Early Growth Responses of Green Gram (*Vigna radiata*) under Different Environmental Conditions: A Comparative Study

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Abstract

This study evaluated the early growth responses of green gram (*Vigna radiata*) under four contrasting environmental conditions over a 10-day experimental period. Four treatment conditions were examined: artificial grow-light with drip irrigation and smoke exposure (P1), artificial grow-light with drip irrigation (P2), natural sunlight with drip irrigation (P3), and natural sunlight with surface irrigation (P4). Morphological parameters, including plant height, leaf length, leaf width, root development, and stem characteristics, were assessed on Days 4, 7, and 10. By Day 10, P1 showed the highest observed plant height (13.5 cm), leaf length (3.0 cm), and leaf width (1.2 cm), followed by P2 (12.5 cm, 2.7 cm, and 1.0 cm, respectively), P3 (12.0 cm, 2.5 cm, and 0.9 cm), and P4 (9.5 cm, 2.0 cm, and 0.5 cm). Qualitative observations indicated greater root branching in P1 and greater root elongation in P2, while P4 exhibited comparatively limited root development and weaker stems. The observed differences suggest that the combination of artificial lighting and drip irrigation was associated with greater early morphological development under the conditions examined. The additional association observed with smoke exposure in P1 warrants further investigation using replicated experiments and controlled assessment of smoke-related exposure. Given the exploratory nature and limited replication of the present study, the findings should be interpreted as preliminary evidence rather than definitive treatment effects. The study provides a basis for further investigation of environmental manipulation in controlled cultivation of green gram.

Keywords: Plant growth responses; Sustainable agriculture; Combination approach

Background

Green gram (*Vigna radiata*) is widely cultivated leguminous crop valued for its nutritional properties, short growth cycle. With the increasing application of controlled-environment technologies in agriculture, understanding how environmental factors such as light conditions, irrigation practices, and atmospheric exposure influence plant growth and development has become increasingly relevant. Light serves both as the primary energy source for photosynthesis and as an important regulatory signal governing photomorphogenesis. Its spectral composition, intensity, and duration of exposure can influence plant architecture, leaf expansion, stem elongation, and developmental processes. Recent advances in artificial lighting, particularly light-emitting diode (LED) technology, have enabled greater control over light

characteristics and have provided opportunities to investigate and optimize lighting conditions for plant growth and productivity [1].

Water availability and irrigation practices are also important determinants of plant development. Drip irrigation can improve the efficiency of water delivery to the root zone and has been associated with improved water-use efficiency and deeper root development compared with conventional surface irrigation methods [2]. In addition to light and water availability, atmospheric factors may influence plant physiological responses. Smoke

exposure represents an unconventional environmental condition that may alter plant stress responses and growth patterns; however, its effects on plant development remain comparatively underexplored.

The spectral characteristics of artificial light are particularly relevant to plant growth. Previous studies have demonstrated important roles for red and blue wavelengths in photosynthetic activity and plant development, with red light influencing stem elongation and blue light contributing to chlorophyll biosynthesis and stomatal function. Combinations of red and blue wavelengths have also been associated with changes in photosynthetic efficiency and overall plant vigor in different plant species [3]. Despite the growing understanding of individual environmental factors, limited research has investigated the combined influence of artificial lighting, irrigation practices, and smoke exposure on the early growth of leguminous crops such as green gram [4].

Therefore, the present study was undertaken to comparatively evaluate the early morphological growth responses of *Vigna radiata* under four different environmental conditions incorporating variations in light source, irrigation method, and smoke exposure. The study focused on changes in plant height, leaf dimensions, root development, and stem characteristics over a 10-day experimental period.

Introduction

The growing demand for sustainable agriculture and food security has increased interest in optimizing plant growth under controlled environmental conditions. Artificial lighting, particularly grow lights, has become increasingly important in indoor and vertical farming by providing consistent and controllable light conditions [5]. Red and blue light combinations have been associated with improved vegetative growth and leaf expansion in legumes and other crops [6]. Irrigation practices also influence plant growth and productivity [7], with drip irrigation providing targeted water delivery and being associated with improved root development and reduced water stress compared with surface irrigation [8]. Atmospheric stressors such as smoke exposure may also influence plant physiological responses and growth patterns [9].

