

Interactive Effects of Gibberellin Application and Shading Regimes on The Growth and Yield of Red Lettuce (*Lactuca sativa* L.) in Verticulture System

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Abstract

Background: Red lettuce (*Lactuca sativa* var. Arista) cultivated in lowland areas often experiences growth constraints due to high temperature and excessive light intensity, resulting in reduced productivity. The application of gibberellin and shading is considered a potential strategy to improve plant growth and yield under these conditions. **Methodology:** This study aimed to evaluate the interaction between gibberellin concentration and shading percentage on the growth and yield of red lettuce cultivated using a vertical farming system. This study was conducted in Paji Village, Pucuk District, Lamongan Regency, at an elevation of 7 meters above sea level, with temperatures ranging from 24°C to 34°C and an average rainfall of 8–25 mm per month. A split-plot design with three replications was used, with shading levels of 0%, 50%, and 75% as main plots and gibberellin concentrations of 0, 50, 100, and 150 ppm as subplots. Data were analyzed using ANOVA, followed by a 5% HSD test when significant differences were detected. **Results:** Significant interactions between gibberellin concentration and shading percentage were observed for plant height, leaf number, leaf area, and fresh canopy weight. Gibberellin concentration significantly affected harvest index, whereas shading significantly affected leaf color. The combination of 100 ppm gibberellin and 75% shading produced the highest growth and yield, while harvest index and leaf color were not significantly affected by the interaction. **Contributions:** This study provides practical guidance for optimizing gibberellin concentration and shading to enhance red lettuce growth and yield in vertical farming systems, supporting urban agriculture practices in lowland areas.

Keywords: Gibberellin; Lowland Cultivation; Red Lettuce; Shading; Verticulture



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INTRODUCTION

Red lettuce (*Lactuca sativa* L.) is a horticultural commodity highly sought after by the public due to its high antioxidant content (Sunarjono, 2016). A key feature of red lettuce is its high level of anthocyanin pigments, which act as antioxidants and may help prevent cancer and coronary heart disease (Febrianto & Septiyani, 2019). Red lettuce is generally best suited for cultivation in highland areas (Yuliani, 2020). When cultivated in lowlands characterized by high solar radiation intensity and high temperatures the plant's growth and development are impaired, resulting in suboptimal productivity and harvest quality (Timotiwu et al., 2021). Red lettuce production can be increased through intensification strategies, such as managing growing conditions via shading to modify light intensity and applying plant growth regulators to stimulate development (Putri et al., 2022). The application of these techniques is expected to optimize the growth and yield of red lettuce.

Efforts to expand the planting area for red lettuce can be carried out in the medium and lowlands so that it has the potential to be developed as an urban farming commodity. However, limited land in urban areas due to conversion of land into residential areas and commercial buildings is an obstacle in increasing vegetable production (Isnaeni & Ramadhan, 2021). Verticultural cultivation is one solution to maximize the use of narrow land by arranging plants in layers from bottom to top (Harahap & Lubis, 2020). This system has been proven to be able to increase crop yields compared to conventional cultivation, making it an efficient alternative for optimizing limited land and increasing plant productivity (Fitriani et al., 2019).

Cultivation of red lettuce in the lowlands faces obstacles in the form of abiotic stress due to the intensity of sunlight and high air temperatures, resulting in small leaves and reducing the quality of the harvest (Syafputri & Aini, 2018). To overcome this condition, it is necessary to use appropriate growth regulators, such as gibberellin, and provide shade. Gibberellins function to stimulate stem elongation, accelerate leaf growth, and increase plant fresh weight (Triani et al., 2020). The consistent use of gibberellins and shade has been proven to be able to optimize microclimate, growth and yield in horticultural plants (Hidayatullah et al., 2024). Application of 100 ppm gibberellin was effective in increasing plant height, number of leaves and fresh weight in red spinach plants with 50% shade (Putri et al., 2022) and in lettuce plants (Syamsiah & Marlina, 2016). Providing 75% shade has been proven to reduce light intensity and air temperature, thereby creating optimal environmental conditions for the growth of red lettuce (Dakiyo et al., 2022).

Most previous studies tested the influence of these two factors separately or on different commodities, so that information regarding the direct interaction between gibberellin concentration and shade percentage on growth and specific yield in red lettuce plants is still limited. This research aims to analyze the real interaction between the combination of gibberellin concentration and shade percentage, and to determine that the combination of 100 ppm gibberellin concentration and 75% shade shows the best results on the growth and yield of red lettuce plants.

