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Original Article

Influence of colored polyvinyl chloride films as light filters on the growth of iceberg lettuce (*Lactuca sativa var. capitata Linnaeus*)

Fritz Gerard B. Javier[1] and Ma. Grace C. Sumaria[1,2*]

ABSTRACT

The two components of light – light quality and light intensity – significantly affect plant photosynthesis as well as the morphological, physiological, and biochemical parameters of plants. The response of plants to different spectral radiations and intensities differs in various species and depends on growing conditions. Four set-ups were constructed for each film color to test its influence on the growth of iceberg lettuce (*Lactuca sativa var. capitata L.*). A drip irrigation system passed through the four set-ups and supplied water throughout the duration of the study. Temperature and Humidity sensors were also installed to monitor maximum and minimum temperature and humidity values. Three replications were made following the Completely Randomized Design (CRD). Each replication obtained data regarding chlorophyll a and b, light intensity, fresh weight, plant height and number of lettuce leaves. The analysis reveals significant difference between set-ups suggesting how film color influences the growth of iceberg lettuce in terms of light intensity received, lettuce height and fresh weight (Transparent>Purple>Blue>Red), while there is not enough evidence to support that film color influences the number of leaves. In addition, results of the laboratory analysis also revealed that Transparent

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[1]Department of Agricultural and Biosystems Engineering, Visayas State University, Baybay City, Leyte 6521-Philippines
[2]Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

***Corresponding Author.** Address: Department of Agricultural and Biosystems Engineering, Visayas State University, Baybay City, Leyte 6521-Philippines; Email: grace.sumaria@vsu.edu.ph

chlorophyll a and b while blue light exhibited higher chlorophyll b than red light and the latter having higher chlorophyll a than blue light. The main objective of this study is to observe the influence of colored polyvinyl chloride films as light filters on the growth of iceberg lettuce (*Lactuca sativa var. capitata Linnaeus*).

Keywords: Chlorophyll, Iceberg Lettuce, Intensity, Spectral radiation

INTRODUCTION

Iceberg lettuce, known for its crisp, refreshing crunch, boasts a dense, compact head with tightly packed leaves. Its leaves are typically pale green in color, with a smooth, waxy texture. Iceberg lettuce is often described as having a mild, neutral flavor, making it a versatile addition to various dishes. Its crisp texture adds a refreshing crunch, while its subtle flavor allows other ingredients to shine. (Amanda & Amanda, 2024).

Iceberg is a type of head lettuce, meaning it grows in a ball rather than in a leafy form, it is known for its comparatively small, densely packed heads. The outer leaves are bright green in color, while the inner leaves and heart are light green to yellow and sometimes even white. The center of the head is the sweetest part, though the entire iceberg lettuce plant has a very mild flavor, making it ideal as a backdrop to more potent salad and sandwich ingredients. Typically, iceberg lettuce seeds take about 1 - 2 weeks to fully germinate (Allison, 2023).

Plants use light as an energy source for photosynthesis and as an environmental signal, and respond to its intensity, wavelength, and direction. Light is perceived by plant photoreceptors that include phytochromes, cryptochromes and phototropins, and plants generate a wide range of specific physiological responses through these receptors. A major challenge to plants is controlled by supplying sufficient quantity and quality of light intensities. While heat cannot entirely replace light in this process, light can in large measure replace heat. The quality and the quantity of the sunlight transmitted to growing plants are both dependent upon atmospheric conditions, as well as upon the season of the year. They vary from place to place and from month to month. Of the various weather elements, sunshine, directly through radiation and indirectly through its effect upon air temperatures, influences the distribution of crops. Because it furnishes the required energy for certain chemical activities within growing plants, and promotes transpiration from the foliage, abundant sunshine is required of most plants (Palmer, 1920).

LEDs (light emitting diodes) are gaining attention because of their ability to provide light of different spectra. In the light spectrum, red and blue regions are often considered the major plants' energy sources for photosynthetic CO2 assimilation. While sunlight contains a variety of color spectra, it turns out that plants only need specific color spectra to grow properly (Cosmos, 2023).

Prior to 1950, all greenhouses in existence were made of glass. Plastics were not yet available for widespread commercial use. Today, mainly the older greenhouses are glazed (or covered) with glass. Sometimes, greenhouses are still constructed using glass because it does have some excellent advantages, but most greenhouses today are glazed with flexible or rigid plastics (McMahon, 2000).

