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IMPACT OF GROW LIGHTS ON PLANT GROWTH IN VERTICAL FARMING UNDER SIMULATED GROWING ENVIRONMENT

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ABSTRACT: *The study entitled "Impact of grow lights on plant growth in vertical farming under simulated growing environment" was undertaken with the objective to develop a vertical farming structure with artificial lighting using grow lights suitable for cultivation in shaded areas. For analyzing the impact of grow lights on plant growth, artificial lighting sources such as LEDs and fluorescent lamps were provided in the structure and biometric observations were made under 9 treatments with different combination of light (red, blue and red-blue combination) and rooting media (vermiculite, perlite, sand and coir peat). Studies were conducted under shaded condition supplemented with LED and fluorescent light with amaranthus plants (Kannara local). Results of the study with amaranthus revealed that there is significant correlation between plant growth and applied light condition and plants showed a positive response to artificially supplied grow lights especially to red-blue combination. The use of vermiculite, perlite mixture enhanced the plant growth as it provides a better root zone environment with good aeration and fair amount of water holding capacity along with good drainability. Hence from the study it can be concluded that direct sunlight exposure is not at all necessary for plants, as the photosynthesis and plant growth depends only on the PAR range. Providing PAR in the form of artificial light with sufficient luminance can support plant growth and vertical farming structure with grow light under controlled growing environment can make urban indoor farming a great success.*

Key words*: grow lights, vertical farming, rooting media, simulated growing environment, PAR range*

1. INTRODUCTION

Agriculture, the backbone of Indian economy, contributing to the overall economic growth of the country and determines the standard of life for more than 50% of the Indian population. Light, water and soil are the major factors concerned with a plant's growth and for all biological processes in a plant these factors are essential. The availability of water and land for cultivation are decreasing day by day. Water helps the plant by transporting important nutrients and dissolved sugar through the plant. Nutrients are drawn from the soil and used by the plant. Vertical farming is the advanced level of agriculture technology which can be practiced when there is unavailability of land and other basic requirements for the normal farming. and is very useful for indoor cultivations. Vertical farming can be defined generally as cultivation of plants and other life forms by artificially stacking them vertically above each other. The concept of vertical farming helps in the efficient utilization of land and water resources. In this system crops are protected under the building so plants or crops cannot be affected by rain and other vagaries of nature. Lesser amount of water is needed for vertical farming and this method requires less manpower than open field farming and it either uses direct sunlight or artificial light. Energy is less utilized in the vertical farming system where LED lights (a grow light) are used instead of direct sunlight. A grow light or plant light is an artificial light source generally an electric light designed to stimulate plant growth by emitting an electromagnetic spectrum appropriate for photosynthesis. Grow lights are used in applications where there is either no naturally occurring sunlight or where supplemental light is required. Outdoor conditions are mimicked with varying colour, temperature and spectral outputs from the grow lights as well as varying intensity of lamps. Depending on the type of plant being cultivated, the stage of growth and the photoperiod required by the plants, specific range of spectrum, luminous efficiency and colour lamps are desirable for use with specific plants and time periods. The initial vegetative phase requires a blue spectrum of light and later flowering stage requires red-orange spectra. The ability of plant to absorb light varies with species and environment, however, the general measurement for the light quality as it affects the plants in the PAR value or Photo synthetically Active Radiation.

A light quality rich in red light relative to far-red light can suppress elongation growth, making many plants shorter; a light quality relatively rich in far-red light promotes extension growth, making plants taller. Soil less medium along with drip irrigation conserves water. A vertical structure suitable for indoor farming which contains lightning by LED grow lights, drip irrigation system for irrigation etc. under controlled environment will be beneficial for people living in flats and in urban areas. This type of set up can be established also in offices, industries, railway stations, schools etc., thus available space can be effectively utilized and demands of food supply can be met from within the cities. The main objective of the present study is to study the impact of grow lights on crop performance under simulated growing environment.

