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CROP-SPECIFIC GROWTH RESPONSES TO LED OVEREXPOSURE: A STUDY ON *Brassica rapa* (PETCHAY) AND *Ipomoea aquatica* (WATER SPINACH)

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ABSTRACT

Urban farming and controlled-environment agriculture have become critical strategies for sustainable food production. This study investigates the effects of overexposing blue and purple LED light on the growth of *Brassica rapa* (petchay) and *Ipomoea aquatica* (water spinach) under controlled outdoor conditions. The research evaluated plant height, number of leaves, leaf length, and leaf width across three lighting treatments: natural sunlight, blue LED, and purple LED. Using one-way ANOVA and post-hoc analysis, significant differences were observed in selected growth parameters. Blue LED light significantly increased the plant height of Water Spinach (mean = 14.82 cm, $p = 0.0339$), while purple LED light significantly enhanced the number of leaves in Petchay (mean = 8.46, $p < 0.001$). No significant differences were found in leaf length and width across treatments for both crops. These findings suggest that specific LED wavelengths can improve particular growth traits depending on crop type. The study provides a basis for optimizing artificial lighting strategies in controlled agriculture and urban farming systems.

Keywords: *Brassica rapa, Controlled Environment Agriculture, Experimental Research, Ipomoea aquatica, LED Lighting, Plant Growth Responses*

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1.0 INTRODUCTION

The global demand for food continues to rise due to increasing urban populations and the rapid depletion of agricultural land. In response, urban farming and controlled-environment agriculture have become critical strategies for sustainable food production. Technological innovations, particularly the use of artificial lighting, play a pivotal role in maximizing yield in space-limited settings like vertical farms and greenhouses (Hernandez & Martinez, 2020; Kerch, 2015; Lohani et al., 2020)

In the Philippines, urban agriculture is gaining traction, especially in densely populated cities where traditional farming is no longer feasible. Leafy vegetables such as Petchay (Brassica rapa) and Water Spinach (Ipomoea aquatica), known for their high nutritional value and short cultivation cycles, are ideal crops for these systems (Massa, 2006). Optimizing their growth using LED (Light Emitting Diode) technology is an area of growing interest, as LEDs provide targeted light wavelengths that support photosynthesis and plant development efficiently.

Blue (≈460 nm) and purple (≈395–400 nm) LEDs, in particular, have shown potential to stimulate different aspects of plant growth. Blue light enhances chlorophyll production and leaf expansion, while purple light—comprising both red and blue wavelengths—may support photosynthesis and plant hormone signaling. However, existing studies primarily focus on optimal light exposure rather than overexposure to these wavelengths. The effects of excessive blue and purple LED exposure on crops like Petchay and Water Spinach remain underexplored, particularly in tropical outdoor settings.

This study addressed this gap by examining how overexposing blue and purple LED light influences plant height, number of leaves, leaf length, and leaf width in these two crops. The findings are expected to inform LED application strategies in urban farming, helping improve productivity in non-traditional settings.

This study was guided by the Photosynthetic Action Spectrum Theory, which posits that different wavelengths of light have varied effects on photosynthetic efficiency and plant morphology. The research assumes that LED wavelengths differentially trigger plant responses based on species and light dosage.

Research Objectives.

This study aimed to fill this gap by comparing the effects of blue and purple LED lights on the growth of Petchay and Water Spinach, focusing on key growth parameters such as plant height, leaf number, leaf length, and leaf width. Specifically, it sought to: evaluate the effects of overexposing blue and purple LED lights on plant growth in Petchay and Water Spinach, comparing their performance under natural light conditions and examine the differences in response to blue and purple light wavelengths between two crops—Petchay and Water Spinach—under controlled conditions.

Hypothesis

Ho: There is no significant difference in the growth parameters (plant height, number of leaves, leaf length, and leaf width) of Petchay and Water Spinach under natural light, blue LED, and purple LED treatments.

Significance of the Study

This study holds significant value for various stakeholders who play key roles in agriculture, education, and research. For Department of Agriculture (DA) officials, the findings would provide evidence-based insights to support the creation of policies and guidelines for the sustainable and responsible use of artificial lighting in agriculture. For Local Government Units (LGUs), the results could guide the development of urban farming and community gardening programs that incorporate energy-efficient lighting systems. Farmers and growers would benefit from practical recommendations on optimizing artificial lighting in greenhouses or indoor farms, enabling improved productivity while reducing energy consumption and minimizing plant stress.

