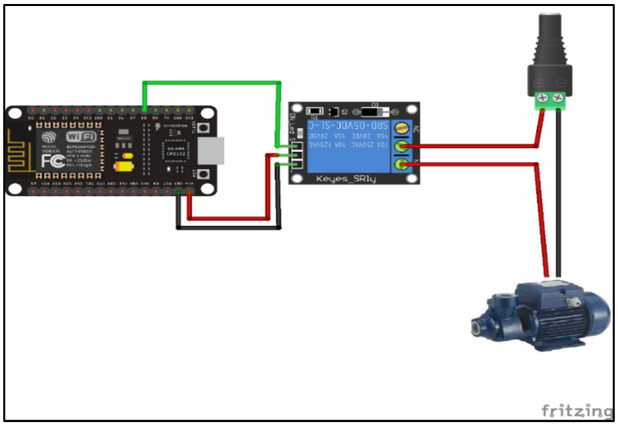

Figure (3): The control irrigation system.

2.5 Monitoring temperature and humidity using the internet of things

Figure (4) demonstrates the IoT-based temperature and humidity monitoring system, outlining the workflow for transmitting sensor data to Google Sheets. The DHT11 sensor interfaces with a NodeMCU microcontroller, where firmware is programmed to collect precise environmental readings. A Google Sheet is initialized, and the Google Sheets API is enabled through the Google Cloud Console. API credentials are configured to authenticate secure Wi-Fi-based data transmission between the microcontroller and the cloud service. The NodeMCU's code integrates the Google Sheets API library, enabling direct real-time data logging to the spreadsheet.

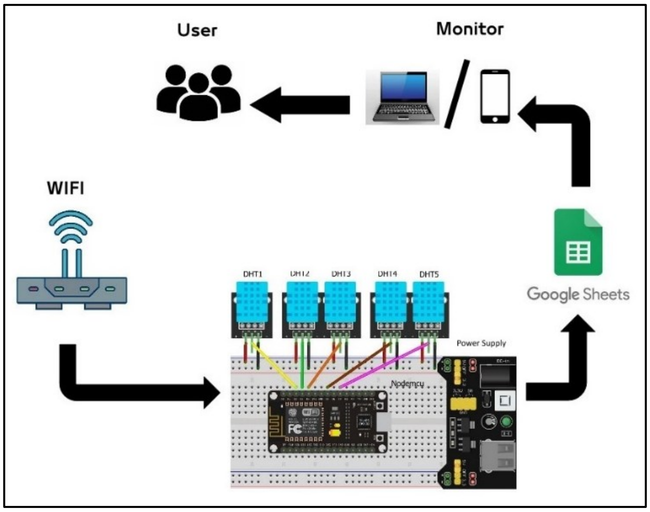

Figure (4): Monitoring Temperature and humidity Circuit.

Users then access and visualize the aggregated data via web or mobile interfaces for continuous environmental analysis, Singh *et al*. (2023), who focused on manual data collection but acknowledged the need for affordable IoT solutions in precision agriculture.

2.6 Light Intensity Measuring Device

Illuminance was measured using the UT383S Digital Light Meter. The technical specifications of the device are presented in Table (3).

Table (3): Detailed specification of Light Intensity Measuring Device.

Specifications	Range	Resolution	Accuracy	Figure
Illuminance	0~199,900Lux	1Lux (0~9999Lux)	± (4%+8)	
		10Lux (≥10,000Lux)	± (5%+10)	
		100Lux (≥100,000Lux)	± (5%+10)	

3. Results and Discussion

3.1 Effect of the covering color on the greenhouse temperature

Figure (5) shows the relation between the internal greenhouse Temperatures and the external temperatures during the experimental days. As shown in the figure, the lowest value of the Temperature inside greenhouses were 22.55 °C, while the highest value was 30.7 °C compared with the lowest value outside greenhouse that was 19.5°C and the highest value 24°C. Based on these results, it is clear that the increase in internal Temperature is affected by the increase in external Temperature, unless wind speed has an impact on it. The figure shows the effect of the covering color of the internal Temperature of the greenhouse, it was ranged (29.7, 30.45, 29.75, and 29 °C) for the colors (Blue, Red, White, and Green "BRWG") respectively. The highest value was with the red color, its value was 30.45°C. The lowest value was with the green color, its value was 29 °C, while for the cover with white and blue color was have close value (29.75, and 29.7) respectively. From these results we concluded that the red cover is not significantly permeable to infrared radiation. The white cover comes in second, while the green cover is characterized by high permeability to infrared radiation. These results supported by Sun *et al*. (2015), who reported that black polyethylene films retained higher soil temperatures compared to clear films, with reduced infrared radiation loss, and He *et al*. (2021), who noted that light-altering covers with lower transmissivity in the infrared spectrum increased thermal retention in greenhouses.

