Journal of Experimental Agriculture International

Volume 46, Issue 12, Page 205-213, 2024; Article no.JEAI.123702
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

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

Kshitiy V. Vibhute [a*] and Archana R. Mohite [a]

[a] DMCAET Rajmachi, Karad Maharashtra, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jeai/2024/v46i123125

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/123702

Original Research Article

Received: 13/09/2024
Accepted: 17/11/2024
Published: 11/12/2024

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 carried out under 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, Maharashtra, India. Cucumber (*Cucumis sativus*) HY shiny variety was grown in both the environments to evaluate different morphological characteristics such as average leaf count, leaf area, stem diameter, plant height and root length. Dutch bucket system of

**Corresponding author: E-mail: vibhutekshitiy2052@gmail.com;*

Cite as: *Vibhute, Kshitiy V., and Archana R. Mohite. 2024. "Effect of Artificial LED and Natural Light on the Growth of Cucumber Plant (Cucumis Sativus) in Hydroponic System". Journal of Experimental Agriculture International 46 (12):205-13. https://doi.org/10.9734/jeai/2024/v46i123125.*

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. From the present experiment it was observed that, most of the selected parameters were found more satisfactory in artificial light as compared to natural light. Before the flowering stage, average leaf count, average leaf area, average plant height, and average root length was observed approximately 26, 123.15 cm^2, 154 cm, 30.1 cm for artificial light and 22, 56.07 cm^2, 110 cm, 25.3 cm for natural light, respectively. The average stem diameter was observed almost similar in both the systems and it was about 1.1 cm. Therefore, from this study it was envisaged that overall average leaf count, average leaf area, average plant height and average root length was improved in artificial light by 18%, 54%, 28%, and 25%, respectively over natural light.

Keywords: Dutch bucket system; leaf area; morphological; plant height; root length.

1. 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 (Pretty 2020, Wishkerman et al., 2017). 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. 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) (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 (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., 2004) but uses large amount of electricity, low operating life span, and produces heat which leads to scorching or marginal leaf burn in plants. At present, the most used light sources are HPS (*High Pressure Sodium*) lamps. They provide large amount of photosynthetically active radiation (*PAR*), but small amount of blue light (5 %). Blue light affects the efficiency of photosynthesis and plant growth. In contrast to sunlight which provides 18 % blue light (Islam et al., 2012). 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. (Singh et al. 2015)

The aim of this study was to analyses the growth responses of cucumber (*Cucumis sativus*) at different sources of light to analyze the effect of natural light and artificial LED light on cucumber plant in Dutch Bucket System.

2. MATERIALS AND METHODS

2.1 Experimental Setup and Growth Condition

The present study was carried out in the campus of Dadasaheb Mokashi College of Agricultural Engineering and Technology, Rajmachi, Karad, Maharashtra, India. Dutch bucket hydroponic system with indoor setup (artificial light) was established in the Department of Irrigation and Drainage Engineering and another setup was installed in naturally ventilated polyhouse (NVPH), constructed in the farm area of campus.

The main goal in building the structure was to create a hydroponic system that is suitable for urban areas therefore should be compact, low maintenance and cost effective. A system was designed horizontally which allowed single layers of planting areas in a relatively small space. Generally, for a small system which is used for personal or residential purposes, fully automation is not practical due to relatively less plant capacity. Therefore, parameters for plant growth were only monitored and not controlled. As the present study is a part of the undergraduate project with a limited time, cucumber plants for only one season with no replications were monitored to study its morphological characteristics. The specifications of entire Dutch Bucket system are shown in Table 1.

Two Dutch bucket systems were installed in artificial LED light as an indoor setup in laboratory (System1) and other with natural sun light in naturally ventilated polyhouse (System 2). Different materials used in construction of the hydroponic system are specified in Table 1. The buckets selected herein were 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. (George et al., 2016) 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. Cucumber (*Cucumis sativus*) HY shiny variety was grown in both the environments to evaluate different morphological characteristics such as average leaf count, leaf area, stem diameter, plant height and root length. As per (Cammarisano et al., 2022) all the parameters were measured. Initial seedlings of 15 days were transplanted in both environments.

