The effect of light intensity and carbon dioxide on the growth characteristics Vegetative growth of Epipremnum aureum

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Abstract

This study was carried out in the woody canopy of the Department of Horticulture and Landscape Architecture, College of Agriculture, Tikrit University during the spring season of 2023-2024. The study showed that the growth of Gad Epipremnum aureum is significantly influenced by light intensity and carbon dioxide (CO_2) concentration, as they enhance photosynthesis and increase plant biomass. Moderate levels of light intensity and high CO_2 concentration improved vegetative growth, as evidenced by the observed increase in plant height, tender weight, and dry weight, as well as a higher rate of leaf production. This interaction reflects a perfect integration of environmental conditions that catalyze physiological processes, as moderate light provides energy for photosynthetic reactions, while high CO_2 concentration enhances photosynthetic efficiency, leading to accelerated cell division and increased vegetative growth. However, exceeding the optimal light intensity leads to light stress, manifested by the accumulation of active oxygen species (ROS) and inhibition of photosynthesis, limiting growth. Excessive levels of CO_2 or light may reduce the efficiency of physiological processes, emphasizing the importance of a balance between these two factors for optimal growth. These results support previous research suggesting that the synergistic interaction between moderate light and high CO_2 concentration improves photosynthetic efficiency, contributes to carbohydrate accumulation, and promotes vertical growth. However, intense light or very high concentrations of CO_2 may lead to increased photorespiration and carbon loss, negatively affecting plant productivity. This study emphasizes the importance of precise control of light intensity and CO_2 concentration to optimize the growth of ornamental plants such as Epipremnum aureum, while highlighting the need for further research to improve growing conditions in protected environments.

Keywords: Light intensity, CO2 concentration, vegetative growth, photosynthesis, light stress, Epipremnum aureum.

Introduction:

Environmental factors are among the most important influences on plant growth and development, and light intensity and carbon dioxide concentration are two of the most important factors that play a pivotal role in photosynthesis. [1] Gad's Boots (Epipremnum aureum) is known as a common houseplant due to its ability to adapt to various low and semi-low light conditions, making it an ideal model for studying how it responds to environmental changes.[2] The response of plants to light intensity varies by species, with some species tending to thrive in bright light while others prefer low-light conditions [3]. Carbon dioxide is known to be a limiting factor for plant growth, as its higher concentration can increase photosynthetic rates and thus improve overall plant growth, especially in protected environments.[4] The study of these interactions is complex, as the

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effect of one factor may vary with different levels of the other factor [5]. Increasing the CO_2 concentration may not have a significant effect on plant growth if the light intensity is too low to allow efficient photosynthesis to occur [6]. Similarly, plants may not be able to take full advantage of high light intensity if the CO_2 concentration is limiting [7]. In previous studies on the effect of light intensity on Epipremnum aureum, the effect of different light intensities (low, medium, and high) on chlorophyll content, leaf area, and biomass was investigated. Moderate light (2000-3000 lux) was found to promote optimal growth, while very low or high light led to stress [8]. In another study [9], Epipremnum aureum was shown to grow by 1.42% every two weeks, while producing 15 new leaves in five months, making it effective in absorbing carbon dioxide indoors. These results contribute to the development of sustainable strategies to improve air quality through the use of indoor plants. In a study [10], the plant showed a biweekly growth of 1.42%, with an approximate leaf area per plant of 0.0502 square meters. According to the statistical analysis, the plants showed a similar growth pattern. In addition, it was observed that at the end of the five months of the study, fifteen (15) new leaf units were obtained and, in a study, where Epipremnum aureum (Potts) showed superior CO_2 uptake capacity compared to the other species examined. The plant's CO_2 uptake averaged -36 mg\l during the day, while the average release was only 2 mg\l in the closed chamber at night. The aim of the study was to evaluate the effect of light intensity and CO_2 concentration on the growth of Gad's pot plant Epipremnum aureum and determine the optimal levels to promote photosynthesis and vegetative growth, while avoiding the negative effects of light stress and inappropriate high concentrations.