METHOD

This research was carried out from 9 October to 26 November 2025 in Paji Village, Pucuk District, Lamongan Regency, at the coordinates 7°05'45.1"S 112°18'17.6"E, with an altitude of 7 meters above sea level, temperature 24 – 34° C and average rainfall of 8 - 25 mm per month. The tools used in this research were six verticulture system installation units, shovels, rulers, scissors, pump hand sprayers, plastic ice lollies, glass beakers, thermohygrometers, lux meters, analytical scales and digital scales. The materials needed are red lettuce seeds of the Arista variety, distilled water, planting media (soil, compost, husks, manure), gibberellin ZPT, plastic cover, NASA liquid organic fertilizer, 50% shade net and 75% shade net.

This research is a factorial experiment with two factors arranged using a Divided Plot Design (RPT). The first factor which is the main plot is the shade percentage treatment (N) with 3 treatment levels, namely no shade; 50% shade and 75% shade. The second factor which is a sub plot is the gibberellin concentration treatment which consists of 4 treatment levels, namely 0; 50, 100 and 150 ppm. Based on these two factors, 12 treatment combinations were obtained which were repeated 3 times, resulting in 36 experimental units. Each experiment consists of 3 sample plants so that the entire experimental unit to be observed is 108 plants. The data will be analyzed using variance (ANOVA) and if there are significant differences, further tests will be carried out using the Honestly Significant Difference (HSD) test with a level of 5%.

The research implementation consisted of preparing verticulture facilities and infrastructure, using 6 verticulture installation units with each installation surrounded by 4 supports. The percentage of paranet used was in accordance with the research design, namely 50% and 75%. Paranet is cut to the size of 5.5 meters x 4 meters. The paranet is placed horizontally at a distance of 1.5 meters from the top of the installation. The planting media used for research is a mixture of soil, husks, compost and manure in a 1:1 ratio. Procurement of Arista Variety red lettuce seeds from PT. Citra Asia Seeds. Seeds are sown and transplanted when they have 4 leaves or are 14 days after sowing (HSS). The application of gibberellin to red lettuce plants was carried out when the plants were 14 and 21 days after planting (DAP). The gibberellin used is Gibgro 10 SP with an active ingredient content of 10% gibberellin. The gibberellin concentrations used were in accordance with the research design, namely 50 ppm, 100 ppm and 150 ppm. A concentration of 50 ppm was made by weighing 0.5 g of Gibgro 10 SP, a concentration of 100 ppm was made by weighing 1 g of Gibgro 10 SP and a concentration of 150 ppm was made by weighing 1.5 g of Gibgro.

The preparation of the solution begins by placing gibberellin powder in a beaker and adding 5 ml of distilled water, then stirring slowly until the solution is homogeneous, marked by the absence of sediment, then adding distilled water while stirring until it reaches a volume of 1 liter. Maintenance carried out includes replanting, watering, fertilizing, weeding, pest and disease control. Fertilization is carried out when the red lettuce plants are 10, 20 and 30 DAP. The fertilizer used is NASA liquid

organic fertilizer (POC) with a dose of 3 mL/L. Apply fertilizer using a pump hand sprayer by spraying the fertilizer evenly onto the leaves and stems of the plants.

Harvesting is carried out at the age of 35 DAP with the criteria for red lettuce plants that can be harvested, namely, the color of the leaves changes to purplish red to dark red. Observation of environmental factors, such as: intensity of sunlight, temperature and humidity. Observations of light intensity using a lux meter and observations of temperature and humidity are carried out every day using a Thermohygrometer. Measurements were carried out three times a day, namely at 08.00, 12.00 and 16.00 P.M.

Parameters for observing plant growth and yield consist of plant length, number of leaves, leaf area, fresh crown weight, leaf color and harvest index. Observation of leaf color is carried out after harvest visually using the Colorimeter application software. Harvest Index observations are calculated by adding up the fresh weight of the plant canopy and dividing it by the total fresh weight of the plant (Gardner et al., 2017). The harvest index can be calculated using the formula:

$$\text{Harvest index} = \frac{\text{Fresh weight of plant canopy}}{\text{Total fresh weight of plant}}$$

The observation data were analyzed statistically using analysis of variance (ANOVA) to determine the effect of treatment on the growth and yield of red lettuce plants. If there is a real effect, then a further test is carried out using the Honestly Significant Difference (HSD) test with a level of 5%.