Vertical farming will reduce the dependency on land resources and help in re-growth of forests. Further, due to less use of equipments, it will lead to decrease in CO_2 emission, thus help in conservation of the environment (Garg and Balodi, 2014). Energy is less utilized in the vertical farming system where LED lights are used instead of the sunlight for the growing of crops better than under the sunlight (Massa et.al, 2008). Presently, many types of garden crops are cultivated under fluorescent lamps, HPS and LEDs, which are becoming especially popular for vegetable crops (Liu et al.2011). Amount and effects of air temperature and sunlight intensity during plant growing period, significantly affected biomass yield, leaf colour and betacyanin accumulations. (Khandaker et.al, 2010). Bula et al. (1991) at the University of Wisconsin first suggested using LEDs to grow plants and reported that growth of lettuce plants under red LEDs supplemented with blue fluorescent (BF) lamps was equivalent to that under cool-white fluorescent (CWF) plus incandescent lamps. The main vegetable type of amaranth, *Amaranthustricolor*L., seems to have originated in South or Southeast Asia and then spread through the tropics and the temperate zone (Martin et.al, 1979).

2. MATERIALS AND METHODS

2.1 Location of the study

The experiment was conducted at Kelappaji College of Agricultural Engineering and Technology (KCAET), Tavanur, in Malappuram district of Kerala. The location is situated at 10 □ 52' 30" North latitude and 76 □ East longitude.

2.2 Experimental set up

2.2.1 Vertical structure

The vertical structure for the project was of four arrays fabricated with 30 mm MS angle and mild steel sheet of 1.5 mm thickness. Each array has an area of 85x125 cm. One array lies at a height of 65 cm above the other. Three arrays (total area of 3.19 m^2) were used for the cultivation and top layer was constructed with an aim to install a small water tank to support irrigation. Total height of the setup was 2.4 m.

2.2.2 LED strip

Red-Green-Blue (RGB) strip having 5 m length was used for the study in order to use any colour combinations by supplying power to the terminals. Each 1 m strip contains 40 lights. LED grow strip for plant production is coated with water resistant silicon cover. High flexibility, small size and low thermal emission makes it ideal for use in many horticultural applications where lighting can be precisely directed for optimal plant growth.

2.2.3 Growing media

Soil less growing media is more suitable for indoor vertical farming, since they are lighter in weight, has increased water holding capacity, reduced risk of soil born pest and disease, good aeration etc. The media made with vermiculite, perlite, coir peat and sand combination is used. The following combinations of media were prepared and are filled in growing containers for comparing their performance:

Table 2. 1. Different treatments of root media used for the study

Composition	Ratio
Vermiculite+ Perlite (V+P)	2:1
Vermiculite + Perlite + Sand (V + P + S)	2:1:1
Coco peat + Cow dung (CP + CD)	3:1

2.2.4 Irrigation system

Irrigation was done using drip method. Laterals of 12 mm size and online drippers of 2 litres per hour capacity were used. For this type of cultivation practice drip irrigation is more suitable. Plants were irrigated once in two days for about 10 minutes. Since the growing media are of with high water holding capacity and transpiration is comparatively less small quantity of water is needed.

2.2.5 Crop for experiment

Crop selected for cultivation under diffused sunlight supplemented with grow lights was Kannara local variety Amaranthus. It is the most common leafy vegetable grown during summer and rainy season in India, which belongs to the family *Amaranthaceae* and is one of the most resistant varieties of amaranthus. It is classified under C-4 group of plants and has efficient photosynthetic ability. Crop selection was based on characteristics such as resistance to pests, diseases and adverse climate, plant height, root growth etc. Leafy vegetables are more suitable for this kind of cultivation and a temperature range of 20 to 30^{o}C is required for better vegetative growth.