Materials and methods:

(1Plant Sources and Growing Conditions

Potts 'Jad' (Epipremnum aureum Jad) was obtained from a nursery in Baghdad. Healthy cuttings were taken, two from each phloem (mother), except for the basal phloem, from which one cutting were taken to preserve the developing apex. The cuttings were planted in plastic pots (12 x 12 cm) containing sterilized culture medium. The medium consisted of a mixture of Dutch Pitmus and Saudi Agricultural Perlite in a ratio of 2:1, respectively, and was provided by an agricultural office in Al-Kurayat, Baghdad. The potting medium was compacted to the specified level in the pots and then sterilized with 0.5 ml/L potable water using a 2-liter hand-held sprayer from Angeco.

(2Growth conditions:

The seedlings were placed in a greenhouse to protect them from climate fluctuations, then the seedlings were transferred to a caravan (sandwich pen) with dimensions of 3 m length * 2 m width * 2.5 m height, the windows and door window of the caravan were closed tightly using aluminum foil (1 mm thick food cellophane) and glued with silicone to prevent the penetration of external light and control the internal temperature, as one surface of the aluminum was reflective of sunlight.

(3CO2 Injection System

For the purpose of controlling the CO_2 level, a precision injection system was installed inside the caravan, consisting of a CO_2 gas cylinder, a regulator with two gauges (capacity and discharge), and two sets of stops (gas locks) to control the flow. These components were connected to polyethylene tubing that terminated in syringes securely attached to the

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cork to ensure no leakage. Gas was injected at concentrations of 2000 and 3000 mg\l for 3 seconds and 4 seconds respectively for each, as well as a control group at 0 mg\l.

(4Lighting system:

A lighting system that mimics natural sunlight was designed to support photosynthesis. The lamps were attached to ceramic stands and their wires were fixed to the ceiling of the bottle. Two light intensities were tested: 2000 and 4000 lux, with each lamp representing 1000 lux, and were distributed according to coefficients by opening two or four holes in the top cork. To ensure optimal control, 2 cm deep glass panels were fixed with silicone, and the wires were connected to an inverter and a photovoltaic cell to automatically adjust the lights on and off based on external sunlight.

Factors studied:

This study analyzed the effect of two main factors on plant growth:

Factor I: Light (L(

This factor includes two levels of light intensity:

2000L1: Lux (achieved with two lamps(

4000L2: Lux (achieved with four lamps) The lamps were distributed in each corks according to the required level, with a margin of ±100 Lux.

The second factor: Carbon dioxide (CO_2) enrichment (G(

This factor included three levels of CO_2 concentration:

G1: 2000 mg\l

G2: 3000 mg\l

G3: 0 mg\l (comparison level, no addition(

Vegetative growth traits studied:

.1Rate of increase in plant height (main stem(

The length of the main stem of Potts plant was measured from the nearest node to the surface of the growing medium to the top of the plant at the last node of the main stem at the end of the season. Measurements were taken using a tape measure, according to the method of [11.[

.2Average soft weight of the vegetative population:

Vegetative tender weight of plants was measured after removing dust from the leaves with a damp cloth (raw) [13.[

.3Average dry weight of the vegetative population:

To estimate the dry weight of the vegetative population of potts, the roots were first removed, and then the samples were dried in an electric oven at 65-70°C until the weight was stabilized. Then, a sensitive balance wasused to weigh the dried samples [12.[

.4Carbon dioxide gas percentage:

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To accurately measure and calculate the carbon dioxide (CO2) ratio in controlled environments for growing plants as mentioned in Section 3, careful monitoring of CO2 levels [13[

.5Average number of leaves:

To estimate the average number of leaves, leaves were counted for three plants from each replicate. The average was then calculated by dividing the total number of leaves of plants in each replicate by the number of plants in that replicate [14.[

Statistical analysis :

The results of the experiment were analyzed using statistical software (SAS) and the means were compared by Duncan's test at 5% probability level [15 .[

Results:

-1Morphological response of potts (Epipremnum aureum) to the effect of light intensity and CO_2 concentration: Main stem length (cm(

Table (1) contains the results in correlated cells showing the combined effect of light intensity and CO_2 concentration on the stem growth rate of E. aureum, CO_2 concentration has a significant effect on main stem growth, and this effect increases clearly at 3000 mg/L, which reached 22.741 cm.

As for the effect of high light intensity (4000 lux) did not lead to a significant increase, on the contrary, the growth was better at medium light (2000 lux), which amounted to 16.9581 cm, which may indicate that the plant is exposed to light stress at high light.

