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ORIGINAL ARTICLE

Impact of Artificial Light and Albert Fertilizer on Growth, Yield, and Economic Viability of Salad Cucumber under Controlled Conditions

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Abstract

An experiment was conducted in two protected houses to evaluate growth, yield, and economic feasibility of salad cucumber cultivation, influenced by artificial light and varying rates of Albert fertilizer. The experiment was conducted using a two-factor factorial (2 x 2) completely randomized design with five replicates. The two tested factors were presence of artificial light (with and without) and the fertilizer rate (1.5 g and 2.0 g per plant per day). Growth and yield parameters were measured, and collected data were analysed using analysis of variance. Subsequently, means were separated using the least significant difference (LSD) at 5% probability level. The cost-benefit ratio was used to evaluate the economic feasibility. According to the results, significantly higher ($p \leq 0.05$) vine length, number of leaves per vine and leaf chlorophyll content were observed at the 1.5 g per plant per day with artificial lights. Additionally, significantly higher ($p \leq 0.05$) fresh fruit weight per vine, number of fruits per vine, and leaf area of the 21st leaf were recorded at the fertilizer rate of 1.5 g per plant per day and with artificial lights. In conclusion, application of Albert fertilizer at the rate of 1.5 g per plant per day with artificial light is the most effective treatment. Moreover, the cultivation of salad cucumber with artificial lights is economically viable when farmers use their own labour.

***Keywords**: Albert fertilizer, artificial lights, protected house, Salad cucumber*

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1. Introduction

The concept of maximizing sustainable yield per unit area has been the primary focus of agriculture over the past few decades, driven by an expanding global population and shrinking arable land caused by various biotic and abiotic pressures on crops. By 2050, it is predicted that almost two-thirds of the world's population will reside in cities, further decreasing arable lands for crop cultivation by one-third. Farmers are, therefore, under pressure to enhance productivity and adopt more environmentally sustainable alternative agricultural strategies.

Protected agriculture emerges as a technologically and economically feasible solution, enabling farmers to optimize the use of agricultural inputs and revenues by manipulating micro-climatic parameters such as temperature, humidity, CO_2 concentration, and light intensity. This approach creates an environment conducive to plant growth and can produce 5–10 times higher yields compared to its open-field cultivation (Rabbi et al. 2019).

Light is a crucial factor affecting various phases of plant growth and development (Wang et al. 2021). As a source of energy for photosynthesis, light plays a vital role in regulating chloroplast formation and enzymatic activities, which directly impact the overall photosynthetic efficiency of plants (Xie et al. 2015). Low light levels significantly impair vegetable production as they fail to meet the requirements of photosynthetic capacity (Ji et al. 2020; Wang et al. 2021), thereby limiting crop production. Supplementary lighting has been shown to improve the vegetable yields and quality, as confirmed by Hamedalla et al (2022).

However, supplementary light sources must possess spectral qualities that satisfy plants' physiological needs for photosynthesis. Light-emitting diodes (LEDs) are considered ideal, offering advantages such as durability, versatility, and energy efficiency. According to Wang et al (2021), LED lighting can be adjusted for photoperiod, light quality, and intensity to align with individual crop requirements. Consequently, most plant species can achieve their full growth potential under LED lighting, positioning LEDs as the optimal supplementary light source for greenhouses.

As stated by Zakurin et al (2020), each element of the visible spectrum plays an essential and unique role in the healthy development of plants. Thus, the primary artificial light source should be white light. Recently developed sun-like LEDs closely mimic the solar spectrum within the range of photosynthetically active radiation (400–700 nm) (Zakurin et al. 2020).

According to Brazaitytė et al (2009), cucumber is one of the most commercially significant crops grown in protected houses. Cucumbers are a valuable crop, cultivated in over 80 countries worldwide (Hamedalla et al. 2022). In Sri Lanka, cucumbers are widely cultivated by farmers to meet both domestic and international markets demand (Kumara et al. 2015). Xie et al (2015) stated that cucumber plants are highly susceptible to stress caused by low light levels, particularly during cloudy and rainy weather. Consequently, artificial light sources are essential to enhance the growth and photosynthetic efficiency of cucumber plants (Xie et al. 2015). Therefore, in protected agriculture, artificial light supplementation may help to maximise the potential yield of salad cucumber.

