Effect of Artificial LED and Natural Light on the Growth of Cucumber Plant (Cucumis sativus) in Hydroponic Dutch Bucket System

ABSTRACT

Hydroponics is the latest innovation in farming where plants are grown in the absence of soil. In India adoption rate of hydroponics is estimated 13 – 15 % annually. In this context present study was conducted to analyze the morphological characteristics of cucumber plant in Dutch Bucket Hydroponic system. Moreover, comparative evaluation of morphological characteristics of cucumber plants were compared for natural light as well as artificial light emitting diode (LED). The experiment was carried out in the Naturally Ventilated Polyhouse (NVPH) and in the laboratory (as an indoor practice) in the campus of Dadasaheb Mokashi Collage of Agricultural Engineering and Technology Rajmachi, Karad (MH). Cucumber (*Cucumis sativus*) HY shiny variety was grown in natural and artificial light to evaluate different morphological characteristics such as leaf area, plant height and root length. Dutch bucket system of 10 buckets (each having capacity of 11 liters) was installed each in natural and artificial light source. Cucumber plants were grown in both environment for months June- July 2024. Initial seedlings of 15 days were transplanted in both environments. From the present experiment it was observed that, during and at the end of season growth of all the three selected parameters were found more satisfactory in artificial light as compared to natural light. Before the flowering stage of the experiment average leaf area, average plant height, and average root length was observed approximately 123.15 cm^2, 154 cm, 30.1 cm for artificial light and 56.07 cm^2,110 cm, 25.3 cm for natural light, respectively. Therefore, from this study it was envisaged that overall average leaf area, average plant height and average root length was improved in artificial light by 54%, 28%, and 25%, respectively over natural light.

Keywords: Hydroponics, Dutch Bucket System, Morphological, Natural light, Artificial light (LED).

INTRODUCTION

Hydroponics is latest innovation in farming where plants are grown in the absence of soil i.e. plants are completely nurtured and grown on liquid media. Throughout their growing cycle all the nutrient required by the plant are provided through water and for indoor setup the light required for photosynthesis is provided through artificial source of light. Hydroponic farming gives an effective way to conserve both water and space, making it a viable urban farming method.

The container-type system commonly known as dutch bucket includes a reservoir at the bottom for additional water and nutrient retention. Expanded clay balls known as hydrotones, are commonly used due to their good water-holding capacity and uniform water and salinity profiles (Wallach, 2019). The system utilizes individual buckets or containers filled with an inert growing medium. The media used during the study were hydrotones. These buckets are arranged in rows or lines and are connected to a main reservoir tank of nutrient-rich water through a network of tubing. The capacity of tank depends on number of buckets. A pump delivers water from the reservoir to the highest point of the system, and it flows down through each bucket providing water and nutrients directly to the plants roots. Gravity assists in the distribution of nutrient water while drainage holes in the buckets prevent waterlogging ensuring the roots have access to oxygen. The system is ideal for vine crops which require substantial support and space for optimal growth like tomatoes, cucumbers, peppers, and eggplants.

Light is a most crucial factor for plant. Visible spectrum light ranges between 400 to 700 nanometers (nm) are sufficient for photosynthesis and chlorophyll concentration in plants known as photosynthetically active radiation (PAR) (Muzammal Rehman et al - 2017) from which 400-520 nm is used by pigments (chlorophyll and carotenoids) for photosynthesis and vegetative growth. 580 to 700 nm for flowering and reproductive growth (Deram et al. (2014), Singh et al. (2015)). Among all lights red, blue, and white light majorly contributes in plant growth as they are high in energy sources for photosynthetic Co_2 assimilation in plants (Kuan-Hung Lin et al.- 2012). Red light with a range of 600-700nm is essential for flowering and fruiting in plants. Blue light ranging between 400-500nm encourages vegetative growth and is ideal for seedling as well as development of plants at an early stage. White light is a broad-spectrum light source that includes a mixture of various colours which is suitable for general plant growth and is often used in conjunction with other color for a more balanced spectrum. Ultraviolet (UV) and Infrared (IR) are also important. UV light can stimulate the production of certain secondary metabolites in plants also it helps in eradication of pests and diseases on plants, while IR light can help with heat management and energy efficiency