Despite research on individual environmental factors, limited information is available on their combined effects on the early growth of green gram. Therefore, this study comparatively evaluated green gram under four conditions: grow lights with drip irrigation and smoke exposure, grow lights with drip irrigation, natural sunlight with drip irrigation, and natural sunlight with surface irrigation. Plant height, leaf dimensions, root development, and stem characteristics were assessed over 10 days to provide preliminary evidence on the response of green gram to contrasting environmental conditions.

Objectives

The objective of this study was to comparatively evaluate the early growth of green gram (*Vigna radiata*) under different environmental conditions. Specifically, the study assessed the effects of light source (artificial grow lights and natural sunlight), irrigation method (drip and surface irrigation), and smoke exposure on key morphological characteristics, including plant height, leaf dimensions, root development, and stem strength. Growth responses were compared across four treatment conditions over a 10-day period to provide preliminary evidence on the influence of environmental conditions on early green gram growth.

Rationale

Green gram (*Vigna radiata*) is a short-duration legume whose early vegetative development is influenced by environmental conditions, particularly light availability and water delivery. The present study therefore selected light source, irrigation method, and smoke exposure as contrasting environmental factors to examine their potential influence on early morphological development under controlled and semi-controlled conditions. Artificial grow lighting was included because it provides a consistent and controllable light environment, whereas natural

sunlight represents a conventional environmental condition. Drip irrigation was selected to provide targeted water delivery to the root zone, while surface irrigation was included as a more conventional alternative. Smoke exposure was incorporated as an additional atmospheric condition because its potential influence on early plant development is less clearly understood and therefore provides an exploratory environmental contrast.

The four treatment combinations were selected to permit structured pairwise comparisons of the major environmental factors. P1 and P2 were maintained under the same artificial-light and drip-irrigation conditions, with smoke exposure present only in P1, allowing an exploratory comparison of growth with and without smoke exposure. P2 and P3 both received drip irrigation without smoke exposure but differed in light source, enabling comparison between artificial grow lighting and natural sunlight. P3 and P4 were both maintained under natural sunlight without smoke exposure but differed in irrigation method, allowing comparison between drip and surface irrigation. Thus, the treatment arrangement provides a simple comparative framework in which the potential contribution of individual environmental conditions can be explored while maintaining other conditions as similar as possible.

The rationale for this design was therefore not to establish definitive causal effects of individual factors, but to identify contrasting early growth patterns and generate hypotheses for subsequent replicated and factorial experiments. This approach is particularly relevant for controlled-environment cultivation, where optimization of lighting and water delivery may contribute to more consistent and resource-efficient plant production. The observations may also help identify environmental combinations worthy of further investigation using larger sample sizes, longer experimental periods, physiological measurements, and factorial experimental designs for sustainable and adaptable crop production.

Methodology

The experimental framework illustrates the overall study design, integrating the environmental treatment conditions, observation timeline, and morphological assessment strategy. Four treatment combinations (P1–P4) were evaluated over 10 days, with plant height, leaf dimensions, root development, and stem characteristics assessed at defined observation points. This framework enabled comparative evaluation of early morphological responses under contrasting light, irrigation, and smoke-exposure conditions [Figure 1].

Study Method

A comparative experimental design was used to evaluate the early growth responses of green gram (*Vigna radiata*) over a 10-day period under four environmental conditions. Quantitative measurements included plant height and leaf dimensions, while root branching and stem characteristics were assessed through qualitative morphological observations.

Data Collection method

As part of the data collection process, a time-series observation method was employed, wherein plant growth parameters were recorded at multiple intervals—specifically on days 4, 7, and 10—to monitor and analyze the progression of morphological changes over time rather than relying on a single endpoint measurement. The morphological parameters Plant height (in cm), Leaf length and width (in cm), were measured. Also, the root and stem developments were observed and assessed as macroscopic morphological observation method. Measurements were taken using a standard ruler for quantitative variables and visual inspection for qualitative variables such as stem and root. Root observations were conducted by gently removing the plants from the cocopeat and examining the root structure. Stem strength was assessed based on thickness and visual inspection.