Vinyl films, also known as polyvinyl chloride (PVC) films, are often used in greenhouse construction due to their durability, affordability, and versatility. Vinyl films used for greenhouse covers are typically designed to allow sunlight to pass through while providing some level of insulation and protection for the plants inside. The film can help create a controlled environment by trapping heat and maintaining higher temperatures, which is beneficial for plant growth. When using vinyl films as greenhouse covers, it is important to consider factors such as light transmission, heat retention, UV stability, and durability. Different types of vinyl films may have varying thicknesses, additives, or coatings to optimize these characteristics. It is worth noting that there are other materials commonly used as greenhouse covers, such as polycarbonate sheets and polyethylene films, which also have their own advantages and considerations. The choice of greenhouse cover material depends on factors such as climate, budget, specific plant requirements, and personal preferences (McMahon, 1992).

Crops grown using controlled environment agriculture are much more reliable as they are not prone to extremes of temperature and rainfall. At present, only a few types of crops are grown in this way. This study aims to observe the influence of colored polyvinyl chloride films as light filters on the growth of iceberg lettuce (*Lactuca sativa var. capitata Linnaeus*) under a controlled environment.

Due to the availability and popularity of iceberg lettuce (*Lactuca sativa var. capitata Linnaeus),* this study aimed to observe the influence of colored polyvinyl chloride films as light filters on the growth of iceberg lettuce (*Lactuca sativa var. capitata Linnaeus*) only under a controlled environment. Other parameters that were not mentioned are beyond the scope of the study.

MATERIALS AND METHODS

Figure 1 represents the methodological framework of the study. The framework provides a process flow for the study including experimentation, data collection, analysis, and interpretation.

Determination of Parameters and Selecting the Appropriate Experimental Design

The crop used in this study was iceberg lettuce (*Lactuca sativa var. capitata Linnaeus*). The independent variables were polyvinyl chloride film colors (Red, Blue, Purple and transparent) gauge #10 with 8 samples for three replications. The research design used in the study was a Completely Randomized Design (CRD). Assignment of treatments to the experimental unit were generated randomly using Design Expert Software (Version 13).

Construction of the Structure

A thorough assessment of the specific requirements for the structure was made. This includes the appropriate dimensions to provide the required spacing between rows and lettuce heads. Taking into account the availability, durability, and cost of materials, wood was selected for the frame, while polyvinyl chloride film was used as the cover. The study was conducted indoor near Plant Oil Training Center (POTC) at Visayas State University – Main Campus, Baybay City, Leyte from August 2023 to March 2024.

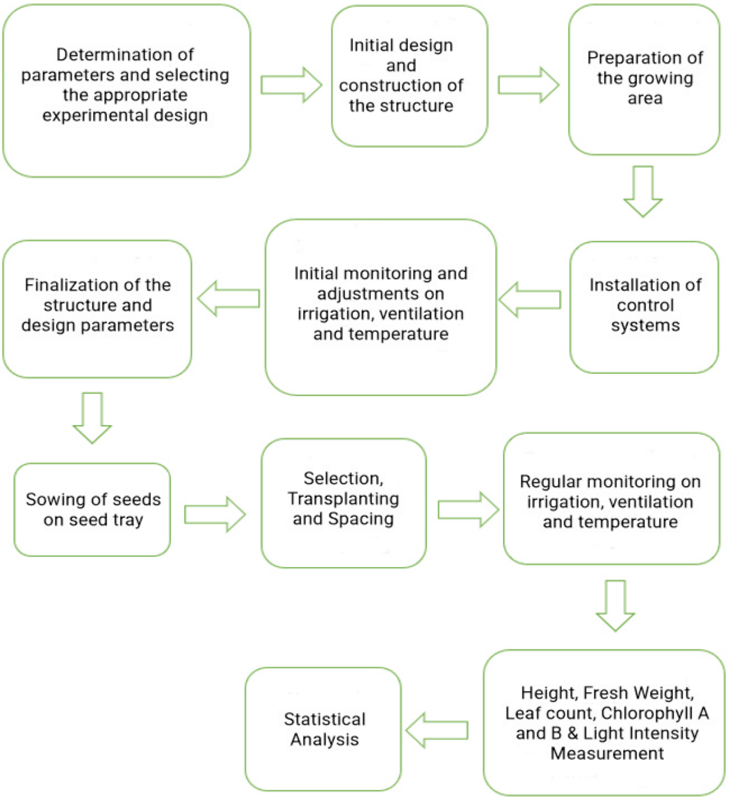

Figure 1. Methodological framework of the study

The design of the structure was based on the appropriate requirements for iceberg lettuce. Two seedbeds per set-up were constructed, each measuring 30.48cm in width, 121.92cm in length, and 15.24cm in depth. The design was based on the space requirement for every lettuce head and space requirement between rows. The seedbed was elevated at a height of 15.40cm from the ground. The height of the wooden columns was 76.20cm to accommodate the average height of mature plant samples and promote air circulation. The sides of the structure were covered with a colored polyvinyl chloride film varying in each set-up. An opening of 15.24cm between the seedbeds was made to further allow air circulation. It is worth noting that a single structure was constructed for each film color, with 4 structures in total where 3 replications were made at the end of each month. Isometric view of the growth structure is presented in Figure 2.