In Sri Lankan protected agriculture, hydroponics fertilizers are often applied indiscriminately, without considering the specific nutrient requirements of the crop or variety. Therefore, it is crucial to ascertain the nutrient requirements of each crop species to prevent potential toxicities resulting from over-fertilization (Samarakoon et al. 2006). Knowledge regarding cost-effectiveness, ideal fertilization patterns and the effect of light intensity on growth and yield of salad cucumbers cultivated under controlled environmental conditions remains limited. Therefore, it is essential to assess the growth and yield performances of salad cucumber under varying fertilization patterns and artificial light supplementation. The present study aims to examine the economic viability and effect of artificial lights combined with hydroponics fertilizer application rates, namely Albert fertilizer, on the growth and yield performances of salad cucumber cultivated in controlled environmental conditions.

2. Materials and Methods

The present study was conducted in two protected houses at the Faculty of Agriculture, University of Ruhuna, Sri Lanka, where salad cucumbers were grown hydroponically using fertilizer rates previously identified as optimal for the crop (Perera et al. 2022). Two optimized fertilizer rates for crop growth and yield were tested with and without artificial light supplementation. The experiment was laid-out in a two-factor factorial completely randomized design (CRD), with five replicates. The two tested factors were artificial light (L_0: without artificial lights; L_1: with artificial lights) and the rate of Albert fertilizer (R_1: 1.5 g per plant per day; R_2: 2.0 g per plant per day). Treatments were applied daily.

White-coloured light-emitting diodes (LEDs, 60 W) were used for artificial light supplementation, placed 30 cm above the crop canopy. The LEDs were automated to turn on whenever the lux level inside the protected house fell below 3000 lux between 6:00 a.m. to 6:00 p.m., and turned off when the lux level rose above 3000 lux during the same period. Hence, a minimum lux level of 3000 was maintained inside the protected house using an IoT-based automation system. During the nighttime from (6:00 p.m. to 6:00 a.m.), no artificial light was supplied to support the dark reaction phase of photosynthesis. Artificial lights were installed in one protected house to maintain two different light environments, while each fertilizer treatment was applied to separate plots in both greenhouses.

Following a seven-day nursery phase, salad cucumber (variety: Efdal F1) seedlings were cultivated in coir grow bags, with one plant per bag. They were positioned 61 cm x 61 cm (2 x 2 ft^2) apart on the protected house floor (DOA, 2022). Plants were treated with two rates of Albert fertilizer solutions, prepared and administered once daily. Each plant received 200 ml of Albert fertilizer solution every day, with 1.5 g and 2.0 g concentrations applied as designated in two treatments. Following fertilizer treatment, plants were irrigated at a rate of one litre per day in three 200–400 ml splits at 3-hour intervals between 8:00 a.m. and 2:00 p.m.

Disease and pest management was carried out in accordance with the guidelines of the Department of Agriculture (DOA, 2022). Tendrils were routinely pruned, and old and damaged leaves, as well as aborted and malformed fruits were removed. Salad cucumber plants were trained weekly. According to worldwide export market standards, salad cucumber fruits were harvested when their center diameter reached 30 mm (Seminis Grow Forward, 2018).

Weekly measurements of vine length and leaf count per vine were used to evaluate crop growth. Additional measurements were taken of the internode lengths of the 7th, 14th and 21st internodes, the leaf area of the 7th, 14th and 21st leaves, and the chlorophyll content of the 21st leaf using SPAD meter readings. Yield parameters included the number of days to first flowering, fresh fruit weight, fruit length and number of fruits. This study was repeated in the same protected houses to verify the consistency of results.

Collected data from two experiments were statistically analysed using analysis of variance (ANOVA) with Statistical Analysis System (SAS) version 9.1.3, separately. The Least Significant Difference Test (LSD) at 5% probability level was used to compare significant means. Levene's Test was performed to assess variation among replicated values of both experiments using the Statistical Package for Social Sciences (SPSS) version 25. Based on the results of the Levene's Test, the original replicated values from both experiments were averaged and reanalysed using ANOVA in SAS version 9.1.3. The means were then extracted at a 5% probability level using the Least Significant Difference Test (LSD).

The economic feasibility of the study was evaluated using the cost-benefit ratio. Variable costs and revenue of the two protected houses were calculated and averaged independently for both studies. The average revenue and variable cost data were converted to per square meter by dividing them by the cultivated area. Excluding fixed asset depreciation costs (i.e., water pump, irrigation system, protected house), labour, agricultural inputs, and utility costs were considered variable costs. Revenue was defined as the income generated from the harvest, which was then divided by the total variable cost to determine the cost-benefit ratio.