Data analysis method

Quantitative measurements of plant height, leaf length, and leaf width were recorded on Days 4, 7, and 10 for each treatment (P1–P4). The data were analyzed descriptively by comparing the observed values and changes over time across the four treatment conditions. Growth

patterns were presented using tabulated measurements and graphical trend analysis. Root development and stem characteristics were evaluated qualitatively through macroscopic observation, including assessment of root length and branching, stem thickness, and visible changes in stem appearance. As only one plant was evaluated per treatment, the analysis was limited to descriptive comparisons, and no inferential statistical tests were performed.

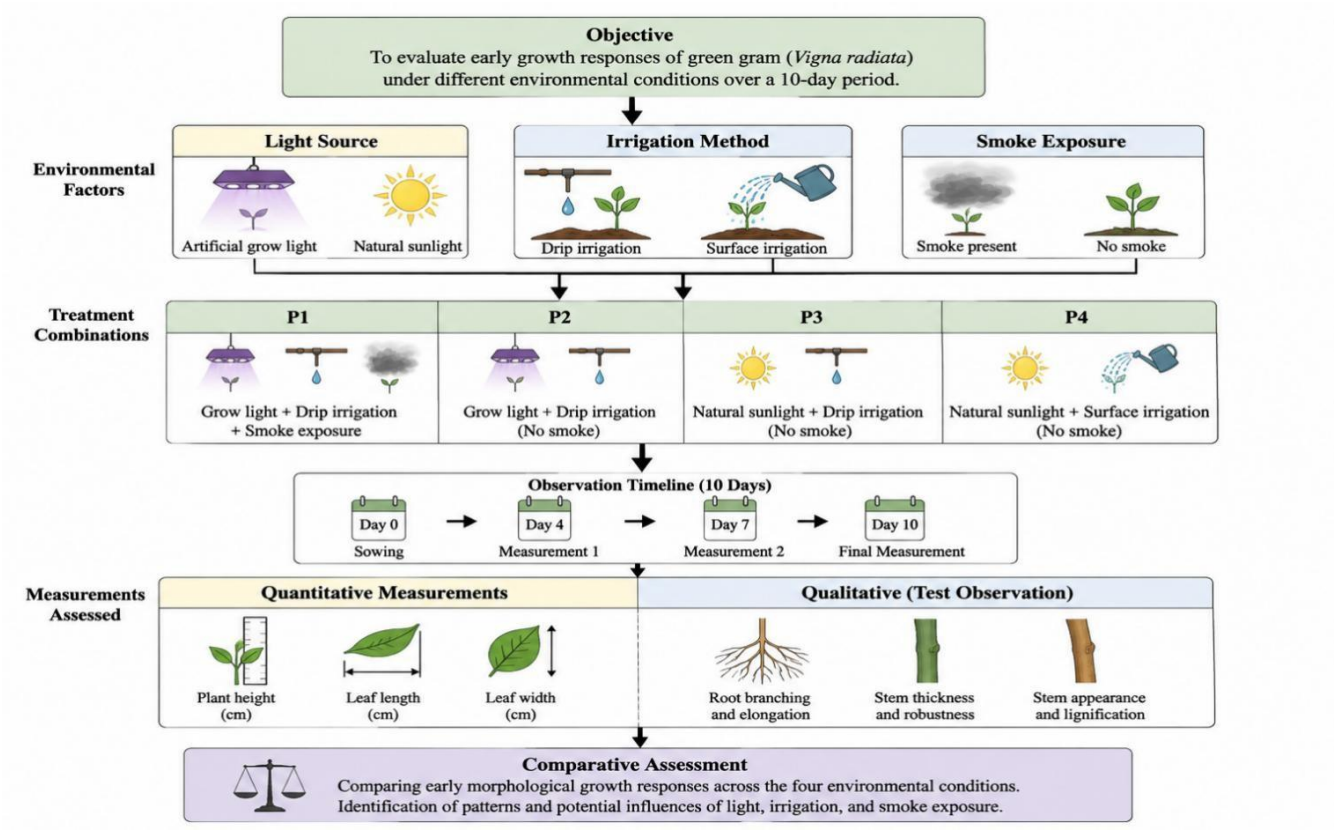

Figure 1. Experimental framework

Materials

Specimen

To investigate the influence of environmental conditions on the early growth of *Vigna radiata* , four freshly budded specimens were cultivated under distinct treatment regimes. Each plant was assigned to one of the following experimental groups: Artificial grow lights with drip irrigation and smoke exposure(P1), Artificial grow lights with drip irrigation(P2),