Preparation of the Growing Area

The soil was collected from the same source at the VSU lower campus to ensure that the sample would have the same soil type. Vegetation, weeds, rocks, or debris were removed. The sterilized soil used in the experiment was purchased from the Department of Horticulture Garden at the Visayas State University – Lower Campus. Prior to planting, the soil was moistened but not waterlogged and had willow holes for planting the iceberg lettuce seedlings.

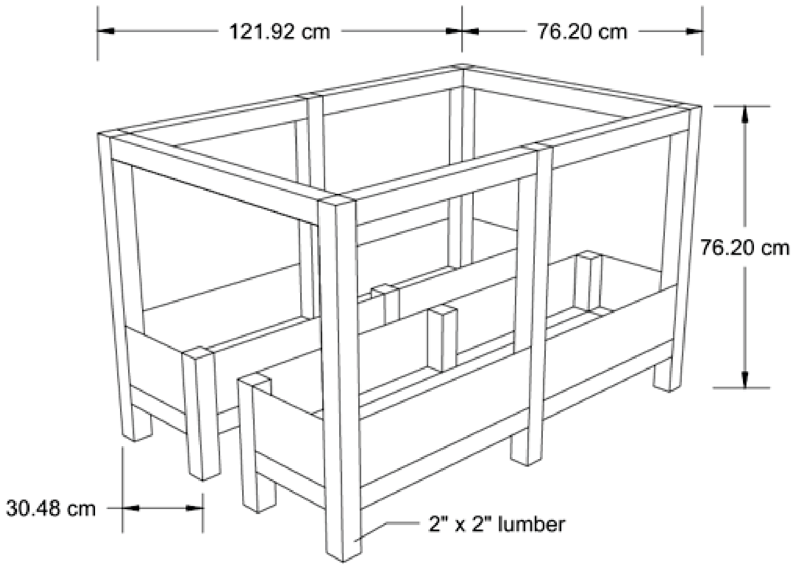

Figure 2. Growth structure covered with PVC film

Installation of Irrigation Control Systems

For the drip irrigation system, there were four lines installed in series, one for each seedbed. The irrigation requirement for the iceberg lettuces was calculated and careful consideration was made in selecting the appropriate drip irrigation system components including punch-in emitters, connectors, and tubing. Layout of the tubing along the row followed proper spacing and coverage. An exhaust fan was installed at the highest point on the shorter side to allow hot air to escape. Temperature and humidity sensors were installed at a specified location within the growing area. The irrigation requirement for the iceberg lettuces was calculated as shown below.

Data and Assumptions:

Type of Crop	: Iceberg Lettuce
Peak Consumptive Use	: 0.381cm day^{-1}
Actual Evapotranspiration (ET_a)	: 0.381cm day^{-1}
Percentage Groundcover	: 45.71%
Electrical conductivity of water (EC_w)	: 2dS m^{-1}
Rainfall (R)	: 0
Electrical Conductivity of Lettuce (max EC_e)	: 9dS m^{-1}
Application Efficiency	: 80%
Total area	: 6,967.728cm
Area per plant	: 929.03cm
Spacing per plant	: 30.48cm
Ground cover reduction ratio (keller and karmelli)	: 0.54

Computation:

$$\text{Net IR } (IR_n) = ET_{crop-loc} - R + LR$$
$$ET_{crop-loc} = ET_a \ x \ k_r$$
$$= 0.381 \frac{\text{cm}}{\text{day}} x \ 0.54$$
$$= 0.206 \frac{\text{cm}}{\text{day}} = 2.06 \ mm/day$$
$$IR_n = 2.06 \frac{mm}{day} + 0 + LR = 2.06 \frac{mm}{day} + LR$$
$$IR_n = \frac{IR_n}{E_a} = \frac{\left(2.06 \frac{mm}{day} + LR\right)}{0.80} = 2.575 \ \frac{mm}{day} + LR$$
$$\text{Leaching rate } (LR_t) = EC_w/(2 * \max EC_e) = \frac{2}{2(9)} = 0.11$$
$$\text{LR} = LR_t \ x \left(\frac{IR_n}{E_a}\right)$$
$$= 0.11 \ x \ 2.575 = 0.283 \ mm/day$$
$$IR_g = 2.575 \frac{mm}{day} + 0.283$$
$$IR_g = 2.858 \frac{mm}{day} x \ (9290.3 \ mm)$$
$$= 26{,}551.677 \ mm^3$$
$$= 0.27 \frac{L}{plant}/day$$