The study also offers important contributions to education and innovation. For agricultural students and educators, it would serve as a valuable resource for understanding plant physiological responses to light spectra and sustainable

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farming practices. Engineering students would gain deeper insights into the design, application, and optimization of artificial lighting systems within controlled-environment agriculture and sustainable technology. Lastly, future researchers and agricultural technologists would find in this study a source of empirical data to guide further investigations on crop performance under controlled lighting and to support the development of innovative farming systems that contribute to sustainable agriculture.

Scope and Limitations

This study evaluated the effects of overexposure to blue and purple LED lights on the growth performance of two leafy vegetables, *Brassica rapa* locally known as petchay, and *Ipomoea aquatica* or water spinach or locally known kang kong, under outdoor controlled conditions. The scope was limited to four measurable growth parameters: plant height, number of leaves, leaf length, and leaf width, observed over a 30-day period. Three lighting treatments were applied: natural sunlight, blue LED (460 nm), and purple LED (395 – 400 nm). Experiments were conducted outdoors in a tropical setting, focusing exclusively on the early vegetative growth stage; reproductive stages were not included. The study was applied to two common urban-farmed crops in the Philippines.

The limitations include the following: the 30-day duration may not capture long-term growth effects or overall crop yield. Environmental conditions such as ambient temperature and humidity were not strictly controlled, which could have influenced plant responses beyond lighting effects. Only one light intensity per LED type was tested, without variation in intensity or photoperiod. Although treatments were replicated, the sample size may not be sufficient to generalize findings across broader agro-ecological contexts.

Other factors potentially affecting growth such as pest resistance, chlorophyll content, or root development were not measured. Future research would benefit from extending the experimental period, testing additional light wavelengths (e.g., red or white), and investigating broader physiological responses to enhance and build upon the findings of this study.

2.0 METHODS

Research Design

This study employed a true experimental research design to evaluate the effects of overexposing Brassica rapa (Petchay) and Ipomoea aquatica (Water Spinach) to blue and purple LED light compared to natural sunlight. A completely randomized design (CRD) was used, comprising three lighting treatments:

1. Natural light (control)
2. Blue LED overexposure
3. Purple LED overexposure

Each treatment was replicated three times, resulting in nine plots per crop. This design allowed for systematic comparison of four key growth parameters: plant height, number of leaves, leaf length, and leaf width.

The experimental setup was adapted from the methodologies of Pagarigan and Caya (2018), who developed LED light compensation systems in outdoor agricultural conditions, and Yumang et al. (2021), who investigated the effects of various artificial LED lights on crop growth performance.

Experimental Setup and Procedures

The experimental setup and procedures involved preparing crop plots for *Brassica rapa* (petchay) and *Ipomoea aquatica* (water spinach), applying specific lighting treatments, automating light exposure through sensor-based controls, preparing soil for optimal growth, and implementing controls and validations to ensure consistent and reliable results.

Crop Preparation

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All plots were irrigated daily with 240 ml of water. The soil was enriched with organic matter to ensure uniform nutrient availability. The petchay is in nine plots (2 ft × 2 ft each) were prepared and planted with 90 seeds of the 'Hari Digma' variety (10 seeds per plot, 2 cm deep). Water spinach is in nine plots (3 ft × 3 ft) were planted with 36 cuttings (4 stems per plot, 1.5 cm deep).

Figure 1

Petchay under Purple LED Overexposure

Note: The figure shows young petchay seedlings cultivated in soil plots enriched with organic matter.

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Figure 2

Water Spinach under Purple LED Overexposure

Note: The figure shows young water spinach seedlings cultivated in soil plots under purple LED overexposure.

Lighting Treatments

Three lighting setups were implemented as natural light (control) where plants received only ambient sunlight. Blue LED overexposure where a 12-watt LED array (460 nm, 100–300 lumens) was positioned 50 cm above each plot. Purple LED overexposure where a 12-watt LED array (395–400 nm, 50–100 lumens), was also placed 50 cm above the plants.

All LED treatments were controlled using an automated lighting system based on Light Dependent Resistors (LDRs), which activated LEDs during low-light conditions such as cloudy days or nighttime.