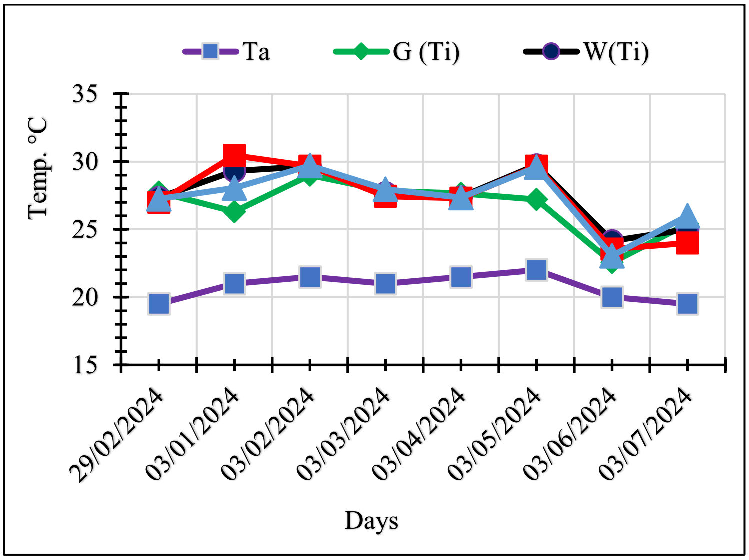

Figure (5): The relationship between the internal greenhouse temperature and the external temperatures during the experimental days.

3.2 Effect of the covering color on the greenhouse humidity

Figure (6) shows the relation between the inside greenhouse Humidities and the outside one during the experimental days. As shown in Figure (6), the lowest value of the Humidity inside greenhouses were 46.5 %, while the highest value was 66.5 % compared with the lowest value outside greenhouse that was 32.5% and the highest value 55%, it is clear that the increase in internal Humidity is affected by the increase in external Humidity, unless wind speed has an impact on it. The figure shows the effect of the covering color of the internal Humidity of the greenhouse, it was ranged (62.5, 66.5, 61.5, and 58.5 %) for the colors (Blue, Red, White, and Green "BRWG") respectively. The highest value was with the red color, its value was 66.5%. The lowest value was with the blue and white color, their value was 46.5%, while the cover with green color was have value (47.5%). From these results, concluded that the relative humidity for the greenhouse with the red covering color increased, and it's decreased for the greenhouse with green covering color, this agreeable with the change rate of temperature and the increase of evaporation rate. Results show that the red cover can be used in cultivating crops that require high temperatures and relatively high humidity. It is also evident that the green cover can be used in cultivating crops that require relatively low temperatures and humidity. These results Supported by Alhelal *et al*. (2024), who found that red shading nets increased humidity by reducing ventilation efficiency, while green nets promoted airflow and lower moisture retention. It can also result that the color red stresses plants to increase the process of evapotranspiration, while the colors blue and green are characterized by maintaining plants within their thermal comfort range. As shown in Figure (7) the relation between Temperature and Humidity. Supported by Roslan *et al*. (2024), who argued that green nets are optimal for humidity-sensitive crops like strawberries due to balanced PAR and cooling effects.

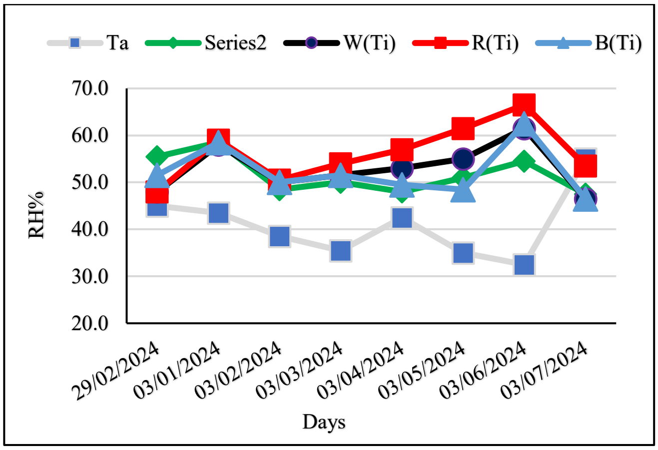

Figure (6): A relationship between the internal greenhouse humidity and the external humidities during the experimental days.