Initial Monitoring and Adjustments on Irrigation, Ventilation and Temperature

A test of the drip irrigation system to check for leaks, uneven water distribution or other issues was made. The ventilation system was checked to see that adequate air was provided. The temperature sensor and real time clock (RTC) module were already calibrated as purchased to ensure accurate temperature readings. Other necessary adjustments were made to ensure proper functioning.

Finalization for the Structure and Design Parameters

After several tests, the same adjustments were applied to all set-ups. Estimation of the overall cost of materials, labor, and equipment was made according to the final design. Construction of the set-ups proceeded.

Sowing of Seeds on Seed Tray

The seeds were sown in a seed tray. The individual holes were placed on the sterilized soil. Lettuce seeds were allowed to germinate and grow for a total of 2 weeks for this stage.

Selection, Transplanting and Spacing

After 2 weeks of germination, selection was done randomly for a total of 32 samples. These were then transplanted on the seedbed of the structure with eight plant samples for each set-up. Iceberg lettuce plants were spaced 12 inches apart.

Regular Monitoring on Irrigation, Ventilation and Temperature

Irrigation was adjusted based on any signs of overwatering or underwatering. Complete fertilizer was dissolved in the container with a ratio of 1 pack per 50L. The movement of air within the structure was observed, ensuring there was sufficient airflow and that it reached all plants. Vents were regularly checked if they were obstructed. Temperature variations relative to the noon temperature was evaluated to identify the need for better ventilation.

Measurement and Data Acquisition of Parameters

At the end of two weeks after transplanting, plant samples were harvested, cleaned off debris, and left dry. The number of leaves, starting from the outermost near the base towards the center, was counted. The height of each iceberg lettuce, from the base of the stem to the topmost point of the plant, was measured using a ruler, ensuring it was held straight and aligned vertically with the plant. The plant samples were placed on a digital scale to record the weight. A container was used to hold the lettuce under the analytical balance. The container was tared and the fresh weight of the plant samples was recorded. Chlorophyll a and b were analyzed at the PRCRTC CASL Laboratory. One leaf per lettuce was prepared and placed in a zip lock bag submitted at the laboratory. Acetone was used as the solvent in extracting chlorophyll content of the plant samples. Light intensity was measured using a light meter, with the sensor stationed at the base of each planting area, having a total of eight (8) measurements per set-up.

Statistical Analysis

All statistical analyses were carried out with Design Expert Software (Version 13). Data across all experimental units from the experiment were analyzed using analysis of variance, specifically the one-way ANOVA. Differences between treatment means were analyzed using Tukey's HSD test at a 0.1 significance level. Normality of data was evaluated using the Shapiro-Wilk Test since the sample size was <50.

RESULTS AND DISCUSSION

General Observations

Data on maximum and minimum ambient temperature throughout the duration of the study were recorded along with data on maximum and minimum relative humidity. It is worth noting that the data presented below were for observation purposes only and were not included as parameters of the study.

Treatment B (Red PVC Film) showed the lowest recorded minimum temperature, 24.8°C, followed by Treatment A (Purple PVC Film) – 24.9°C, Treatment C (Blue PVC Film) – 25.1°C, and Treatment D – 25.2°C. Blue black-body radiation corresponds to higher temperatures while red corresponds to cooler temperatures. The peak of the blackbody curve in a spectrum moves to shorter wavelengths for hotter objects (Thumbs, 2024). In terms of visible light, the hotter the blackbody, the bluer the wavelength of its peak emission. Purple light falls between these two colors as it is a combination of both. Purple light falls between these two colors as it is a combination of both. Lastly, the set-up under transparent film exhibited the highest temperature because transparent films allow maximum light transmission and results in a higher internal temperature.

Treatment B (Red PVC) showed the highest recorded maximum relative humidity of 84% followed by Treatment A (Purple PVC) – 83.2%, Treatment C (Blue PVC) – 83.1%, and Treatment D (Transparent PVC) – 82.4%. At lower temperatures, air holds less moisture, so the same amount of water vapor results in higher relative humidity. This inverse relationship is supported by Hao & Lu (2022), who found that relative humidity increases as temperature decreases when vapor content remains constant due to the reduced moisture-holding capacity of cooler air. Following the trend of decreasing ambient temperature, the respective relative humidity was highest on Set-up B (Red PVC) which showed the lowest recorded minimum temperature. Conversely, Treatment D (Transparent PVC) showed the lowest recorded relative humidity of 67.1%, followed by Treatment C (Blue PVC) – 68.7%, Treatment A (Purple PVC) – 69.6% and lastly, Treatment B (Red PVC) – 70.4%).