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]

2.2 Light Control

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 power intensities of RBW LEDs were chosen 22 W (Lin et al., 2012). The duration of LED lights was scheduled to 16 hours 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 Slot	Duration (hours)
Daytime without LED light support	8 AM to 4 PM	8
Daytime with LED light support	4 PM to 12 AM	8
Nighttime with LED light support	12 AM to 8 AM	8

Table 3. Different Parameters Maintained in Hydroponic System (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 (Adjusting the light distance)	15,000 – 25,000 lux	LUX Meter
4	Light/Dark Duration in LED	16/8 hours	Digital cyclic timer programmed to switch on and off the lighting.

2.3 Instruments Used

Different parameters maintained during the study are listed in the Table 3 along with its specification and instruments used for its measurement.

3. RESULTS AND DISCUSSION

Measurements of different morphological characteristics such as average leaf count, leaf area, stem diameter, plant height and root length (at the time of harvesting) were carried out to track the performance of cucumber plant and its nutrition intake in the hydroponic unit throughout the experiment duration. Duration of germination and complete vegetative growth observed is mentioned in Table 4. Here it is noted to be that in following results growth period after transplantation of seedlings in hydronic system is considered.

Table 4. Growth stages of cucumber plant

Stage	Duration
Germination stage	07 Days
Vegetative growth	60 Days

Results for the selected parameters are given in detail as follows.

3.1 Average Number of Leaves

The number of leaves per plants differed significantly between the two systems. Data collected for both the environments is shown in Table 5 and Fig. 3 shows the graph of effect of natural sun light and artificial LED light on average leaf count. The leaf count was done with the interval of every 5 days. It was observed from the result that average leaf count before the flowering stage was improved by 18% in artificial light over natural light.

Table 5. Average number of leaves of plant in artificial LED and natural light

Period	Average leaf count	
	Artificial LED light	Natural Sun light
Day 10	0	0
Day 15	3	2
Day 20	10	6
Day 25	13	9
Day 30	17	11
Day 35	20	14
Day 40	22	19
Day 45	26	22

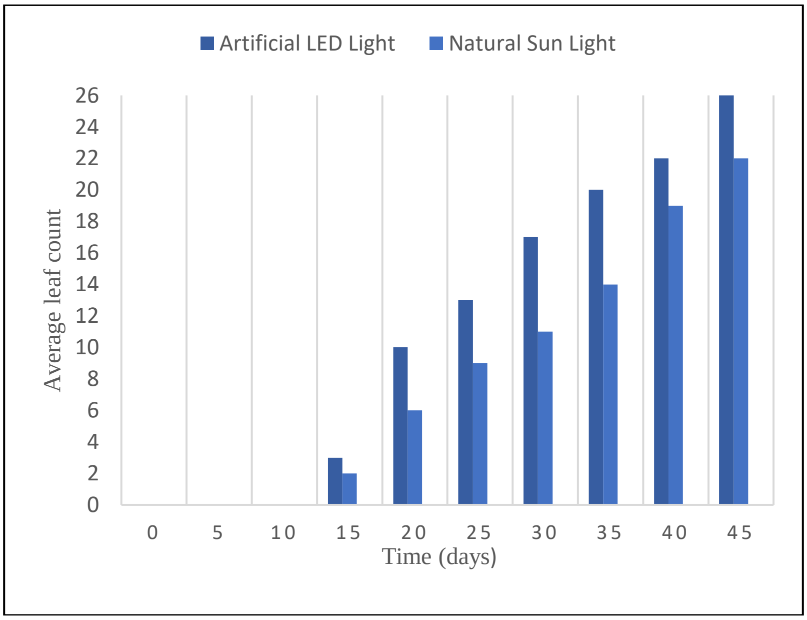

Fig. 3. Effect of natural sun light and artificial LED light on average leaf count

3.2 Average Leaf area

The average leaf area of cucumber plants before flowering stage in artificial light was observed 123.15 cm^2 and that of natural light was 56.07 cm^2 as shown in Fig. 4. This shows about 54% growth improvement over natural light.

3.3 Average Plant Height

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 6. Fig. 5 Shows the average height difference of plants.