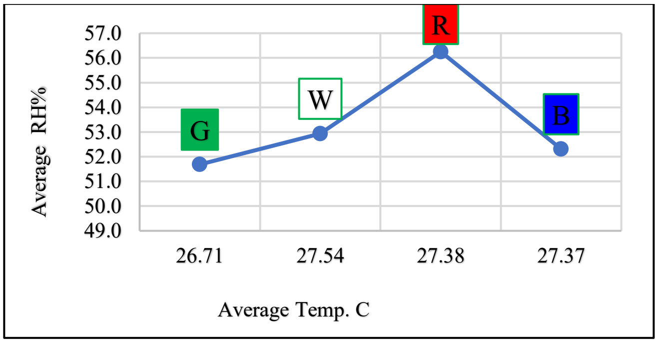

Figure (7): The relationship between the internal greenhouse humidity and the temperature during the experimental days.

3.3 Effect of wind speed on the greenhouse temperatures

It's concluded from Figure (8) that there is an inverse relationship between temperature change and wind speed for all greenhouses of different colors. The lowest temperature value both outside and inside the greenhouse (19.5, 22.55, 24.15, 23.55, 23.05°C, respectively), were observed at the highest wind speed (24 km/hr.), while the highest external and internal temperature (22, 29, 29.75, 30.45, 29.7 °C) were recorded at the lowest wind speed (17 km/hr). These results were supported by Atilgan *et al*. (2020), who reported that wind-driven ventilation reduced greenhouse temperatures by 4°C, mitigating heat stress in tomato plants.

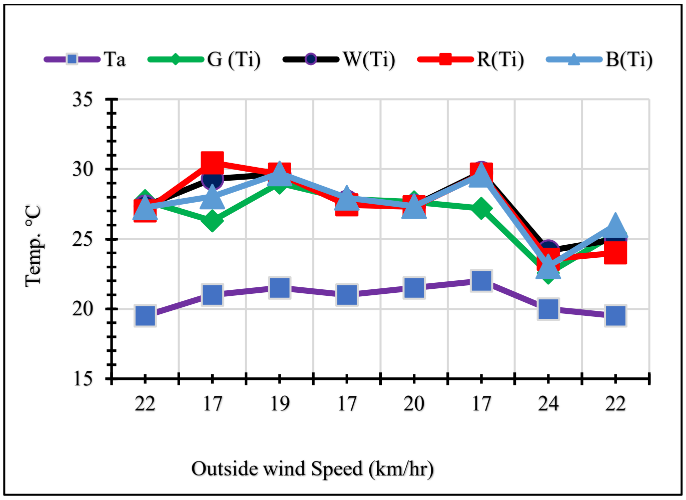

Figure (8): The relationship between the internal greenhouse temperature and wind speed during the experimental days.

3.4 Effect of the covering color on the biomass (wet weight)

Light is essential for the process of photosynthesis, which is the factory for producing food materials for plant growth. One of the most important factors related to light that directly affects plants is the quality of light, the length of the photoperiod, and the intensity of illumination. By studying the quality of lighting on four different colors of covers, as shown in Figure (9), the effect of color on the weight of plants becomes evident.

3.5 Effect of the covering color on the length of the plant

As shown in Figure (10), during the first five days of the experiment, green and red light significantly enhanced barley seedling growth, with plant length reaching approximately 100 mm. This phase highlights the role of red light in stimulating chlorophyll production and green light in activating germinationrelated photoreceptors. Beyond the fifth day, a distinct shift occurred: blue light became the dominant driver of vegetative growth, propelling plant length to 160 mm by day 10. This surge is attributed to blue light's efficiency in activating chlorophyll-a and optimizing photosynthetic processes. In contrast, red light sustained steady growth (120 mm by day 10) through stem elongation, while green light's limited absorption by plants caused growth to plateau near 105 mm. The results underscore blue light's superiority in promoting advanced growth stages, whereas green and red lights are more effective in early developmental phases. These results agreed with He *et al*. (2021), who stated that blue light optimizes photosynthetic efficiency and chlorophyll-a synthesis, whereas red light enhances stem elongation through gibberellin activation, and Ilić *et al*. (2017), who observed that red nets increased sweet pepper yield by 20% compared to unshaded controls, while blue-enriched light improved leaf expansion.