2.3 Methodology

A shaded room was selected and required condition of light was supplemented with LED and fluorescent grow lights so that light intensity sufficient for plant growth was available. Kannara local variety was selected for study under this condition. Amaranthus seedlings of 20 days old were transplanted from pro-trays to grow bag containing three different media. Each growing array contains 9 containers with vermiculite - perlite media, 9 containers with coir peat –cow dung media and last 9 containers with vermiculite- perlite-sand media. Drip emitters of 2 lph were placed at the root zone of the plant and irrigation was given once in two days for about 10 minutes. A total number of 27 plants were used for this study. Biometric observation of plants in each array under blue light, red light and red-blue combination and three different media were taken and tabulated for ANOVA.

Plate 2.1 Amaranthus under shaded condition supplemented with grow lights

The following treatments were used

T1 – Mix of vermiculite, perlite and sand as rooting media under blue light
T2 – Mix of vermiculite and perlite as rooting media under blue light
T3 – Mix of coco peat and cow dung as rooting media under blue light
T4 – Mix of vermiculite, perlite and sand as rooting media under red light
T5 – Mix of vermiculite and perlite as rooting media under red light
T6 – Mix of coco peat and cow dung as rooting media under red light
T7 – Mix of vermiculite, perlite and sand as rooting media under red and blue combination
T8 – Mix of vermiculite and perlite as rooting media under red and blue combination
T9 – Mix of coco peat and cow dung as rooting media under red and blue combination

2.4 Determination of light intensity inside the room

Light intensity is an important parameter, since main aim of this project is to study the impact of artificial grow light on plants. Light intensity in lux, inside the room was measured using a high range lux meter. Measurement of light intensity was made thrice in a weak during morning, noon and evening and average lux was obtained.

2.5 Biometric observations

For analyzing the growth of the plants under different treatments, three plants were selected randomly from each array. Biometric observations such as plant height and number of leaves were made after every 10 days and the overall growth was assessed over a period of 30 days. The collected data were tabulated and compared separately for each trial. The heights of the randomly selected plants were measured from the surface of the rooting media to the tip of the plant. Numbers of leaves of randomly selected plants of each array were counted at an interval of 10 days. Harvesting of amaranthus was done 30 days after transplanting and was weighed for analysing the total yield.

3. RESULTS AND DISCUSSION

3.1 Light intensity

The measured light intensity inside the shaded room supplemented with grow lights (LED and fluorescent light) was within the range of 5000-25000 lux.

3.2 Growth and yield parameters

3.2.1 Plant height

The observations on plant height were made on 10, 20 and 30 DAP and the values are given in Table 3.1.

Table 3.1 Effect of different treatments on plant height (cm) of amaranthus

Treatment	Days after planting		
	10	**20**	**30**
T1	7.28	10.16	16.33
T2	8.23	10.25	18.66
T3	4.15	9.19	10.67
T4	4.12	6.28	8.33
T5	10.15	13..5	14.66
T6	6.81	8.51	9.67
T7	14.78	19.25	26.35
T8	15.38	19.18	26.33
T9	12.08	16.8	18

Based on the observations two-way ANOVA was done to find out the variation among plant height under different treatments and the results are shown in Table 3.2.

Table 3.2. Analysis of variance of plant height (amaranthus) in response to different treatments (significant at 1% level)

Treatment	Count	Sum	Average	Variance
T1	3	33.77	11.25667	21.37763
T2	3	37.14	12.38	30.5989
T3	3	24.01	8.003333	11.68373
T4	3	18.73	6.243333	4.432033
T5	3	38.31	12.77	5.4847
T6	3	24.99	8.33	2.0692
T7	3	60.38	20.12667	34.04263
T8	3	60.89	20.29667	30.91083
T9	3	46.88	15.62667	9.794133
10 DAP	9	82.98	9.22	17.5213

20 DAP	9	113.12	12.56889	23.21686		
30 DAP	9	149	16.55556	43.91755		
ANOVA						
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**	**F crit**
Treatments	619.2149	8	77.40187	21.34092	3.78E-07	3.889572
DAP	242.7568	2	121.3784	33.46595	1.92E-06	6.226235

From the ANOVA it can be seen that there is significant difference in plant height between various treatments. It is evident from the results that plants under treatment T7 and T8 have a maximum height at all growth stages, whereas the treatments T4 and T6 have shown lesser increment in height. In general application of red light recorded lower plant heights compared to that with blue and red-blue combination. Generally plants treated with vermiculite perlite mixture shown higher heights under different light conditions in all growth stages, whereas the plants grown in coir peat shown less increment in plant height compared to other media. The plants grown under the red and blue combination shows a maximum height when compared to red and blue alone as light treatments. This is in agreement with (Bula et al., 1991).