Natural sunlight with drip irrigation(P3), Natural sunlight with surface irrigation(P4). All specimens were planted in uniform containers using equal quantities of cocopeat and water to ensure consistency in substrate quality and hydration. Seeds were sourced from the same batch to minimize genetic variability.

Controlled Lighting Conditions

For treatments P1 and P2, a custom-designed wooden growth chamber (dimensions: height 45 cm × width 30 cm × depth 50 cm) was used to simulate controlled lighting. The chamber featured one open side to facilitate passive ventilation. LED grow lights were affixed to the inner roof, comprising a spectral composition of 60% red light, 30% blue light,10% white light. This configuration was selected based on established photobiological principles to optimize photosynthetic activity and vegetative growth.

Irrigation Protocol

Drip irrigation was employed for P1, P2, and P3 to ensure precise and consistent water delivery directly to the root zone, minimizing water loss and promoting deeper root development. P4 received surface irrigation, simulating conventional field conditions with broader water dispersion and reduced efficiency.

Fumigation material

The fumigation material has been prepared out of dried Neem (*Azadirachta indica*) bark and

leaves in the combination 1:1.

Experiments

The experiment was designed to assess the growth performance of green gram (*Vigna radiata*) under four distinct environmental conditions over a 10-day period. The conditions included light source, irrigation method and the presence of smoke exposure. The four experimental groups were: P1 – grow lights with drip irrigation and smoke exposure; P2 – grow lights with drip irrigation; P3 – sunlight with drip irrigation; and P4 –. sunlight with normal surface irrigation

Result

Plant height assessment:

Plant height was recorded on Days 4, 7, and 10 to compare growth progression among the four treatment conditions.

Table 1. Height chart of green gram (*Vigna radiata*) of green gram plants under four treatment conditions

Height in centimeter				
Plant	**Day 0**	**Day 4**	**Day 7**	**Day 10**
P1	0	4	7	13.5
P2	0	3	6.5	12.5
P3	0	2.4	5.5	12
P4	0	2.4	4	9.5

All plants started at 0 cm on Day 0. By Day 4, P1 showed the greatest observed height (4.0 cm), while P3 and P4 recorded 2.4 cm. By Day 7, P1 and P2 reached 7.0 cm and 6.5 cm, respectively, compared with 5.5 cm for P3 and 4.0 cm for P4. By Day 10, P1 recorded the highest plant height (13.5 cm), followed by P2 (12.5 cm), P3 (12.0 cm), and P4 (9.5 cm) [Table

1; Figure 2]. The greatest increase in height for all four plants occurred between Days 7 and 10, with P1 showing the largest absolute increase during this interval.