RESULT AND DISCUSSION

Observations of environmental factors including light intensity, air temperature and air humidity (Figure 1) were carried out as supporting data to evaluate changes in microclimatic conditions due to the provision of shade treatment during the research. Observation results show that increasing the percentage of shade causes light intensity and air temperature to tend to decrease, while air humidity increases. These changes in conditions show that the use of shade is able to modify the growing environment so that it is more suitable for cultivating red lettuce in the lowlands, considering that red lettuce plants grow optimally in relatively low temperature conditions with fairly high humidity (Mebang & Astuti, 2016). This is in line with Yulianti et al., (2017) which states that shade is able to filter and distribute light more evenly. Muslimin et al., (2020) stated that reducing direct solar radiation also causes environmental temperatures to decrease and air humidity to increase due to lower evaporation rates. This condition helps keep the stomata functioning properly so that gas exchange and the photosynthesis process can take place more efficiently without experiencing stress due to excess light.

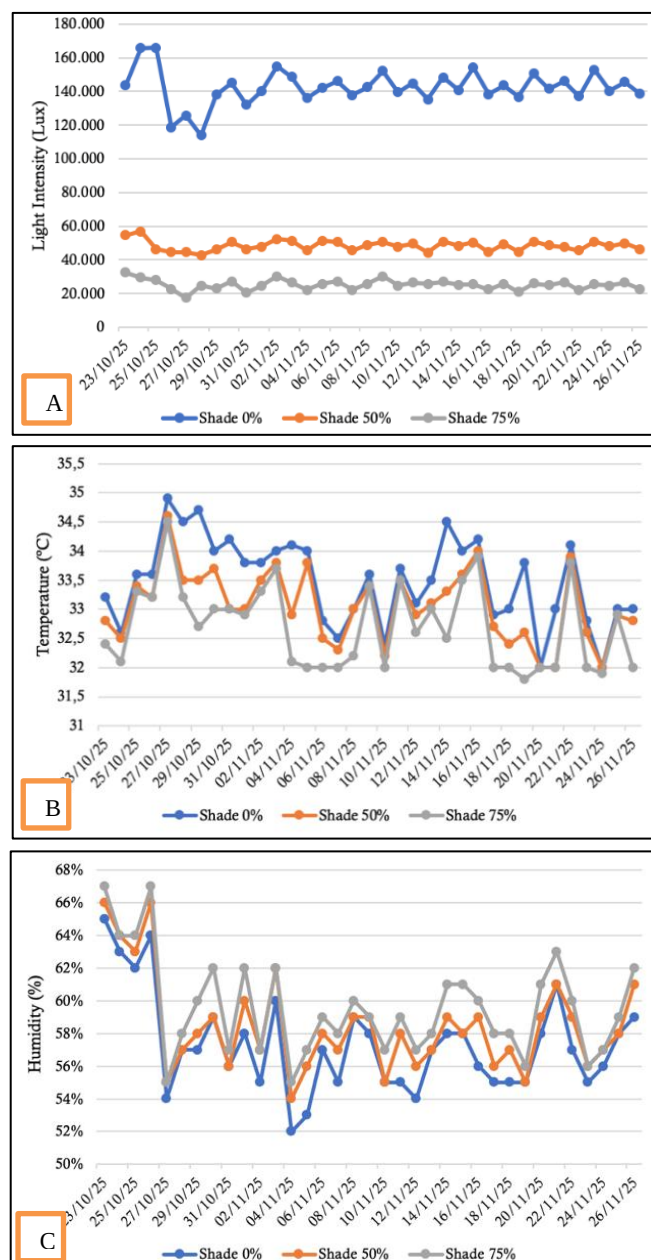


Figure 1. Curves Showing Observations of Sunlight Intensity (A), Temperature (B), and Humidity (C) under Three Shading Treatments from October to November 2025

Plant Length

The results of observations of plant length in combination with gibberellin concentration and shade percentage showed that there was a very significant interaction at the age of 15 - 35 DAP. A gibberellin concentration of 100 ppm and a shade percentage of 75% produced the best plant length (17.40 cm) and was significantly different from all other treatment combinations (Table 1). This shows that a gibberellin concentration of 100 ppm is the optimum concentration which is able to stimulate cell elongation and division so that it can increase plant vegetative growth. Research by [Nisa et al., \(2023\)](#) stated that gibberellins work by eliminating growth

barriers at the cellular level so that genes that play a role in cell elongation can be expressed optimally. [Triani et al., \(2020\)](#) stated that exogenous application of gibberellin can increase metabolic activity and enzyme production which plays a role in mobilizing food reserves as an energy source for the formation of new tissue, thus having an impact on increasing plant length.