While the interaction between CO2 and light intensity had a significant effect on the plant height of the main stem, 2000 lux light intensity and 3000 mg\l enrichment in increasing light intensity gave the highest main stem height of 16.741 cm compared to the lowest plant height of 5.650 cm plant-1

Table (1) Effect of light intensity and carbon dioxide gas on the plant height of the main stem (cm) of E. aureum

Light Intensity Lux	**Carbon dioxide concentration mg L^{-1}**			**Light Intensity Ratio**
	0	**2000**	**3000**	
2000	11.733 c	16.400 a	22.741 b	16.9581 a
4000	5.650 d	5.900 d	9.525 c	7.0250 b
Carbon dioxide concentration	8.6915 c	11.1500 b	16.1330 a	

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-2

Morphological response of Epipremnum aureum to the effect of light intensity and CO_2 concentration on total leaf number.

The results of Table (2) showed the effect of light intensity and CO_2 on the total number of leaves (leaf-1) of E. aureum, it was observed that increasing the concentration of CO_2 leads to an increase in the number of leaves. The higher concentration (3000 mg/L) produced the largest number of leaves 9.0000 (leaf-1), indicating a clear stimulation of photosynthetic activity and increasing the ability to build new tissues.

As for the effect of light intensity, moderate illumination (2000 lux) resulted in a significantly higher leaf number 8.8056 (leaf-1) compared to high illumination (4000 lux = 6.2778 (leaf-1 (

As for the interaction between CO2 and light intensity, the highest total leaf number was recorded at 2000 lux light intensity with a CO2 concentration of 3000 mg L^{-1} (10.25 leaves/plant), with significant differences at 5% probability level compared to the other treatments. This indicates a positive interaction between moderate illumination and increased CO_2 concentration .

Table (2) Effect of light intensity and CO_2 on the total number of leaves (leaf-1) of E. aureum

Light Intensity Lux	**Carbon dioxide concentration mg L^{-1}**			**Light Intensity Ratio**
	0	**2000**	**3000**	
2000	7.5000 b	8.6667 b	10.2500 a	8.8056 a
4000	5.8333 c	5.2500 c	7.7500 b	6.2778 b
Carbon dioxide concentration	6.6667 b	6.9583 b	9.0000 a	

-3

Morphological response of pots plant (Epipremnum aureum) to the effect of light intensity and CO_2 concentration on the soft weight characteristic of the vegetative population.

The results of Table (3) showed the effect of light intensity and CO_2 on the average number of total leaves (leaf-1) of E. aureum, showing that increasing CO_2 concentration leads to a significant increase in the tender weight of the vegetative group, where the highest tender weight of the vegetative group was recorded at 3000 mg L-1, which amounted to 15.0183 (g plant-1.(

While the effect of light intensity increased significantly, low light intensity (2000 lux) resulted in a higher average tender weight (11.5822 g) compared to high light intensity (4000 lux = 10.4867 g). This may indicate that high light intensity may cause light stress, leading to water loss or reduced relative growth, especially at low CO_2 concentration.

As for the interaction between CO_2 and light intensity, the effect of CO_2 had a clear effect on increasing the tender weight of the vegetative population, where the best conditions for tender growth were under 2000 lux and 3000 mg/L CO_2, which reached 15.6633 (g plant-1), indicating that the combination of moderate light and high concentration of CO_2 is optimal for Potts plant growth.

Table (3) Effect of light intensity and CO_2 on the soft weight characteristic of total vegetative mass (g plant-1) of E. aureum

Light Intensity Lux	Carbon dioxide concentration mg L^{-1}			Light Intensity Ratio
	0	2000	3000	
2000	8.4267 e	10.6567 c	15.6633 a	11.5822 a
4000	7.5700 e	9.5167 d	14.3733 b	10.4867 b
Carbon dioxide concentration	7.9983 c	10.0867 b	15.0183 a	

-4

Physiological response of potts plant (Epipremnum aureum) to the effect of light intensity and carbon dioxide gas concentration on the carbon dioxide gas ratio trait.

From Table (4), the effect of light intensity and CO2 gas on the CO2 gas ratio of E. aureum, there are significant differences between the treatments studied for E. aureum under the low light intensity of 2000 lux, where the highest treated concentration was 538,333 mg\l remaining in the cork space (residual gas from the injected gas) compared to the highest light intensity of 4000 lux, where the lowest was 684,555 mg\l.