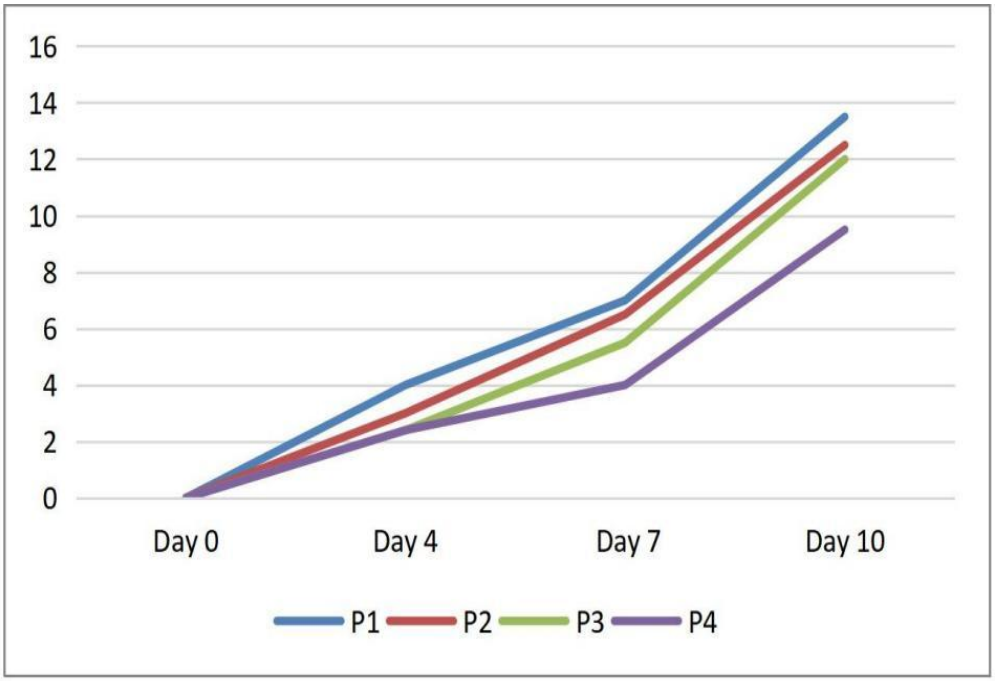

Figure 2. Changes in plant height of green gram (*Vigna radiata*) under four treatment conditions over the 10-day observation period.

Leaf length assessment

Leaf length was recorded on Days 4, 7, and 10 to compare the progression of foliar growth among the four treatment conditions.

Table 2. Leaf length of green gram (*Vigna radiata*) of green gram plants under four treatment conditions

Leaf length in centimeter				
Plant	**Day 0**	**Day 4**	**Day 7**	**Day 10**
P1	0	1	2.2	3
P2	0	0.8	1.9	2.7
P3	0	0.7	1.8	2.5
P4	0	0.7	1.3	2

All plants started at 0 cm on Day 0, followed by progressive increases in leaf length during the observation period. By Day 10, P1 recorded the greatest leaf length (3.0 cm), followed by P2 (2.7 cm), P3 (2.5 cm), and P4 (2.0 cm) [Table 2; Figure 3]. P1 showed the largest increase between Days 4 and 7, while P4 exhibited the lowest recorded leaf length throughout the observation period. Overall, the observed measurements indicate differences in leaf elongation among the four treatment conditions, with P1 showing the highest final leaf length under the conditions examined.