3.2.2 Number of leaves

The data on number of leaves were recorded at 10, 20 and 30 days after planting and are shown in Fig 3.1. From the results it can be seen that the different light treatments influenced the number of leaves produced.

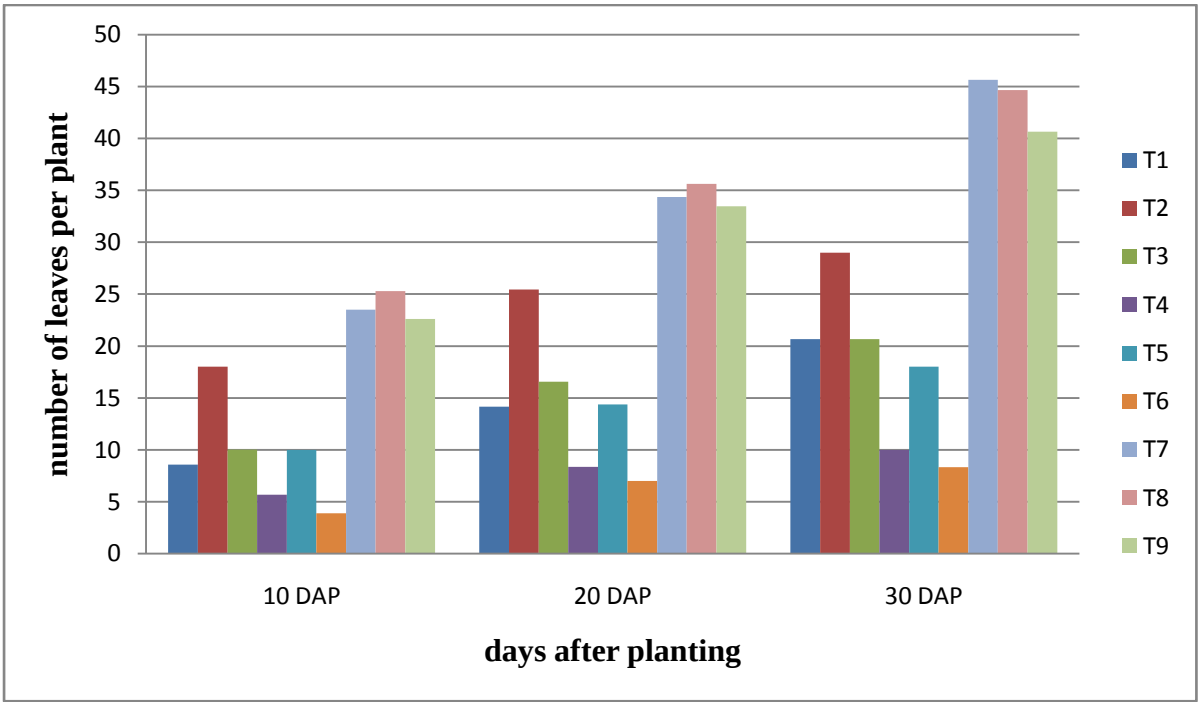

Fig 3.1 Effect of different treatments on number of leaves per plant in amaranthus

Generally plants treated with vermiculite perlite mixture gave more number of leaves per plant among different light conditions at all growth stages, whereas the plants in coir peat gave less number of leaves per plant. The plants grown under the red and blue combination gave more leaves compared to those with red and blue alone as light treatments. This is in agreement with (Bula et al., 1991).

3.2.3 Leaf area

The leaf area measured in square centimetres under various treatments is shown in Table 3.3.The area was measured after the final picking (30 DAP) and the average values are expressed under various treatments.