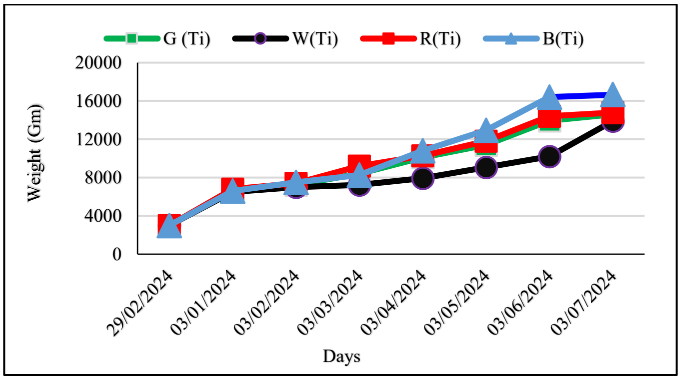

Figure (9): The effect of the covering color on the biomass during the experimental days.

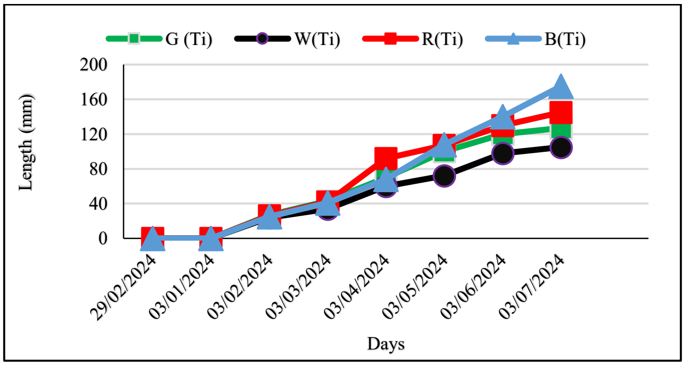

Figure (10): Effect of the covering color on the length of the plant.

3.6 Effect of cover color on Illumination

In Figure (11) and Table (4), Illumination has a trend approximately normal distribution cure at noon before noon and after noon. It could be interpreted by physical phenomena of Illumination as it is electromagnetic flux. the light transmittance values of the covers, represented by the illuminance in lux and the corresponding percentages of light penetration for each cover. The results indicated that the green cover exhibited the lowest transmittance of direct sunlight throughout the average duration of the experiment, with an average illuminance ranging from 10,600 to 28,300 lux—corresponding to 19.4% to 25.9%. In contrast, the transparent cover registered an average illuminance ranging from 28,200 to 98,800 lux, with transmittance percentages between 56.7% and 90.4%. Meanwhile, the blue and red covers recorded average illuminance values of 13,900–44,100 lux (25.7%–40.3%) and 11,900–37,800 lux (19.9%–34.5%), respectively. Furthermore, the data—corroborated by previous studies—demonstrate that the optimal minimum light level for barley growth is 21,600 lux, while the ideal range is between 27,000 and 37,800 lux. These conditions best correspond to the red cover, followed by the blue cover, with the green cover being the least suitable. Conversely, the transparent cover is deemed unsuitable, as its light transmittance significantly exceeds the optimal limits.

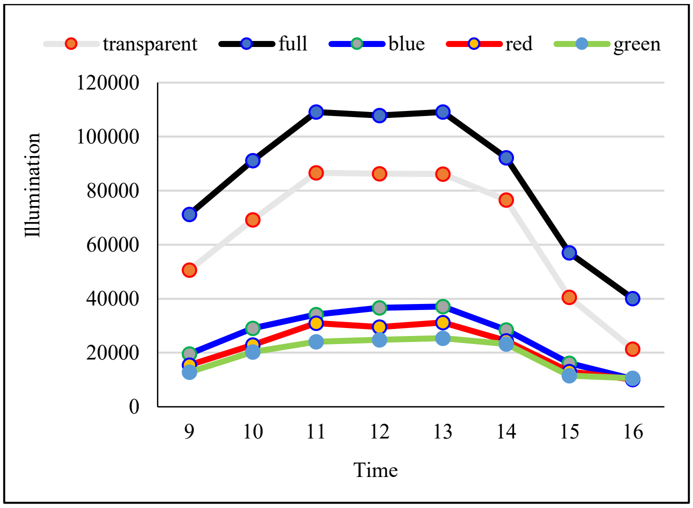

Figure (11): Illumination distribution as affected by local time during experiments.

Table (4): Illumination distribution as affected by local time during experiments.

hr.	Transparent	Red	Blue	Green
9	71.06742	21.63	27.53	17.98
10	75.96048	25.14	31.94	22.28
11	79.37672	28.32	31.26	22.09
12	80.05566	27.37	33.95	23.01
13	79.01008	28.60	34.01	23.28
14	78.74187	26.46	30.91	25.16
15	71.05263	22.98	28.25	20.18
16	53.36658	25.19	25.69	26.43

These results supported by Baeza and López (2012), who emphasized that covers with 30–50% light transmittance maximize photosynthesis without causing photoinhibition, and Roslan *et al*. (2024), who concluded that green nets achieved balanced PAR transmittance (19–26%), ideal for shade-sensitive crops like black ginger.