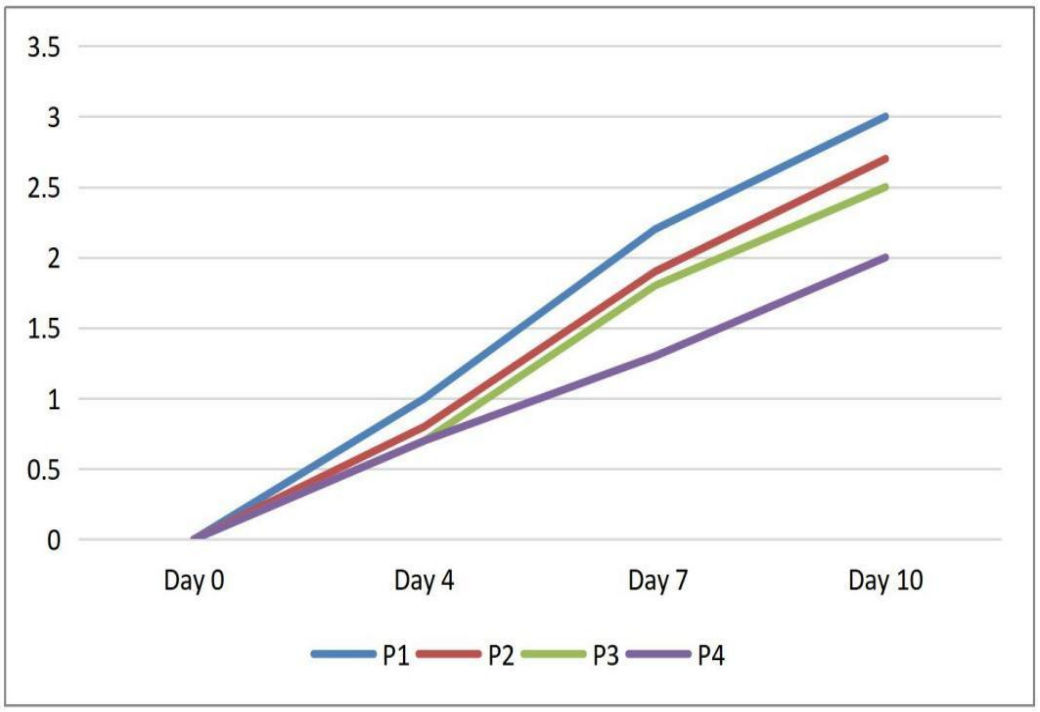

Figure 3. Changes in leaf length of green gram (*Vigna radiata*) under four treatment conditions over the 10-day observation period.

Leaf Width

Leaf width was recorded on Days 4, 7, and 10 to compare the progression of lateral leaf expansion among the four treatment conditions.

Table 3. Leaf width of green gram (*Vigna radiata*) of green gram plants under four treatment conditions

Leaf width in centimeter				
Plant	**Day 0**	**Day 4**	**Day 7**	**Day 10**
P1	0	0.4	0.8	1.2
P2	0	0.4	0.6	1
P3	0	0.3	0.5	0.9
P4	0	0.2	0.3	0.5

All plants started at 0 cm on Day 0, followed by progressive increases in leaf width during the observation period. By Day 10, P1 recorded the greatest leaf width (1.2 cm), followed by P2 (1.0 cm), P3 (0.9 cm), and P4 (0.5 cm) [Table 3; Figure 4]. P1 showed the greatest increase in leaf width over the observation period, while P4 consistently recorded the lowest values. Overall, the observed measurements indicate differences in leaf-width development among the four treatment conditions, with P1 showing the highest final leaf width under the conditions examined.

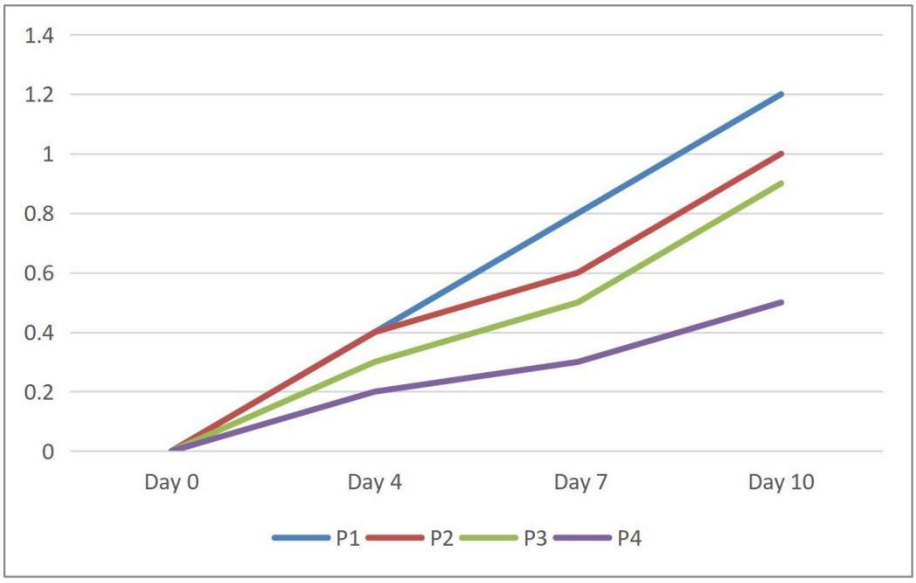

Figure 4. Changes in leaf width of green gram (Vigna radiata) under four treatment conditions over the 10-day observation period.

Root Assessment

Qualitative differences in root development were observed among the four treatment conditions [Figure 5]. P1 exhibited more prominent root branching compared with the other treatment groups, whereas P2 showed greater apparent root elongation. P3 and P4 showed comparatively less developed root systems, with P4 exhibiting the least apparent root development. These observations indicate differences in root architecture among the treatment conditions; however, the qualitative nature of the assessment does not permit conclusions regarding the underlying physiological mechanisms responsible for these differences.