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Figure 3

Blue and Purple LED Arrays Mounted Above the Plots

Note: The figure displays the experimental setup of blue and purple LED arrays positioned 50 cm above the plots, controlled by an automated LDR-based

Figure 4

Automated LED Control System Using LDR Sensors

Note: The figure shows the LED lighting system integrated with LDR sensors, enabling automatic activation of blue and purple lights during low-

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Figure 5

Plot Layout of Petchay and Water Spinach Treatments

Note: The figure illustrates the arrangement of experimental plots exposed to blue and purple LED treatments for petchay and water spinach.

This automation method aligns with the system used by Pagarigan and Caya (2018) to deliver consistent artificial lighting in fluctuating outdoor conditions.

Lighting Automation System

The automated LED control system utilized LDR sensors connected to a BT137 TRIAC switch. When ambient light dropped below a calibrated threshold, the LDR triggered the system to activate the LEDs, ensuring continuous exposure at night or during overcast periods. Lights turned off automatically at sunrise or under sufficient light conditions.

Soil Preparation

Soil was tilled to 2 inches for Petchay and 3 inches for Water Spinach to improve aeration and root penetration. Organic compost was incorporated to improve fertility and uniformity across plots.

Controls and Validations

For this experiment, several control measures and validation procedures were implemented to ensure the accuracy and reliability of the results:

1. Randomization of Plots was carried out to minimize spatial variation and reduce potential bias arising from environmental heterogeneity across the growing area.
2. Environmental Monitoring was conducted daily, with humidity and temperature recorded to account for external factors that could influence plant growth and development.

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3. Standardization of Growth Conditions was maintained through consistent irrigation schedules, uniform soil composition, and balanced nutrient levels across all experimental plots.
4. Species Validation of Brassica rapa and Ipomoea aquatica was confirmed by a local plant science expert prior to the commencement of the study to ensure proper identification and accuracy of experimental subjects.

Data Gathering Procedure

Over a 30-day growth period, data were collected daily to monitor the growth and morphological responses of Petchay and Water Spinach under different lighting conditions. The following parameters were systematically measured:

1. Plant Height was measured from the base of the stem to the tip of the tallest leaf using a ruler to determine vertical growth progression over time.
2. The number of Leaves was recorded by counting all fully expanded leaves on each plant to assess vegetative development and leaf production rate.
3. Leaf Length was determined by measuring the longest leaf per plant, which served as an indicator of leaf expansion and overall photosynthetic surface area.
4. Leaf Width was measured at the widest point of the broadest leaf to evaluate the horizontal growth and shape variation influenced by the lighting treatments.

All measurements were averaged across the plants within each plot and treatment to ensure representative and reliable data for statistical analysis.

Analysis and Interpretation

Both descriptive and inferential statistical analyses were used. To be specific, the following were conducted as follows. Descriptive statistics included means and variances of each growth parameter by treatment group. Inferential statistics involved one-way Analysis of Variance (ANOVA) to assess the significance of differences among the three treatments. Where ANOVA showed significant results, post-hoc Tukey HSD tests were applied to identify.

3.0 RESULTS AND DISCUSSION

This section presents the descriptive and inferential statistical analysis used to evaluate the effects of three lighting treatments Natural Light, Blue LED, and Purple LED in the growth of Petchay (Brassica rapa) and Water Spinach (Ipomoea aquatica). Descriptive statistics (mean and variance) summarize each treatment group, while inferential statistics were analyzed using one-way Analysis of Variance (ANOVA), followed by Tukey's Honestly Significant Difference (HSD) post hoc test for parameters with statistically significant results.

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Plant Growth in terms of Height

Plant height serves as a primary indicator of vegetative growth and responsiveness to light intensity and wavelength. The results for both crops are summarized in Tables 1 and 2.

Table 1

Descriptive and Inferential Statistics for Petchay Plant Height

Treatment	**Petchay Plant Height Mean ± SD (cm)**
Natural Light	3.11 ± 2.23
Blue LED	3.76 ± 1.93
Purple LED	3.35 ± 1.72
ANOVA F-value	1.25
p-value	0.289

The ANOVA results revealed no statistically significant difference in the height of *Petchay* plants across the three lighting treatments (p = 0.289). Although the Blue LED treatment produced a slightly higher mean height, the variation was insufficient to reject the null hypothesis. This suggests that, while blue light may promote elongation through enhanced chlorophyll activity, its influence on *Petchay* height remains limited under the experimental conditions.