The data in the same table also indicate that there are significant differences between the levels of gas injection and CO2 enrichment, with the highest concentration of 3000 mg\l giving the highest significant difference of 573 mg\l compared to the no enrichment treatment of 0 mg\l, which had the lowest significant value for the residual gas in the cork space of 669.500 mg\l.

As for the interference, it shows that there is a significant effect between the study treatments, which reached the highest value of 462.667 mg\l under the effect of the lowest light intensity, which was 2000 lux and injected carbon dioxide gas concentration of 3000 mg\l compared to the control treatment that was not injected and the carbon dioxide concentration was 0 mg\l under 2000 lux light intensity, which reached the lowest value of 628 mg\l.

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Table (4) Effect of light intensity and carbon dioxide gas in characterizing the percentage of carbon dioxide gas (MG\L) remaining in the cork space of E. aureum

Light Intensity Lux	**Carbon dioxide concentration mg L^{-1}**			**Light Intensity Ratio**
	0	**2000**	**3000**	
2000	628.000 d	524.333 e	462.667 f	538.333 b
4000	711.000 a	659.333 c	683.333 b	684.553 a
Carbon dioxide concentration	669.500 a	591.833 b	573.000 c	

-5

Morphological response of Epipremnum aureum to the effect of light intensity and CO2 concentration on vegetative dry weight.

It was observed from the results of Table (5) that the effect of light intensity and carbon dioxide gas on the dry weight (g plant-1) of E. aureum, when the plant was exposed to 2000 lux light intensity, the highest significant value obtained was 1.6955 (g plant-1) compared to the lowest significant value of 1.3567 g plant-1 under 4000 lux light intensity level .

In the same table showing the effect of CO2 as well, the highest significant values for the second factor, CO2 concentration 3000 mg\l, showed 2.1267 g plant-1 compared to the lowest value of 0.995 g plant-1 for the no-addiction treatment.

The results of the same table also confirmed the averages of the interaction between 2000 lux illumination intensity and 3000 mg\l CO2 concentration in the dry weight of potts plant, the highest value of this interaction was 2.4033 g plant-1 and the lowest value of the interaction was 0.8867 g plant-1 between the two experimental treatments of 4000 lux illumination intensity and 0 mg\l CO2 concentration .

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Table (5) Effect of light intensity and carbon dioxide gas on the dry weight characteristic of the vegetative total (g plant-1) of E. aureum

Light Intensity Lux	Carbon dioxide concentration mg L^{-1}			Light Intensity Ratio
	0	2000	3000	
2000	1.1033 cd	1.5800 bc	2.4033 a	1.6955 a
4000	0.8867 dc	1.3333 cd	1.8500 B	1.3567 b
Carbon dioxide concentration	0.9950 c	1.4567 b	2.1267 a	

Discussion:

The results of the present study showed that the growth of Jade pots (Epipremnum aureus) is significantly affected by light intensity and carbon dioxide (CO2) concentration. Research suggests that these two factors promote photosynthesis, a process essential for plant growth and biomass increase. Higher light levels and higher CO2 concentration enhance growth rates, as evidenced by studies on a variety of horticultural plants. Increased light intensity helps enhance photosynthesis, leading to increased biomass and plant height. The observed increase in plant height, tender weight, dry weight, and leaf number is due to a positive interaction between moderate light and high CO2 concentration. This interaction reflects an integration of environmental conditions that lead to the stimulation of plant physiological processes. Where moderate light provides the energy necessary for the occurrence of light reactions, while the high concentration of CO_2 contributes to enhancing the efficiency of photosynthesis, this stimulation leads to an increase in the rate of cell division and tissue growth, which is clearly reflected in the development of the vegetative growth of the plant, and this is reflected in the high rate of leaf production and increased plant biomass, whether soft or dry[16]. Low plant height and tender weight clearly indicate that exceeding the optimal light intensity may be due to light stress, which limits growth and negatively affects the plant's physiological efficiency. When a plant is exposed to excessive light, it exceeds the ability of photosynthetic apparatus to utilize energy, leading to the accumulation of excess energy and the generation of reactive oxygen species (ROS) that cause damage to plant cells and inhibit photosynthesis, thus reducing the overall growth of the plant [17]. These results indicate the efficiency of photosynthesis in converting organic matter to dry matter under these environmental conditions, which is consistent with similar results by other researchers [18]. Studies indicate that Potts plant has a high ability to absorb CO_2 , especially under favorable light conditions, and studies indicate that the balance between light intensity and CO_2 concentration enhances the efficiency of photosynthesis and thus increases the soft weight of the plant [21][20][19]. High light intensity improves photosynthetic capacity by promoting leaf orientation and regulating genes involved in the Calvin cycle, which increases