High pressure sodium lamps, incandescent lamps, florescent lamp, and metal halide lamps are generally preferred and widely used as an artificial source of light (kim et al., 2004b) but uses large amount of electricity, low operating life span, and produces heat which leads to scorching or marginal leaf burn in plants. So, considering these problems there is need for effective, energy-efficient, durable, cheaper, and high-quality source of light. Light Emitting Diode (LED) overcomes all the problem faced in conventional light sources. The cost of lighting is less than 25 % of cost of traditionally used artificial light and results in 75% higher electrical conversion efficiency. (Gomez et al., 2013)

This study focuses on the growth cycle of cucumber plant (Cucumis sativus) in the Dutch bucket system. The aim of this study was to analyses the growth responses of plants at different sources of light to analyze the effect of natural light and artificial LED light on cucumber plant in Dutch Bucket System. This research works towards the advancement in agriculture, rise in quality, pesticides free, residue free, and increase in economic status of farmer.

MATERIALS AND METHODS

Experimental setup and growth condition

The hydroponics system was established in the department of Irrigation and Drainage Engineering, Dadasaheb Mokashi College of Agricultural Engineering and Technology, Rajmachi, Karad. Another setup was installed in naturally ventilated polyhouse Dadasaheb Mokashi College of Agricultural Engineering and Technology, Rajmachi, Karad. In building the structure, the main goal will be to create a hydroponic system that is suitable for urban areas therefore should be compact, low maintenance and cost effective. To create a system that is compact, the structure will be designed horizontally. This will allow single layers of planting areas in a relatively small space. For a small system that will be used for personal or residential purposes, fully automating the system is not practical due to relatively less plant capacity. Therefore, parameters for plant growth were only monitored and not controlled.

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Two Dutch bucket systems were installed one arrayed with artificial LED light as an indoor setup in laboratory and other with natural sun light in naturally ventilated polyhouse. Cucumber plant was cultivated in the system. The buckets were made from UV-resistant and durable plastic with a capacity of 11 litres each, served as the primary containers. These buckets were arranged within a supporting frame to facilitate efficient space utilization and proper air circulation. A soilless growing medium comprising expanded clay pellets (hydrotones) was employed to provide optimal aeration and moisture retention for healthy root development of plant. The irrigation system consisted of a drip system, with each bucket connected to a main supply line for the direct delivery of nutrient-rich water to the plant roots. The pump was connected to a main supply line using PVC pipes or flexible tubing. The main supply line ran along the row of Dutch buckets. Drip laterals of 4 mm were punched into the main supply line. To prevent waterlogging, overflow drains were integrated into the buckets. A nutrient solution reservoir, positioned at a higher level than the buckets, facilitated gravity-driven irrigation, with a submersible pump circulating the solution as needed. pH and electrical conductivity (EC) monitoring systems were utilized to maintain the nutrient solution within the optimal range for cucumber growth. The Dutch Bucket system with artificial light as shown in Fig. 1 and system with natural sunlight as shown in fig.2.

Fig. 1 Artificial LED light setup

Fig.2 Natural light setup

Table 1: Specifications of the Dutch bucket system

Sr. No.	Specifications	Material	Dimensions
1	Iron Frame	Iron	1.5 x 0.6 x 0.6 m
2	Drain pipe	PVC	L-1.5 m, Dia - 0.004 m

3	Irrigation pipe	LDPE	L-1.5 m, Dia - 0.015 m
4	Dutch Bucket	Polypropylene	0.3 x 0.25 x 0.23 m
5	Bucket [Volume]	Polypropylene	11 lit
6	Drip pipe	LDPE	0.016 m
7	Submersible Pump	Water resistance	220V AC [3500 lit/h]

Light control and quality treatment.

Light treatment to system 1 were arrayed with artificial lighting as a source of light i.e. Red-Blue-White (RBW) LED's and system 2 was supplied with natural sunlight. The RBW LED light treatment was chosen. (Kuan-Hung Lin et.al.,) The power intensities of LEDs are 22 W. The duration of LED lights was scheduled to 16 hrs. per day as shown in Table 2. The spectrum was recorded from the top portion of plant canopy of both treatments natural and artificial. In natural light source, spectrum was maintained by closing and opening of curtains in polyhouse and in artificial lighting it is done by adjusting the distance by clamps.