4. Conclusion

This study demonstrates the significant role of colored greenhouse covers and IoT integration in optimizing barley cultivation environments. Key findings include:

1. Color-Specific Microclimatic Effects: Red covers retained the highest internal temperatures (30.45°C) and humidity (66.5%), ideal for crops requiring warm, humid conditions, while green covers maintained cooler temperatures (29°C) and lower humidity (58.5%), suitable for moderate climates.

2. Growth Stage-Specific Optimization: Blue covers drove advanced vegetative growth, with plant length reaching 160 mm by day 10 due to enhanced chlorophyll-a activation. Red covers favored early-stage growth (100 mm by day 5) via stem elongation.

3. Light Transmission: Red and blue covers transmitted optimal illumination levels (27,000–37,800 lux), aligning with barley's photosynthetic needs, whereas green covers underperformed (10,600–28,300 lux).

4. Future: Research will investigate the dual effect of greenhouse cover colors in combination with artificial lighting colors.

5. IoT-Based Validation: Real-time monitoring confirmed wind speed's inverse relationship with internal temperatures, highlighting the system's reliability in tracking environmental variables.

These results confirm the importance of selecting cover colors based on crop-specific requirements. Integrating IoT technologies offers farmers actionable insights to manage microclimates efficiently, particularly in arid regions. Future studies could explore hybrid cover materials and expanded IoT applications for diverse crops, advancing sustainable agriculture in resource-limited settings.

References

Alhelal, I. M., Albadawi, A. A., Alsadon, A. A., Alenazi, M. M., Ibrahim, A. A., Shady, M. and Al-Dubai, A. A. (2024), "Effects of shading nets color on the internal environmental conditions, light spectral distribution, and strawberry growth and yield in greenhouses", *Plants*, Vol. 13 No. 16, Article No. 2318.

Atılgan, A., Erdal, I., Aktaş, H. and Cetin, E. (2020), "Effects of the use of colored cover materials and led lighting in greenhouses on plant nutrient concentration: Case of tomato plant (*Solanum lycopersicum* L.)", *Turkish Journal of Agriculture - Food Science and Technology*, Vol. 8 No. 12, pp. 2550–2555.

Baeza, E. and López, J. C. (2012), "Light transmission through greenhouse covers", *Acta Horticulturae*, Vol. 956, pp. 425–440.

Gmizo, G., Alsipa, I. and Dubova, L. (2012), "The effect of colour plastic films on the growth, yield and plant pigment content of tomatoes", *Acta Horticulturae*, Vol. 952, pp. 217–224.

He, X., Maier, C., Chavan, S. G., Zhao, C. C., Alagoz, Y., Cazzonelli, C., Ghannoum, O., Tissue, D. T. and Chen, Z.-H. (2021), "Light-altering cover materials and sustainable greenhouse production of vegetables: A review", Plant Growth Regulation, Vol. 95, pp. 1–17.

Ilić, Z., Milenković, L., Šunić, L., Barać, S., Mastilović, J., Kevrešan, Ž. and Fallik, E. (2017), "Effect of shading by coloured nets on yield and fruit quality of sweet pepper", *Zemdirbyste-agriculture*, Vol. 104, pp. 53–62.

Ledóné, H., Pék, Z., Helyes, L. and Szuvandzsiev, P. (2017), "Influence of colour net shading on quantity and quality of sweet pepper yield", *Acta Horticulturae*, Vol. 1170, pp. 359–364.

Roslan, I., Mohd, Y., Raship, I., Jusoh, S. and Ramly, M. (2024), "Effect of different shading color on growth and yield performance of (Black Ginger) *Kaempferia parviflora* Wall. ex Baker", *Asian Research Journal of Agriculture*, Vol. 17 No. 2, pp. 217–224.

Singh, H., Dunn, B. L. and Fontanier, C. (2023), "Colored shade nets affect growth but not flowering of four greenhouse-grown potted ornamental species", *HortScience*, Vol. 58 No. 9, pp. 1075–1076.

Sun, T., Zhang, Z., Ning, T., Mi, Q., Zhang, X., Zhang, S. and Liu, Z. (2015), "Colored polyethylene film mulches on weed control, soil conditions and peanut yield", *Plant Soil and Environment*, Vol. 61 No. 2, pp. 79–85.