Figure 5. Comparative root development of green gram (Vigna radiata)under the four treatment conditions.

Stem assessment

Qualitative differences in stem characteristics were observed among the four treatment conditions [Figure 6]. P1 and P2 exhibited comparatively thicker and more robust-appearing stems. P1 showed brownish stem coloration, whereas P2 retained a predominantly green
appearance. P3 exhibited an intermediate stem appearance, while P4 showed a comparatively thinner and less robust stem. These observations indicate differences in visible stem characteristics among the treatment conditions; however, the qualitative assessment does not allow definitive conclusions regarding stem strength or the physiological basis of these differences.

Figure 6. Comparative stem characteristics of green gram (Vigna radiata) under the four treatment conditions.

Result Discussion

The findings indicate that early morphological development of green gram varied across the environmental conditions examined [Table 4, Figure 7]. The combination of artificial grow lighting and drip irrigation, with additional smoke exposure (P1), showed the most favorable observed overall growth, whereas natural sunlight with surface irrigation (P4) showed comparatively lower development. The overall pattern suggests that controlled light and targeted water delivery may support early vegetative development. However, the higher growth observed in P1 compared with P2 cannot be attributed specifically to smoke exposure, as the present design did not independently isolate this factor. The findings should therefore be considered preliminary and hypothesis-generating. The findings provide preliminary support for further investigation of controlled-environment cultivation of green gram, particularly in indoor, urban, vertical, and resource-constrained agricultural settings.

Controlled lighting and targeted irrigation may have potential for improving consistency of early plant development and resource management. Future replicated studies with longer observation periods and factorial designs are required to determine the independent and combined effects of light, irrigation, and smoke exposure and to establish whether the observed early growth patterns translate into differences in biomass, physiological performance, or yield.

The observed differences across treatment conditions highlight the importance of considering multiple environmental factors when evaluating early plant development. The variation in above-ground growth, root architecture, and stem characteristics suggests that environmental management may influence different components of plant morphology in distinct ways. These findings provide a useful preliminary framework for future studies incorporating larger sample sizes, standardized environmental exposure, and quantitative physiological measurements to better understand the mechanisms underlying these growth responses.

The results suggest that early plant growth may respond differently to combinations of environmental factors rather than to individual factors alone. The contrasting responses between artificial and natural lighting conditions highlight the potential importance of light management in controlled cultivation systems.