Table 2: Light Duration for artificial LED light

Criteria	Time	Duration
Daytime without LED light support	8 am to 4 am	8 hrs.
Daytime with LED light support	4 am to 12 am	8 hrs.
Nighttime with LED light support	12 am to 8 am	8 hrs.

Criteria and Specification

Parameters maintained during the study are listed in the (Table 3) along with its specification and mode of control. All adjustments are done on regular basis

Table 3: Hydroponic criteria (Folta et.al.,2008; Lin et.al.,2013; H.S.Chus et.al.,2020)

Sr. No.	Parameters	Specifications	Mode of control
1	E.C	2.4 mS/cm	E.C meter
2	PH	5.8 - 6.2	PH meter
3	Light Intensity	15,000 – 25,000 lux	Adjusting the light distance
4	Light/Dark Duration in LED	16/8 hours	Digital cyclic timer programmed to switch on and off the lighting.

RESULTS AND DISCUSSION

Leaf area, Plant height and Root length

Measurements of vegetative parameters were frequently carried out to track the performance of cucumber and the nutrition in the hydroponic unit throughout the experiment. Entire growth cycle of cucumber plant in artificial light as well as in natural light were examined daily and the results are obtained are stated as under. The leaf area of plants in artificial light was 123.15 cm^2 and that of natural light was 56.07 cm^2 as shown in figure 3. The difference was observed in average height of cucumber plant from the day 10 onwards which shows that artificial LED light significantly increased the growth of plant significantly as compared to plants in natural sun light shown in Table 5. Fig. 4 Shows the average height difference of plants.

Fig.5 shows the average root length of the cucumber plants under different source of light. On the harvesting day the average length of roots of the plant arrayed with artificial LEDs and natural sunlight are shown in Table 6. The plant grown under artificial LEDs had the longest average root length of 30.1 cm as compared to average root length of plants in natural light which is 25.3 cm. This result shows that artificial LED light supports to elongate the plant root.

Table 4: Growth stages of cucumber plant

STAGE	**DURATION**
Germination stage	07 Days
Vegetative growth	60 Days

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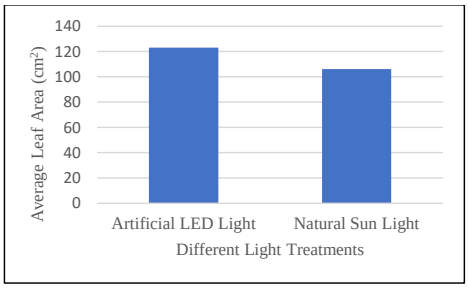

Fig 3: Effect of natural sun light and artificial LED light on average leaf area

Table 5: Distinguishing result of the plants using natural sun light and artificial LED light.

Period	Average Height (cm)	
	Artificial LED light	**Natural sun Light**
Day 10	11	9
Day 15	20	16
Day 20	34	29
Day 25	50	42
Day 30	75	64
Day 35	92	78
Day 40	122	99
Day 45	154	110

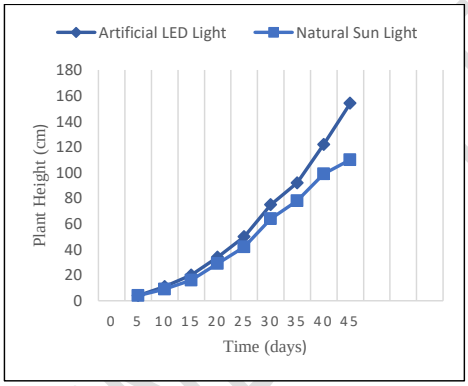

Fig.4. Height growth of cucumber plant grown under natural sun light and artificial LED light.

Table 6: Root length of Cucumber plant under different light treatments during harvesting

Replicates	Root length (cm)	
	Artificial LED light	Natural Sun light
Plant 1	30	25
Plant 2	32	23
Plant 3	29	27
Plant 4	32	25
Plant 5	35	25
Plant 6	30	27
Plant 7	30	24
Plant 8	28	24
Plant 9	27	26
Plant 10	28	27

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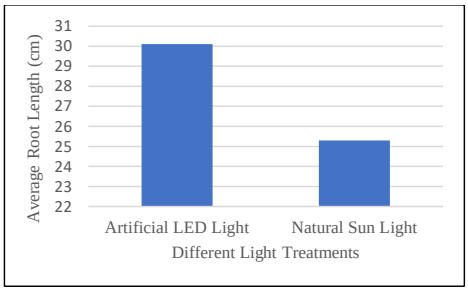