3.4 Stem Diameter

The stem diameter was measured on 45^{th} day after establishment of cucumber plant in hydroponic system. The average diameter of stem in natural light and artificial LED light was observed almost similar, i.e. 1.1 cm. That means stem diameter of cucumber seedlings was not affected by different light source. Table 7 consists of stem diameter of all the plant in artificial LED and natural light and Fig. 6 shows the average stem diameter of plants in natural sun light and artificial LED light.

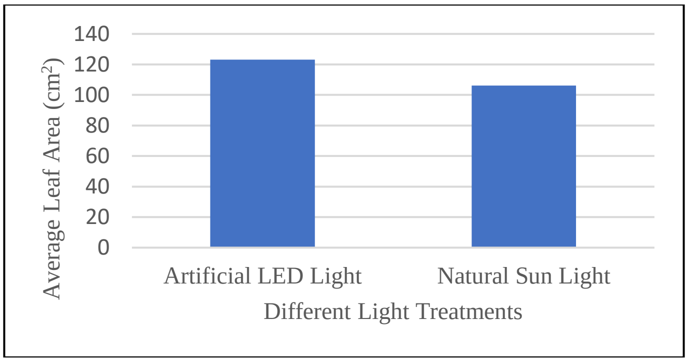

Fig. 4. Effect of natural sun light and artificial LED light on average leaf area

Table 6. Average height of cucumber plants under 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

Table 7. Stem diameter of cucumber plant in artificial LED and natural light

Plant Number	Stem Diameter (cm)	
	Artificial LED light	Natural Sun light
Plant 1	1.1	1.2
Plant 2	1.1	0.9
Plant 3	1.2	1.3
Plant 4	1.3	1.1
Plant 5	1.0	1.2
Plant 6	0.9	1.0
Plant 7	1.1	0.9
Plant 8	1.1	1.2
Plant 9	1.0	1.1
Plant 10	1.2	1.1

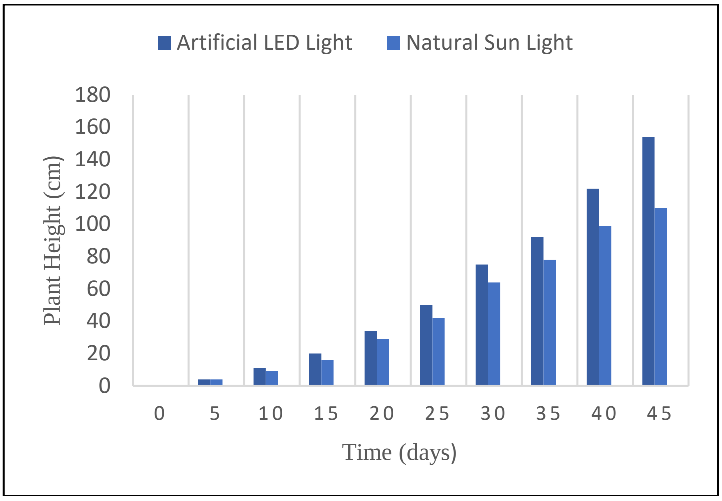

Fig. 5. Average plant height of cucumber plant under natural sun light and artificial LED light.

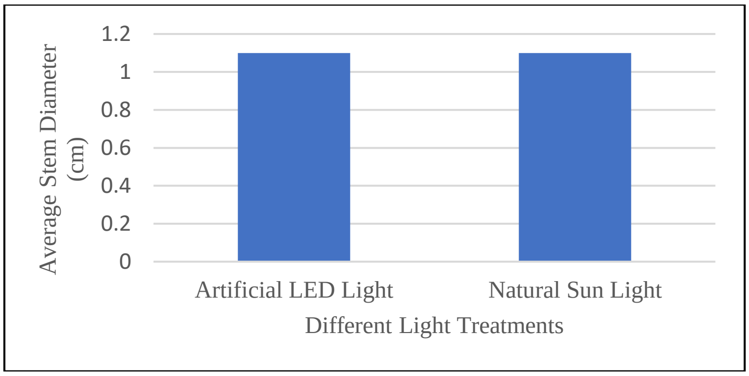

Fig. 6. Effect of artificial LED light and natural sun light on stem diameter

3.5 Root Length

On the harvesting day the average length of roots of the plant arrayed with artificial LEDs and natural sunlight are shown in Table 8. 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 as shown in Fig. 7(Rehman et al., 2017 and Chua et al., 2020).