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carbohydrate accumulation and supports growth [22]. In Pseudolarix amabilis (Christmas tree) seedlings, increasing light intensity promotes plant height by increasing leaf number, biomass, and stem growth, demonstrating a direct relationship between light availability and vertical growth [23]. Elevated levels of CO2 enhance photosynthetic rates by increasing the maximum rate of light-saturated photosynthesis and carboxylation efficiency, leading to enhanced growth and dry matter accumulation [24]. In lettuce, higher CO2 concentration, combined with an optimal light level, contributes to a significant increase in fresh and dry weight, indicating an improvement in growth performance and plant height [26][25]. The synergistic effect of increasing light intensity and CO2 concentration contributes to the creation of optimal growth conditions, such as in tomato seedlings. These factors work together to enhance photosynthesis and water use efficiency, leading to increased plant height [27]. While increasing light intensity and CO2 concentration generally promotes plant height, it should be noted that excessive levels of either of these factors may lead to reduced yield or stress responses in plants. Optimal growth conditions require a balance, and studies have shown that specific thresholds of light and CO2 achieve the best growth results [26][25]. An increase in CO2 promotes photosynthesis, which improves plant growth and water use efficiency. In addition, higher light intensity helps to open stomata, facilitating CO2 uptake, while higher concentrations of CO2 stimulate photosynthetic activity and growth [25]. High light conditions optimize leaf orientation and increase chlorophyll content, which is vital for efficient light capture and energy conversion [22]. Increased light intensity promotes photosynthesis, which requires higher levels of carbon dioxide for optimal growth. When CO2 is deficient, photosynthetic rates may be negatively affected, resulting in reduced plant growth and productivity. This is evident from historical research on greenhouse systems and CO2 concentration dynamics [28]. However, excessive light intensity can reduce the efficiency of photocatalytic processes, demonstrating a complex relationship where excess light can hinder electron transport [29]. Increased light intensity, coupled with rising CO2 levels, increases the light stress on phytoplankton, leading to decreased growth rates and increased respiration. This interaction stimulates photorespiration and mitochondrial respiration [30.[

Conclusion

-1The growth of Potts plant (Epipremnum aureus) is significantly affected by changing light intensity and carbon dioxide (CO_2) concentration. It was found that a moderate increase in light intensity, in parallel with an increase in CO_2 concentration, leads to a significant improvement in vegetative growth indicators, and this is manifested in the studied traits, indicating a positive interaction between the two factors.

-2Exceeding the light intensity to optimal levels leads to photosynthetic stress, as shown by the decrease in soft weight and plant height in some treatments, indicating a decrease in photosynthetic efficiency as a result of physiological stress.

-3These indicators generally indicate that balancing between light intensity and CO_2 concentration is necessary to create an optimal growth environment, as any deviation from this balance - whether by excessive light or low CO_2 concentration - may lead to a

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significant decrease in plant growth and physiological efficiency.

-4Exposing the plant to high light intensity below the prescribed limit was 3500 to 3850 lux to stimulate the plant to establish adventitious aerial roots on the main stem of the plant.

Recommendations

-1

We recommend raising the CO_2 concentration within safe limits for plants, as this factor has been shown to effectively contribute to increasing soft and dry weight, stimulating photosynthetic efficiency and cell division and balancing between light and CO_2 , data indicate that a positive interaction between moderate light intensity and high CO_2 concentration is key to achieving optimal growth. Balanced agronomic strategies that thoughtfully integrate both factors should be adopted, especially in protected environments or greenhouses.

-2Avoid excessive light intensity (not exceeding 4000 lux), it is advisable not to exceed the optimal threshold of light intensity, to avoid negative effects associated with light stress such as reduced physiological efficiency and accumulation of reactive oxygen species (ROS), which reduce growth efficiency.

-3Conducting additional complementary studies on different growth periods and different cultivars of Epipremnum aureus, to explore more physiological interactions and study the long-term effects of light intensity and CO_2 on plant productive performance.

-4Exposing the plant to a higher level of 3000 mg\l CO_2 and observing the development of plant growth and the response of pollutant digestion within the plant tissue .

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