Table 1. Average Length of Red Lettuce Plants Aged 15–35 DAP in Combination of Gibberellin Concentration and Shade Percentage

Observation age	Plant Length (cm)				
	Treatment Percentage of Shade (%)	Gibberellin Concentration (ppm)			
		(0)	(50)	(100)	(150)
15 DAP	0	2.24a	2.78b	3.68cd	3.29c
	50	2.64ab	2.41ab	5.17e	4.76e
	75	3.80d	4.96e	8.49g	7.64f
	HSD 5%	0.44			
20 DAP	0	3.49a	4.56b	6.36d	5.58c
	50	3.66a	3.93a	9.33f	8.51e
	75	6.57d	8.91ef	11.31h	10.08g
	HSD 5%	0.57			
25 DAP	0	5.04a	6.56c	8.36e	7.58d
	50	5.66b	5.93b	11.33g	10.51f
	75	8.57e	10.91fg	12.96i	12.08h
	HSD 5%	0.56			
30 DAP	0	7.04a	7.82b	10.36d	9.80c
	50	7.66b	7.93b	13.33f	12.51e
	75	10.47d	12.77e	14.96h	14.16g
	HSD 5%	0.52			
35 DAP	0	8.40a	9.82b	12.26cd	11.78c
	50	9.63b	9.93b	15.09f	14.33e
	75	12.47d	14.50e	17.40h	16.58g
	HSD 5%	0.50			

Note: The average number followed by the same letter at the same observation age shows no significant difference in the 5% HSD test; N0 = Shade 0%; N1 = Shade 50%; N2 = Shade 75%

The 75% shade treatment plays a role in supporting an increase in plant length because shade is able to create environmental conditions that are more suitable for the growth of red lettuce plants. The research results of [Tarigan et al., \(2025\)](#) reported that a combination of 75% shade and 100 ppm gibberellin provided the best growth response in porang plants. [Muslimin et al., \(2020\)](#) stated that the use of shade can reduce excess light intensity and maintain stable temperature and humidity so that physiological activity and photosynthesis processes take place more optimally. [Fadillah et al., \(2024\)](#) stated that the photosynthate produced is then used as an energy source and biomass building material to support cell division and elongation which is stimulated by gibberellin.

Leaf Area

The results of observations of the combined treatment of gibberellin concentration and shade percentage showed that there was a real interaction on the leaf area of red salad plants. A gibberellin concentration of 100 ppm and a shade percentage of 75% produced the best leaf area (279 cm²) and was significantly different from all other treatment combinations (Table 3). The increase in leaf area is related to the ability of gibberellins to stimulate the process of cell division and enlargement in the leaf blade so that the leaf surface develops wider (Miceli et al., 2019). Leaves with a larger size have a higher light capturing capacity, thus supporting the formation of photosynthesis for plant growth (Kusumodewi et al., 2017). Gardner et al., (2017) explains that enlarging the leaf blade increases the efficiency of capturing light energy with the results of research by Sholilah & Kumala (2023) which shows that the application of 100 ppm gibberellin produces the highest leaf area compared to other concentration treatments.

Table 2. Average Area of Red Lettuce Leaves in the Combination Treatment of Gibberellin Concentration and Shade Percentage

Treatment	Leaf Area (cm ²)			
	Gibberellin Concentration (ppm)			
Percentage of Shade (%)	(0)	(50)	(100)	(150)
0	86.63a	108.10c	139.59f	118.58d
50	95.69b	147.97g	161.95h	195.30i
75	123.70e	158.10h	279.08k	258.91j
HSD 5%	3.98			

Note: The average number followed by the same letter indicates that it is not significantly different in the 5% HSD test; N0= Shade 0%; N1= Shade 50%; N2 = Shade 75%

The research results of Pratama et al., (2024) also showed that 75% shade provided the best leaf area for red lettuce plants. The increase in leaf area in the 75% shade treatment illustrates a form of plant adaptation to maximize light capture in conditions of lower radiation intensity, so that wider leaf blades allow the process of absorbing light energy to take place more efficiently so that photosynthate formation can increase.