Among the different treatments, plants under T8 shown maximum value for average leaf area followed by T7. That is maximum leaf area was obtained under red- blue combination of light and the least for blue.

3.2.4 Fresh matter production

The fresh matter production (FMP) was influenced by both light and rooting media which is given in Table 3.3 and the results revealed that there was considerable variation in biomass production. Generally the FMP was higher in plants under red and blue combination when compared to red light alone. Variation of fresh matter production is graphically shown in Fig.3.2.

Table 3.3. Effect of different treatments on yield parameters of amaranthus

Treatment	Parameter	
	Leaf area(cm^2)	Fresh weight(g/plant)
T1	12.00	14.00
T2	19.66	20.00
T3	10.00	12.33
T4	12.66	15.66
T5	15.33	19.66
T6	12.33	14.66
T7	31.00	28.33
T8	42.33	38.33
T9	23.66	20.33

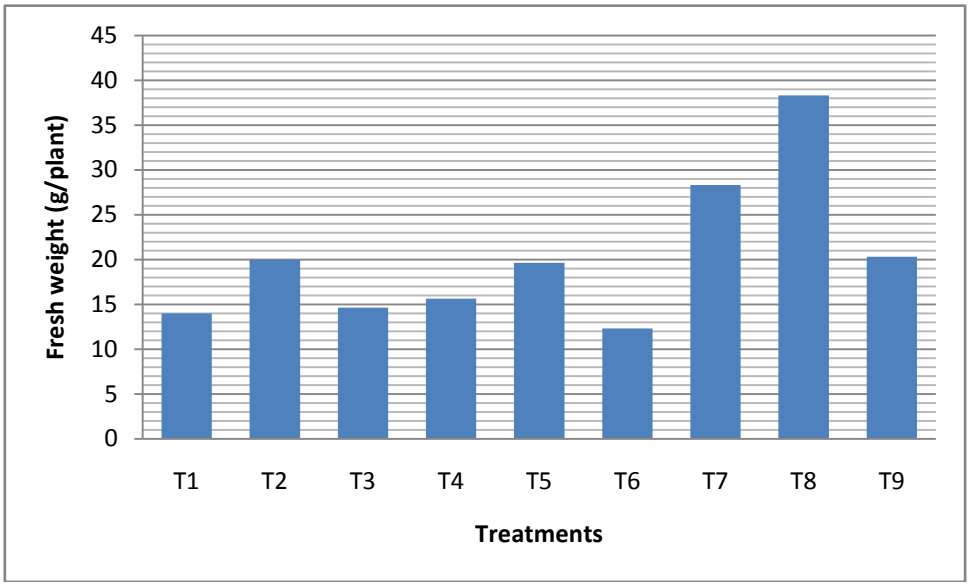

Fig3.2 Effect of different treatments on fresh matter production (g/plant) in amaranthus

The highest fresh matter production was observed in plants treated with red-blue combination of light in vermiculite-perlite-sand mixture (T8), followed by that in vermiculite-perlite media under the same lighting (T7). The lowest fresh matter was obtained in plants under treatment T6, that is with red light and coco peat mixture as the medium. All other treatments, i.e. T1, T2, T3, T4, T5 and T9 have shown an intermediate range of fresh matter production. This revealed that the red and blue combination of light has the highest influence on biomass production, whereas red, blue lights alone have no significant effect.