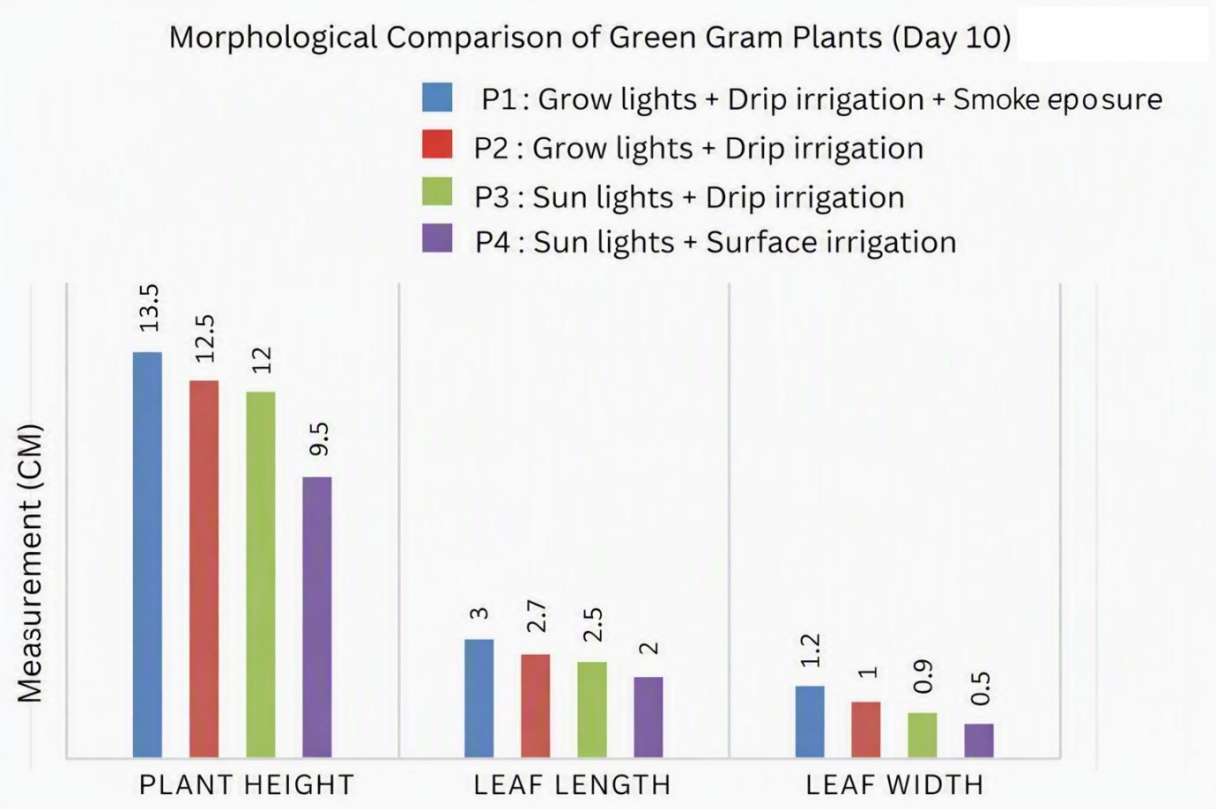

Figure 7. Comparative morphological characteristics of green gram (*Vigna radiata*) on Day 10 under the four treatment conditions.

Table 4. Comparative morphological characteristics of green gram (*Vigna radiata*) on Day 10 under the four treatment conditions.

Green gram plant	**Measurements on 10th Day**				
	Plant Height	**Leaf length**	**Leaf width**	**Root**	**Stem**
Under the grow light with drip irrigation and smoke exposure (P1)	13.5 cm	3 cm	1.2 cm	Increased root Branching in comparison with P2, P3, P4	Brownish color. Stronger stem in comparison with P3, P4

Under the grow light with drip irrigation(P2)	12.5 cm	2.7 cm	1 cm	Increased root Length in comparison with P1, P3, P4	Green color. Stronger stem in comparison with P3, P4
Under the sunlight with drip irrigation(P3)	12 cm	2.5 cm	0.9 cm	Less root length and branching in comparison with P1, P2, but better than P4	Light green color. Stronger stem in comparison with P4
Under the sunlight with surface irrigation(P4)	9.5 cm	2 cm	0.5 cm	Least root length and branching in comparison with P1, P2 and P3	Light green color. Thinner and weaker in comparison with P1, P2, P3

Conclusion

The study demonstrated differences in early morphological growth of green gram under contrasting environmental conditions, with artificial grow lighting combined with drip irrigation and smoke exposure showing the most favorable observed growth. These findings provide preliminary evidence for the potential of controlled-environment cultivation, while further replicated and longer-term studies are required to confirm these observations and determine the individual effects of light, irrigation, and smoke exposure.

Limitation and strength

The study demonstrated differences in early morphological growth of green gram under contrasting environmental conditions, with artificial grow lighting combined with drip irrigation showing the most favorable observed growth. These findings provide only a preliminary observation for the potential of controlled-environment cultivation, while further replicated and longer-term studies are required to confirm these observations and determine the individual effects of light, irrigation, and smoke exposure.

Author Contributions

Ananya Kizhakoodan Jinesh: Conceptualization, study design, methodology, experimental work, data collection, data analysis, interpretation of findings, and preparation of the manuscript.

Jinesh Kizhakoodan Sasidharan: Manuscript preparation, review, and critical revision of the manuscript.

Both authors approved the final version of the manuscript and agreed to be accountable for the work.

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Ethics Statement

The study did not involve endangered or protected species, genetically modified organisms, humans, or animals. The plant materials were handled responsibly, with appropriate care taken to minimize ecological disruption. The study was conducted independently for academic and research interest on private premises, without external funding or institutional sponsorship.

Conflict of Interest

The author declares that there are no financial, personal, or professional conflicts of interest that could have influenced the research presented in this study. No external funding or

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