Color temperature compares a light source's color to that of an idealized, opaque, non-reflective black-body heated to a specific temperature. As the temperature of the black body increases, the color of its emitted light changes. Lower temperatures (around 1,000 K) result in warm colors like red and orange. These are associated with incandescent bulbs and candle flames. Intermediate temperatures (around 3,000–4,000 K) produce neutral white light, similar to daylight. Higher temperatures (above 5,000 K) yield cooler colors like blue and purple. Red light has a lower color temperature (around 1,000–2,000 K), making it cooler than blue light. Blue light and purple light have higher color temperatures (above 5,000 K), so they are cooler than white light. Lastly, white light itself is hotter than any individual color (around 5,000–6,500 K). Warm colors like red/orange light corresponds to lower physical temperatures, while cool colors blue light corresponds to higher temperatures, a naming convention based on visual impression rather than thermal reality (Wikipedia, 2025; Physics Journal, 2025).

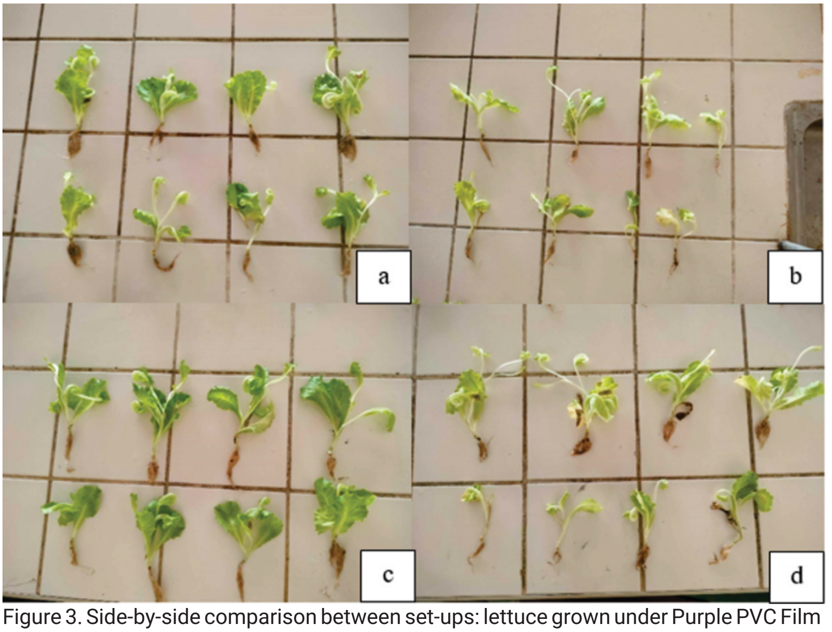

Figure 3. Side-by-side comparison between set-ups: lettuce grown under Purple PVC Film (a), Red PVC Film (b), Transparent PVC Film (c), Blue PVC Film (d)

Light Intensity

In photosynthesis, the sun's energy is converted to chemical energy by photosynthetic organisms. However, the various wavelengths in sunlight are not all used equally in photosynthesis. Instead, photosynthetic organisms contain light-absorbing molecules called pigments that absorb only specific wavelengths of visible light, while reflecting others. In this study, grow lights were used to provide the lighting required for crop cultivation. Table 1 shows the measurements of the light meter for each set-up with eight readings corresponding to eight planting positions.

Table 1. Light Intensity Under the Colored PVC Films in Lux

Purple	Red	Blue	Transparent
517.5 (10.05%)	171.25 (13.76%)	365 (9.82%)	1070 (8.13%)

*Values in parentheses are %CV from the computed mean.

It was observed that all throughout the three replications, the recorded light intensity under the colored filters remained constant. Thus, the table above summarizes the measured light intensity in lux. Results of the ANOVA showed that the computed p-value was less than the critical p-value, suggesting that there was a significant difference between the treatments. Consequently, the results of the Tukey HSD test showed that all of the treatments showed a significant difference. In terms of light intensity, transparent PVC film had the highest light intensity followed by purple, blue and red. This was due to the reflective properties of the materials where purple PVC film produced a light purple light while blue and red PVC films produced dark blue and darker red light respectively. Due to absorptive and reflective properties of these colors, data obtained from the light meter in terms of lux showed significant differences for all set-ups. Given that the PVC films were of the same thickness, gauge #10, we can infer that the varying light intensity received by the plant samples was due to the difference in color. It can also be observed from the above table that the values of light intensity fan out, increasing and then finally decreasing. This is because the measurement was done from edge to edge of the seedbed with the center receiving the highest light intensity.