Table 2

Descriptive and Inferential Statistics for Water Spinach Plant Height

Treatment	**Water Spinach Plant Height Mean ± SD (cm)**
Natural Light	7.14 ± 4.51
Blue LED	14.82 ± 5.02
Purple LED	10.48 ± 4.65
ANOVA F-value	10.18
p-value	0.0339
Post hoc	Blue LED > Natural Light ($p < 0.05$)

In contrast, *Water Spinach* exhibited significant variation in height among treatments (p = 0.0339). The Tukey HSD test confirmed that Blue LED lighting produced significantly taller plants compared to Natural Light. These findings align with those of Hernández and Martínez (2020), who reported that blue wavelengths enhance chlorophyll content and photosynthetic efficiency, thereby promoting stem elongation and overall plant height.

Plant Growth in terms of Number of Leaves

Leaf number reflects vegetative vigor and photosynthetic potential. The results for both crops are shown in Tables 3 and 4.

Table 3

Descriptive and Inferential Statistics for Number of Leaves in Petchay

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Treatment	Water Spinach Plant Height Mean ± SD (cm)
Natural Light	5.02 ± 1.86
Blue LED	7.42 ± 1.70
Purple LED	8.46 ± 1.32
ANOVA F-value	16.51
p-value	< 0.001
Post hoc	Purple LED > Blue LED > Natural Light ($p < 0.05$)

Results showed a significant increase in the number of leaves under Purple LED lighting ($p < 0.001$). The combined effect of red and blue wavelengths in the purple spectrum likely enhanced photosynthesis and stimulated cell division, leading to greater leaf production. These findings corroborate those of Wang et al. (2016), who observed synergistic effects of mixed light spectra on vegetative growth.

Table 4

Descriptive and Inferential Statistics of Leaves in Water Spinach

Treatment	Water Spinach Plant Height Mean ± SD (cm)
Natural Light	7.47 ± 1.77
Blue LED	7.63 ± 1.48
Purple LED	6.36 ± 1.68
ANOVA F-value	0.88
p-value	0.4500

No significant difference was observed among treatments in the number of leaves of Water Spinach ($p = 0.4500$). This suggests that Water Spinach leaf production is less responsive to variations in light spectrum, possibly due to species-specific differences in photoreceptor sensitivity or light absorption efficiency.

Plant Growth in terms of Leaf Length

Leaf length indicates the extent of leaf elongation and photosynthetic surface area. The corresponding data are presented in Tables 5 and 6.

Table 5

Descriptive and Inferential Statistics for Petchay Leaf Length

Treatment	Water Spinach Plant Height Mean ± SD (cm)
Natural Light	1.89 ± 1.79
Blue LED	2.38 ± 1.97
Purple LED	2.11 ± 1.65
ANOVA F-value	1.19
p-value	0.307

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Although *Petchay* grown under Blue LED exhibited slightly longer leaves on average, the ANOVA results showed no statistically significant differences (p = 0.307). This indicates that leaf elongation in *Petchay* was not strongly influenced by light spectrum alone.

Table 6

Descriptive and Inferential Statistics for Water Spinach Leaf Length

Treatment	Water Spinach Plant Height Mean ± SD (cm)
Natural Light	3.07 ± 1.77
Blue LED	3.64 ± 1.79
Purple LED	2.95 ± 1.75
ANOVA F-value	1.87
p-value	0.3143

Similarly, Water Spinach showed no significant change in leaf length under different lighting. While blue light has the potential to stimulate leaf growth (Yumang et al., 2021), these effects may be more pronounced with longer duration or higher intensity.

Plant Growth in terms of Leaf Width

Leaf width serves as a secondary indicator of leaf development and surface area available for light absorption. The results are summarized in Tables 7 and 8.

Table 7

Descriptive and Inferential Statistics for Pechay Leaf Width

Treatment	Water Spinach Plant Height Mean ± SD (cm)
Natural Light	1.76 ± 1.46
Blue LED	2.16 ± 1.57
Purple LED	1.92 ± 1.38
ANOVA F-value	0.88
p-value	0.416

Differences in leaf width across the three light treatments were not statistically significant (p = 0.416). While Blue LED treatment appeared to produce marginally broader leaves, the variation was insufficient to indicate a meaningful effect.