Fresh Canopy Weight

The results of observations of the combination of gibberellin concentration and shade percentage treatment showed that there was a very significant interaction with the fresh weight of the red salad plant canopy. A gibberellin concentration of 100 ppm and a shade percentage of 75% produced the best fresh weight (9.44 g) and was significantly different from all other treatment combinations (Table 4). The increase in fresh canopy weight is related to the role of gibberellins in stimulating the growth of vegetative organs so that stem and leaf development occurs more optimally. Better vegetative organ growth causes the accumulation of biomass and water content in the canopy tissue to increase, so that the fresh weight of the plant becomes higher. These

results are in line with research by [Riko et al., \(2020\)](#) who reported that giving gibberellin at an optimum concentration can increase the fresh weight of plants by increasing vegetative growth, and giving gibberellin at a concentration that exceeds the optimum level does not always provide increased growth because it can disrupt the plant's physiological balance.

Table 3. Average Fresh Canopy Weight of Red Lettuce Plants Under Combinations of Gibberellin Concentration and Shading Percentage Treatments

Treatment	Fresh Canopy Weight (g)			
	Gibberellin Concentration (ppm)			
Percentage of Shade (%)	(0)	(50)	(100)	(150)
0	1.45a	1.97b	4.51e	3.24c
50	3.04c	3.79d	6.18f	4.70e
75	3.09c	3.89d	9.44h	7.20g

Note: The average number followed by the same letter indicates that it is not significantly different in the 5% HSD test; N0 = Shade 0%; N1 = Shade 50%; N2 = Shade 75%

The higher fresh value of the canopy in the 75% shade treatment is related to the increase in the area of the canopy where photosynthesis takes place. A better developed canopy allows the accumulation of assimilation results and the water content in plant tissue increases so that the fresh biomass formed becomes greater ([Sholihah & Kumala, 2023](#)). This condition is supported by [Dakiyo et al., \(2022\)](#) which states that increasing leaf area has an effect on increasing assimilation results and plant biomass and the use of 75% shade produces better vegetative growth of red lettuce compared to treatment without shade.

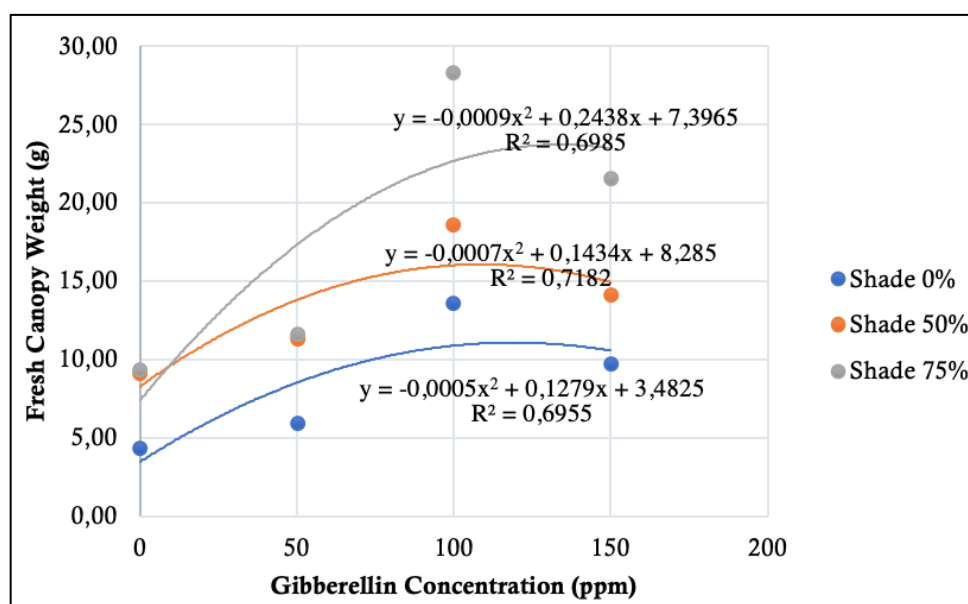


Figure 2. Quadratic Regression Graph of The Relationship Between Gibberellin Concentration and Fresh Canopy Weight at Each Shade Level

Based on Figure 2, the relationship between gibberellin concentration and canopy fresh weight at each shade level forms a quadratic regression pattern with the coefficient of determination (R^2) at each shade level respectively being 0.6955; 0.7182; and 0.6985. The R^2 value describes variations in plant response to the combination of treatments given. The results of the differential regression equation show that the fresh weight of the canopy is maximum at 0% shade, namely at a gibberellin concentration of 127.9 ppm, 50% shade at a gibberellin concentration of 119.5 ppm and 75% shade at a gibberellin concentration of 135.44 ppm.