Chlorophyll Content

There are five main types of chlorophyll: chlorophyll a, chlorophyll b, chlorophyll c and chlorophyll d, and a related molecule found in prokaryotes called bacteriochlorophyll. In plants, chlorophyll a and chlorophyll b are the main photosynthetic pigments (Libretexts, 2021).

Table 2. Chlorophyll Content of Lettuce as Influenced by Film Color

Film color	chlorophyll a (mg g^{-1})	chlorophyll b (mg g^{-1})	chlorophyll a/b Ratio
Purple	0.8743 (7.78%)^{bcd}	0.3720 (8.85%)^{bc}	2.3527 (3.15%)
Red	0.7127 (10.18%)^{cd}	0.2883 (7.19%)^{d}	2.4053 (7.80%)
Blue	0.6970 (6.24%)^{d}	0.3060 (10.30%)^{cd}	2.2843 (4.49%)
Transparent	1.0207 (11.02%)^{ab}	0.4273 (8.80%)^{ab}	2.389 (7.59%)

* Values in parentheses are % CV from the computed mean.

Over the three replications, plant samples grown under transparent PVC film obtained the highest chlorophyll a and chlorophyll b content, followed by plant samples grown under purple PVC film. In addition, it was found that plant samples under red PVC film obtained higher values of chlorophyll a than the plant samples under blue PVC film. Conversely, plant samples under blue PVC film exhibited a higher chlorophyll b content than plant samples under red PVC film. This is because the leaf pigments have distinct absorption spectra due to their molecular structures. Chlorophyll b absorbs more blue light and chlorophyll a absorbs more red light. Chlorophyll a absorption peaks occur in the blue-violet (around 430–450nm) and red (around 640–680nm) regions of the electromagnetic spectrum. Chlorophyll b absorption peaks, on the other hand, are primarily in the blue (around 455–470nm) and red-orange (around 640–660nm) regions. The key difference lies in the side chain of chlorophyll b where it contains an additional aldehyde group instead of the methyl group found in chlorophyll a (Francis et al., 2022). This structural variation alters its absorption properties.

In terms of chlorophyll a, results of the Tukey HSDT showed no significant difference between red film vs blue film. This suggests that there is insufficient evidence to support the claim that plant samples grown under red PVC film are significantly different than plant samples under blue PVC film. However, purple film vs. transparent film having a significant difference means that plant samples under transparent PVC film which had the highest chlorophyll a value, still showed a significant difference despite purple PVC film falling within the range of optimal values. In addition, plant samples grown under blue PVC film which had the lowest chlorophyll a value, also showed comparable results to the plant samples under red PVC film. Thus, we can infer that in terms of chlorophyll a, plant samples under transparent PVC film showed the best results while being significantly different to those under purple, red, and blue PVC film.

In terms of chlorophyll b, results of the Tukey HSD test showed that there was no significant difference between red film vs blue film. Conversely, there was an observed significant difference between purple film vs. red film, purple film vs. blue film, purple film vs. transparent film, red film vs. transparent film, and blue film vs. transparent film. In terms of chlorophyll a-b ratio, results of the ANOVA showed that the computed p-value was greater than the critical p-value, suggesting that there was no significant difference between the treatments.

The optimal values of chlorophyll a (Chl a) and chlorophyll b (Chl b) in lettuce can vary depending on factors such as growth conditions, lettuce variety, and measurement techniques. Studies have reported that the chlorophyll a value for lettuce ranges from 0.87–15.92mg g^{-1}. Chlorophyll b ranges from 0.32–6.42mg g^{-1}, while the chlorophyll a/b ratio ranges from 1.43–7.07mg g^{-1} with a mean value of 2.47mg g^{-1}. For chlorophyll a, it was observed that only plant samples under purple and transparent PVC film exhibited the optimal/normal values for both chlorophyll a and b. Thus, we can infer that lettuce grown under blue and red light alone is undesirable for lettuce growth in terms of chlorophyll content. On the other hand, the values for chlorophyll a/b ratio for all treatments fall within the normal range indicating a balanced distribution between these pigments. Since the values of chlorophyll A-B ratio for all set-ups are close to the mean value, it can be inferred that the plant samples for all set-ups exhibit intermediate chlorophyll ratio suggesting optimal light absorption for growth and energy production. Chlorophyll a and b have specific absorption spectra, meaning they absorb light at distinct wavelengths. In conditions of low light intensity (such as shade), plants adjust their chlorophyll content. Plants exposed to less sunlight tend to have more chlorophyll b in their chloroplasts. This adaptation allows them to absorb a broader range of light wavelengths. However, despite red PVC film having the lowest light intensity, blue, purple and transparent PVC film still exhibited greater chlorophyll b values than red PVC film, as presented in the subsequent table. Hence, the amount of chlorophyll absorbed by the plant samples was not entirely dependent on lighting intensity alone. The results showed that the color of the film influenced the absorption of chlorophyll a and b.