Table 8

Descriptive and Inferential Statistics for Water Spinach Leaf Width

Treatment	Water Spinach Plant Height Mean ± SD (cm)
Natural Light	1.15 ± 1.43
Blue LED	1.46 ± 1.54
Purple LED	1.32 ± 1.39
ANOVA F-value	2.31
p-value	0.244

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No significant differences were found in leaf width among Water Spinach treatments (p = 0.244). These results suggest that leaf breadth may be less responsive to spectral variation compared to other morphological traits such as height or leaf number.

Overall, Blue LED lighting significantly enhanced the height of Water Spinach, while Purple LED light notably increased the number of leaves in Petchay. No significant differences were observed in leaf length and width across lighting treatments for both species. These findings indicate that the effects of LED light on plant growth are species- and trait-specific, emphasizing the need for tailored lighting strategies based on crop type and growth objectives.

Conclusions

The following conclusions were drawn from the experiment:

1. LED overexposure produces species-specific morphological responses, demonstrating that a "one-size-fits-all" lighting approach is unsuitable for urban agriculture.

2. Blue LED light (460 nm) primarily drives stem elongation in Ipomoea aquatica, indicating its effectiveness for promoting vertical biomass in creeping crops.

3. Purple LED light (395–400 nm) significantly increases vegetative proliferation (leaf count) in *Brassica rapa*, making it advantageous for enhancing foliage production in leafy greens.

4. Leaf dimensions did not significantly vary across treatments, suggesting that while spectral quality influences growth allocation (height versus leaf number), it does not independently determine leaf expansion.

5. Optimal lighting strategies should be aligned with economic goals, such as using blue spectra to maximize stem growth in creepers and purple spectra to enhance leaf yield in leafy vegetables.

Recommendations

1. Department of Agriculture (DA) officials should use the findings to develop science-based policies and guidelines promoting the responsible use of LED lighting in crop cultivation. They may also integrate artificial lighting technologies into national programs supporting sustainable and climate-resilient agriculture.

2. Local Government Units (LGUs) should incorporate the study's findings into urban farming and community gardening projects that employ energy-efficient lighting systems. They may also provide training and support to local farmers implementing controlled-environment agriculture.

3. Farmers and growers should apply the results to optimize artificial lighting conditions in greenhouses or indoor farms. By adjusting light intensity and exposure duration, they can enhance productivity, reduce energy waste, and prevent plant stress from overexposure.

4. Agricultural students and educators should use the results as a reference in courses related to plant physiology, crop science, and sustainable farming practices. The study provides practical evidence of how light wavelength and intensity affect plant growth.

5. Engineering students should apply the study's findings to the design and optimization of artificial lighting systems for controlled-environment agriculture. They should explore developing LED lighting solutions that allow adjustable wavelengths, intensities, and exposure durations tailored to specific crop types and growth objectives. Such systems would enhance growth efficiency while reducing energy consumption. Additionally, engineering students could integrate sensor-based feedback systems to monitor plant growth in real time, allowing dynamic adjustments to lighting conditions for improved productivity and sustainability.

6. Researchers and agricultural technologists should build on this study by testing other light spectra, varying exposure durations, and integrating artificial lighting with other growth factors to deepen understanding of crop performance under controlled environments.

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1.0 COMPETING INTERESTS

The authors declare that they have **no competing interests** related to the publication of this work.

6.0 AUTHOR'S CONTRIBUTIONS

Jamie Eduardo Rosal led the conceptualization, methodology design, statistical analysis, and manuscript drafting. Roberto Melanio Jr. and Marjove Masinadion contributed to the review of related literature, the experimental setup for Petchay, and data collection. All authors reviewed and approved the final version of the manuscript.

7.0 CONSENT

There was no informed consent needed in this study as this does not involve animal or human participants. This study only focused on studying the growth rate of spinach after being exposed to a treatment.

8.0 ETHICAL APPROVAL

This study did not secure ethical clearance from an Ethics Committee as it was conducted in accordance with institutional guidelines that did not mandate such approval.

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