Fig 5: Effect of natural sun light and artificial LED light on average root length

CONCLUSIONS

The present study was conducted to analyze the morphological characteristics of cucumber plants in Dutch Bucket Hydroponic system. Moreover, comparative evaluation of growth parameters of cucumber plants was carried out in natural light and artificial light emitting diode (LED). The experiment was carried out in the Naturally Ventilated Polyhouse (NVPH) and in the laboratory (as an indoor practice) in the campus of Dadasaheb Mokashi Collage of Agricultural Engineering and Technology Rajmachi, Karad (MH). Cucumber (Cucumis sativus) HY shiny variety was grown in natural and artificial light to evaluate different physical factors such as leaf area, plant height and root length. Dutch bucket system of 10 buckets (each having capacity of 11 liters) was installed each in natural and artificial light source. Cucumber plants were grown in both environment for months June- July 2024. Initial seedlings of 15 days were transplanted in both environments. From the present experiment it was concluded that, from transplant to the flowering stage all the three selected parameters were found more satisfactory in artificial light as compared to natural light. Before the flowering stage of the experiment average leaf area, average plant height, and average root length was observed approximately 123.15 cm^2, 154 cm, 30.1 cm for artificial light and 56.07 cm^2 ,110 cm, 25.3 cm for natural light, respectively. Therefore, from this study it was envisaged that overall average leaf area, average plant height and average root length was improved in artificial light by 54%, 28%, and 25%, respectively over natural light.

As a future scope of this study, comparative evaluation of yield of cucumber plant in both the light environments could be an interesting research work to analyze further economic aspects.

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REFERENCES

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Deram P, Lefsrud M, Orsat V (2014) Supplemental lighting orientation and red-to-blue ratio of light-emitting diodes for greenhouse tomato production. Hortscience 49:448–452

Singh D, Basu C, Meinhardt-Wollweber M, Roth B (2015) LEDs for energy efficient greenhouse lighting. Renew Sust Energy Rev 49: 139–147

Kuan-Hung Lin, Meng-Yuan Huang, Wen-Dar Huang, Ming-Huang Hsu, Zhi-Wei Yang, Chi-Ming Yang. 2013. The effects of red, blue, and white light-emitting diodes on the growth, development, and edible quality of hydroponically grown lettuce (Lactuca sativa L. var. capitata). Scientia Horticulturae 150 86–91

Auerswald, H., Schwarz, D., Kornelson, C., Bruckner, B., 1999. Sensory analysis, sugar, and acid content of tomato at different EC valuables of the nutrient solution. Sci. Hortic. 83, 227–242

Kim H-H, Goins GD, Wheeler RM, Sager JC (2004a) Green-light supplementation for enhanced lettuce growth under red and blue light emitting diodes. Hortscience 39:1617–1622

Muzammal Rehman, Sana Ullah, Yaning Bao, Bo Wang, Dingxiang Peng, & Lijun Liu. 2017. Light-emitting diodes: whether an efficient source of light for indoor plants? Environ Sci Pollut Res 24:24743–24752

Motsa, M.M., Slabbert, M.M., van Averbeke, W. & Morey, L. 2015. Effect of light and temperature on seed germination of selected African leafy vegetables. South African Journal of Botany 99: 29-35.

Folta, K.M. & Childers, K.S. 2008. Light as a growth regulator: Controlling plant biology with narrow-bandwidth solid state lighting systems. HortScience 43(7): 1957-1964

Lin, K.H., Huang, M.Y., Huang, W.D., Hsu, M.H., Yang, Z.W. & Yang, C.M. 2013. The effects of red, blue, and white light emitting diodes on the growth, development, and edible quality of hydroponically grown lettuce (Lactuca sativa L. var. capitate). Scientia Horticulturae 150: 86-91.

H.S. Chua, Lai Siew Wei, Sivajothi Paramasivam, T.T. Goh & Gee Chia Chen. 2020. Effect of Artificial Night Lighting on the Growth of Loose Head Lettuce in Hydroponic System. Sains Malaysiana 49(12): 2891-2900

Janda T, Majláth I, Szalai G (2014) Interaction of temperature and light in the development of freezing tolerance in plants. J Plant Growth Regul 30:460–469