First Weight, Number of Leaves, and Height of Plant Samples

The fresh weight, number of leaves, and the height of plant samples are presented in Table 3. According to the report of Hortidaily (2022), these parameters serve as important index for an accurate evaluation of growth processes, which are affected by factors such as temperature and radiation fluctuation, especially in a passive solar greenhouse.

Table 3. Fresh weight (g), Number of Leaves, and Height of plant samples (cm)

Parameter	Purple	Red	Blue	Transparent
Fresh weight, g	4.5404^{b}	3.6041^{d}	3.7388^{cd}	4.7013^{ab}
No. of Leaves	4	4	4	4
Height, cm	9.4210^{bc}	7.6960^{d}	8.4960^{cd}	9.7210^{ab}

**Values in parentheses are %CV from the computed mean except for No. of leaves where Kruskal-Wallis Test was used.

Samples grown under transparent PVC film showed the largest average fresh weight followed by purple, blue, and red respectively. Based on the Tukey HSD results, the comparison between purple vs transparent PVC film showed no significant difference between these treatments. This suggests that in terms of fresh weight, the observed differences between these pairs were not exactly equal but lacked sufficient evidence to claim otherwise. On the other hand, purple film vs red film, purple film vs. blue film, red film vs. transparent film, red film vs. blue film, and blue film vs. transparent film showed a significant difference. Thus, we can infer that the observed differences between these treatments in terms of fresh weight unlikely occurred by random chance but rather, the variability in data suggests that the color of the PVC film influenced the fresh weight of the plant samples, with those under purple and transparent PVC film yielding higher fresh weights than those under red and blue PVC film.

The Kruskal-Wallis test was used as a nonparametric alternative to the one-way ANOVA. Results of the Kruskal-Wallis test showed that there was a non-significant difference between the different groups, $\chi 2(3)=8.68$, $p=.034$, with a mean rank score of 59.71 for purple, 42 for red, 40.02 for blue, and 52.27 for transparent. The corrected α using Bonferroni correction method was 0.001667 and the test statistic $H=8.6822$ was in the 99% region of acceptance. Since the p-value > α, H_0 was not rejected. The mean ranks of all groups were assumed to be equal. In other words, the difference between the mean ranks of all groups was not big enough to be statistically significant. Thus, we can infer that there was no significant difference between the mean ranks of any pair in terms of number of leaves.

It was observed that plant samples under transparent PVC film exhibited the highest height followed by purple, blue, and red. In comparison to plant samples grown under purple and transparent PVC film where the plant samples exhibited relatively higher height, plant samples grown under blue PVC film exhibited disproportionate stalk height–leaf width ratio, indicating stem elongation. The results of the ANOVA showed that the computed p-value was lower than the critical p-value suggesting that there is a significant difference between treatments in terms of height. The Tukey HSD Test showed that there was no significant difference between purple film vs transparent film, and red film vs blue film. Conversely, there was an observed significant difference between purple film vs. red film, red film vs. transparent film, and purple film vs. blue film, under 0.1 level of significance. Thus, these results suggest that among the four treatments, plant samples grown under transparent film showed greater height of plant samples compared to samples under red light, while there was not enough evidence to conclude that plant samples grown under blue light exhibited positive results in terms of height.

Desirability

Composite desirability evaluates how the settings optimize a set of responses overall. It combines information from multiple responses into a single measure. The composite desirability is typically calculated as the weighted geometric mean of the individual desirability for all relevant responses. The table below presents the desirable treatments having light intensity, chlorophyll a and b, fresh weight, number of leaves, and height as the responses in evaluating the growth of iceberg lettuce.