Table 8. Root length of cucumber plant under natural light and artificial LED light 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

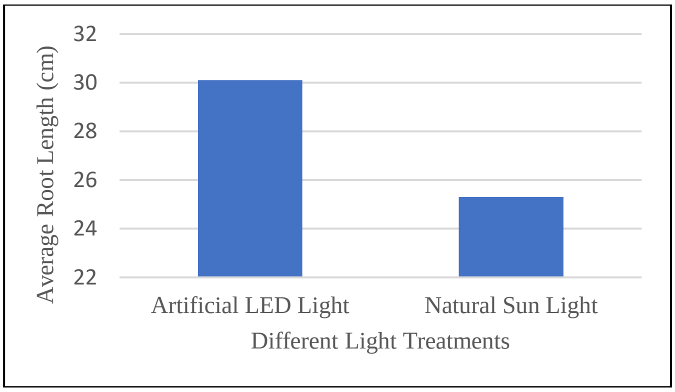

Fig. 7. Effect of natural sun light and artificial LED light on average root length

4. CONCLUSION

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). From the present experiment it was concluded that, from transplant to the flowering stage all the five selected parameters (except stem diameter) were found more satisfactory in artificial light as compared to natural light. Before the flowering stage of the experiment average leaf count, average leaf area, average plant height and average root length was observed approximately 26, 123.15 cm^2, 154 cm and 30.1 cm for artificial light and 22, 56.07 cm^2, 110 cm and 25.3 cm for natural light, respectively. Therefore, from this study it was envisaged that overall average leaf count, average leaf area, average plant height and average root length was improved in artificial light by 18%, 54%, 28%, and 25%, respectively over natural light. Stem diameter of cucumber plant didn't show any change due to either artificial or 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.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Cammarisano, L., Graefe, J., & Korner, Ö. (2022). Using leaf spectroscopy and pigment estimation to monitor indoor grown lettuce dynamic response to spectral light intensity. *Frontiers in Plant Science, 13*, 821832.

Chua, H. S., Lai, S. W., Paramasivam, S., Goh, T. T., & Chen, G. C. (2020). Effect of artificial night lighting on the growth of loose head lettuce in hydroponic system. *Sains Malaysiana, 49*(12), 2891-2900.

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*(4), 448-452.

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.

George, P., & George, N. (2016). Hydroponics (soilless cultivation of plants) for biodiversity conservation. *International Journal of Modern Trends in Engineering and Science, 3*(6), 97-104.

Islam, M. A., Kuwar, G., Liu Clarke, J., Blystad, D.-R., Gislerod, H. R., Olsen, J. E., & Torre, S. (2012). Artificial light from light-emitting diodes (LEDs) with high portion of blue light results in shorter poinsettias compared to high pressure sodium (HPS) lamps. *Scientia Horticulturae, 144*, 97-102.

Kim, H.-H., Goins, G. D., Wheeler, R. M., & Sager, J. C. (2004). Green-light supplementation for enhanced lettuce growth under red and blue light emitting diodes. *HortScience, 39*(7), 1617-1622.

Lin, K.-H., Huang, M.-Y., Huang, W.-D., Hsu, M.-H., Yang, Z.-W., & Yang, C.-M. (2012). 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.

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.

Pretty, J. (2020). New opportunities for the redesign of agricultural and food systems. *Agriculture and Human Values, 37*(1), 27-49.

Rehman, M., Ullah, S., Bao, Y., Wang, B., Peng, D., & Liu, L. (2017). Light-emitting diodes: Whether an efficient source of light for indoor plants? *Environmental Science and Pollution Research, 24*, 24743-24752.

Singh, D., Basu, C., Meinhardt-Wollweber, M., & Roth, B. (2015). LEDs for energy efficient greenhouse lighting. *Renewable and Sustainable Energy Reviews, 49*, 139-147.

Wishkerman, A., & Wishkerman, E. (2017). Application note: A novel low-cost open-source LED system for microalgae cultivation. *Computers and Electronics in Agriculture, 132*, 56-62.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/123702