Leaf Color

The single treatment of gibberellin concentration showed no significant effect, while the single treatment of shade percentage showed a very significant effect. A shade percentage of 75% produces the best redness percentage value (56.00%) and is significantly different from other treatments (Table 5).

Table 4. Average Color of Red Lettuce Leaves in the Treatment of Gibberellin Concentration and Shade Percentage

Treatment	Leaf Color (% R)
Gibberellin Concentration (ppm)	
0	44.78
50	47.96
100	46.67
150	43.37
HSD 5%	ns
Percentage of Shade (%)	
0	37.03a
50	44.06b
75	56.00c
HSD 5%	1.65

Note: The average number followed by the same letter indicates that it is not significantly different in the 5% HSD test; N0 = Shade 0%; N1 = Shade 50%; N2 = Shade 75%; ns = not significantly different

Differences in leaf color in shade treatments are influenced by changes in light intensity received by plants. Light intensity is one of the environmental factors that plays a role in the formation of anthocyanin pigments in red lettuce. [Hutagalung et al., \(2021\)](#) emphasized that by increasing the light intensity received by plants, anthocyanin synthesis tends to increase so that the color of the leaves becomes redder, while shaded conditions cause the accumulation of chlorophyll to be more dominant so that the color of the leaves appears more reddish green. [Gardner et al., \(2017\)](#) stated that light intensity influences pigment formation in leaves through changes in plant physiological activity, so that the level of shade affects the color quality of red lettuce leaves.

Harvest Index

The single treatment of gibberellin concentration showed a very significant effect on the harvest index, while the single treatment of shade percentage showed no real effect on the harvest index of red lettuce plants. A gibberellin concentration of 100 ppm showed the best results (0.82) and was not significantly different from other treatments (Table 6). According to [Nisa et al., \(2023\)](#) a higher harvest index value indicates that the photosynthesis results produced by the plant are able to be allocated efficiently towards the part of the plant that is harvested. Giving gibberellin at optimum concentrations is thought to support balanced growth between organs so that biomass distribution occurs more proportionally ([Rana et al., 2023](#)). [Kasri et al., \(2024\)](#) stated that giving gibberellin at concentrations that are too high tends to increase vegetative growth excessively so that the efficiency of biomass distribution is less than optimal.

Table 5. Average Harvest Index of Red Lettuce Plants in the Treatment of Gibberellin Concentration and Shade Percentage

Treatment	Harvest Index
Gibberellin Concentration (ppm)	
0	0.68a
50	0.81a
100	0.82a
150	0.79a
HSD 5%	0.21
Percentage of Shade (%)	
0	0.76a
50	0.80a
75	0.76a
HSD 5%	ns

Note: Mean values followed by the same letter indicate no significant difference according to the HSD test (5%); N0 = 0% shading; N1 = 50% shading; N2 = 75% shading; ns = not significantly different.

[Gardner et al., \(2017\)](#) explained that the harvest index reflects the efficient distribution of photosynthesis results to the harvested organs. The 75% shade treatment also plays a role in increasing the harvest index value by creating a growth balance between the canopy and the harvested plant parts. Suitable environmental conditions allow assimilation results to be utilized more efficiently for the formation of economic biomass so that the proportion of harvest results to total biomass increases ([Zhang et al., 2021](#)).

CONCLUSION

The combination of a gibberellin concentration of 100 ppm and a shade percentage of 75% showed the best results for the growth and yield of red lettuce plants. The use of gibberellin concentrations and appropriate shading arrangements has proven to be effective in modifying the microclimate, so as to overcome environmental

stress barriers for red lettuce cultivation. The application of a combination of gibberellin concentration and shade provides a significant contribution to the development of verticultural cultivation systems in the lowlands. Optimizing light intensity through 75% shade combined with 100 ppm gibberellin hormone stimulation offers an applicable solution to increase productivity, visual quality (leaf color), and efficiency of the planting space in a sustainable manner.

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