Table 4. Desirability for Four Treatments of Categoric Factor Levels

Film Color	A	B	C	D	E	F	G	H
Transparent	1070.000	1.021	0.427	4.701	4	9.721	0.246	0.281
Purple	517.222	0.874	0.372	4.540	4	9.421	0.084	0.097

*A – Light Intensity (Lux); B – Chlorophyll A (mg g^{-1}); C – Chlorophyll B (mg g^{-1}); D – Fresh Weight (g); E – Number of Leaves; F – Height (cm); G – Desirability; and H – Desirability w/o intervals

The above table suggests that the most suitable treatment in terms of light intensity, fresh weight, number of leaves and height alone was transparent PVC film. For chlorophyll a and b, acceptable values were based on the optimal/normal values of chlorophyll a and b where an upper limit and a lower limit was established. Hence, the desirability presented above shows that the most desirable treatment in terms of chlorophyll a and b alone was still transparent PVC film. Thus, results of the ANOVA shows that among the four treatments, plant samples grown under transparent PVC film showed the greatest desirability followed by purple PVC film.

CONCLUSION

In conclusion, only purple PVC film showed comparable results to transparent PVC film on the growth of iceberg lettuce in terms of height, fresh weight, and number of leaves. The significant difference between purple and transparent PVC film suggests that purple PVC film underperforms in comparison to transparent PVC film for the growth of iceberg lettuce. Consequently, blue and red PVC film fell behind the latter two. Although it was given that chlorophyll a absorbs more red light and chlorophyll b absorbs more blue light, the results of the study showed that monochromatic red and blue light alone yielded lesser chlorophyll a and b values than purple and transparent. This suggests that both blue and red light are equally important in the growth of iceberg lettuce.

It can also be concluded that, among the parameters of the study, only the number of leaves showed no significant differences for all treatments while the plant samples under different colored PVC film exhibited significant difference between treatments in terms of chlorophyll a, chlorophyll b, light intensity, height, and fresh weight of the plant samples. Thus, transparent PVC film is the most recommended glazing material for protective structures, while purple PVC film is also a viable option although it underperformed compared to transparent PVC film.

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AUTHOR CONTRIBUTIONS

FGJ writing, conceptualization, methodology, data curation, writing-original draft, visualization. MGCS writing, review and editing, validation, supervision.

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AVAILABILITY OF DATA AND MATERIALS

Data will be made available on request.

ETHICAL CONSIDERATIONS

This article did not include human subjects or animal studies.

COMPETING INTEREST

The authors declare no conflict of interest.

REFERENCES

Allison. (2023). *How to grow iceberg lettuce: The complete guide*. Garden Auntie. https://gardenauntie.com/how-to-grow/iceberg-lettuce/

Amanda, & Amanda. (2024, March 2). *Iceberg lettuce vs green leaf: The pros and cons of using*. Cooknight. https://cooknight.net/iceberg-lettuce-vs-green-leaf/

McMahon, R.W. (2000). *An introduction to greenhouse production.* (2nd ed.). https://eric.ed.gov/?id=ED346253

Cosmos. (2023). *Making sunlight better: Using films to manage sunlight for crop productivity*. Cosmos. https://cosmosmagazine.com/technology/making-sunlight-better/

Francis, Francis, & Francis. (2022, February 26). *Why do plants absorb red and blue light?* Infrared for Health—Best Infrared Products for Health. https://infraredforhealth.com/why-do-plants-absorb-red-and-blue-light/

Hao, J., & Lu, E. (2022). Variation of relative humidity as seen through linking water vapor to air temperature: An assessment of interannual variations in the near-surface atmosphere. Atmosphere, 13(8), 1171. https://doi.org/10.3390/atmos1308117

Hortidaily (2022). Dynamic fresh weight prediction of substrate-cultivated lettuce

LibreTexts. (2021). *8.3.2: Absorption of light*. In *LibreTexts Biology*. https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Map%3A_Raven_Biology_12th_Edition/08%3A_Photosynthesis/8.03%3A_Pigments/8.3.2%3A_Absorption_of_Light

Noah. (2023). Understanding the Relationship between Color and Temperature. The Color Ency. https://www.thecolorency.com/color-and-temperature/

Palmer, A. H. (1920). *The agricultural significance of sunshine as illustrated in California*. *Monthly Weather Review, 48*(3), 151–154. https://doi.org/10.1175/1520-0493(1920)48<151:TASOSA>2.0.CO;2

Physics Journal. (2025). Physics of colour temperature and applications: A review. International Journal of Physics and Applications, 7(1).

Thumbs, T. S. a. T. G. (2024). The Importance of Greenhouse Clarity vs. Color: Plastic Sheeting Blog

Wikipedia. (2025, June). Color temperature. Retrieved June 2025, from Wikipedia.