4. SUMMARY AND CONCLUSION

The study entitled "Impact of grow lights on plant growth in vertical farming under simulated growing environment" was coducted to develop a vertical farming structure with artificial lighting using grow lights, suitable for cultivation in shaded areas. Structure was installed inside a shaded condition with light supply using

LEDs and fluorescent lamps. Amaranthus was used for the study inside shaded region. Seedlings were raised in pro-trays and transplanted at the 4 leaves stage. Three rooting media were used under different treatments viz. vermiculite and perlite in 2:1 ratio, vermiculite, perlite and sand in 2:1:1 ratio and coco peat, cow dung in 3:1 ratio. Irrigation was given once in two days using drip irrigation system. Biometric observations such as plant height and number of leaves were made in randomly selected plants from all the treatments at 10, 20 and 30 DAP. Analysis of the results obtained from study revealed that there is significant correlation between the plant growth and applied light condition. Plants under T7 and T8 showed maximum height than plants under remaining treatments. The highest plant height obtained on 30 DAP was 26.35 cm in T7, followed by 26.33 cm in T8 and the least recorded value was 8.33 cm in T4. In this case the use of vermiculite, perlite mixture enhanced the plant growth since it provides a better root zone environment with good aeration and fair amount of water holding capacity. In addition to better water holding capacity, vermiculite and perlite possess good drainability, which might have helped the establishment of good root system and enhancement of overall growth. The treatments were given inside a room where direct sunlight is not available, which is supplemented with LEDs and fluorescent lamps to provide the sufficient luminance for plant growth and biomass production. There was a remarkable increase in number of leaves produced and the leaf area at all stages of growth. The average number of leaves were counted from three plants selected randomly under each treatment and maximum number of leaves at the final picking (30DAP) was 45.66 in T7 followed by 44.66 in T8. Maximum average leaf area was also obtained in T8 followed by T7 with values 42.33 cm^2 and 31 cm^2. Number of leaves as well as leaf area observed in plants under red and blue light treatments was found to be lesser. Fresh matter production in amaranthus on 30 DAP was maximum under T8 and T7 with an average yield of 38.33 g/plant and 28.33 g/plant respectively.

From the results of the study, it can be concluded that direct sunlight exposure is not at all necessary for plants as the photosynthesis and plant growth depends only on the PAR range. Providing PAR in the form of artificial light with sufficient luminance can support plant growth. Analysis of the results obtained revealed that grow light based vertical farming can be recommended for indoor precision farming in urban areas as a substitute to the conventional farming practice on limited land area. There is scope for accommodating more number of plants per unit area and performance of individual plants can be improved by adequate access for light and through proper management of growing environment. Scope for further study includes the following.

- Studies using different plants and cultivation techniques such as hydroponics, aquaponics, aeroponics etc.
- Studies using improved portable structures with insect proof nets.
- Studies on automation of irrigation and lighting systems.

REFERENCES

[1]. Bula, R.J., Morrow R.C., Tibbitts T.W., Barta D.J., Ignatius R.W. and Martin T.S. 1991. Light emitting diodes as a radiation source for plants. *Hort Science*.26:203–205.

[2]. Garg A. and Balodi R. 2014. Recent trends in agriculture: vertical farming and organic farming. *Adv Plants Agric. Res.*1(4):0023.

[3]. Khandaker L., A. S. M. G. Masum AKOND and Shinya OBA. 2009. Air temperature and sunlight intensity of different growing period affects the biomass, leaf color and betacyan pigment accumulations in red amaranth (*amaranthus tricolor* L.). J.Central European Agriculture.10(4):439-448.

[4]. Li H., Tang C., Xu Z. and Liu X. 2012. Effects of Different Light Sources on the Growth of Non-heading Chinese Cabbage (*Brassica campestris* L.). *J. Agrl. Sci.* 4 (4): 262- 273.Available Online: www.ccsenet.org/jas.

[5]. Martin F.W. and Telek L. 1979. Vegetables for the hot humid tropics. Part 6: Amaranth and Celosia. U.S. Dept of Agric, New Orleans, LA.

[6]. Massa, G.D., Emmerich., J.C., Morrow, R.C. and Mitchell, C.A. 2005. Development of a reconfigurable LED plant-growth lighting system for equivalent system mass reduction in an ALS. SAE Technical Paper 2005-01- 2955.

[7]. Massa, G.D., Emmerich., J.C., Morrow, R.C., .Bourge.t, C.M. and Mitchell, C.A. 2006. Plant growth lighting for space life support: A review. *Gravit. Space. Biol.* 19:19-29.

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