The prices listed in Section 84 of the National Water Supply and Drainage Board Law No. 02 of 1974 were used to determine the cost of water (The Gazette of the Democratic Socialist Republic of Sri Lanka, 2022). The cost for electricity was based on the tariff rates outlined by the Public Utilities Commission of Sri Lanka (Public Utilities Commission of Sri Lanka, n.d.). The horsepower rating of the water pump in the drip irrigation system was converted into kilowatt-hours to calculate the electricity costs for irrigation.

According to data from the IoT-based automation system, artificial lights were activated for a total of four hours daily between 6:00 a.m. to 6:00 p.m., and electricity costs were calculated accordingly. The cost for labour was calculated based on wages at research farm of Faculty of Agriculture, University of Ruhuna. The Narahenpita Economic Centre provided the average wholesale price for one kilogram of salad cucumber during the study period (Naveen H. G., personal communication, 30.04.2023), which was LKR 315.00. The data was assessed using basic statistical methods as averages, ratios, and percentages.

3. Results and Discussion

3.1 Vine Length

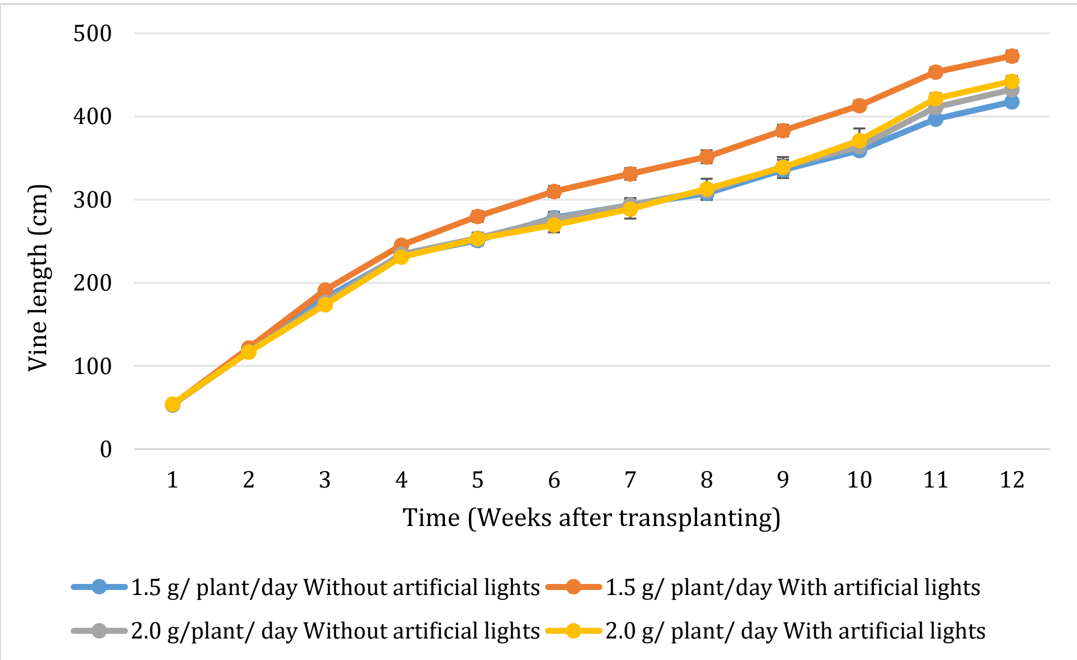

Figure 1: Vine length of salad

cucumber plants at different weeks after transplanting as affected by fertilizer rate and artificial lighting

Salad cucumber vine length varied significantly with the interaction of artificial lights and rate of fertilizer ($P \leq 0.05$). The highest vine length was observed with the 1.5 g per plant per day of Albert fertilizer with artificial lights (Fig. 1), starting from the third week after transplanting. This result aligns with the findings of Wang et al (2021), who reported greater vine elongation with three hours of light supplementation compared to the control treatment (no light supplementation). The growth of cucumber seedlings was significantly enhanced by additional light exposure (Wang et al. 2021). According to Dyśko and Kaniszewski (2021), artificial lighting resulted substantially taller salad cucumber plants and further stated insufficient light significantly inhibits plant growth.

Furthermore, the overuse of chemical and organic fertilizers is a global concern due to the lack of scientifically standardized application guidelines. This often leads to environmental pollution and adverse effects on crop health. Hence, for high-efficiency cucumber production, balanced nutrient management using optimized fertilizer techniques is crucial (Li et al. 2023). Therefore, the 1.5 g per plant per day Albert fertilizer rate is most suitable, as it resulted in greater vine length compared to 2.0 g per plant per day rate.

3.2 Number of Leaves per Vine

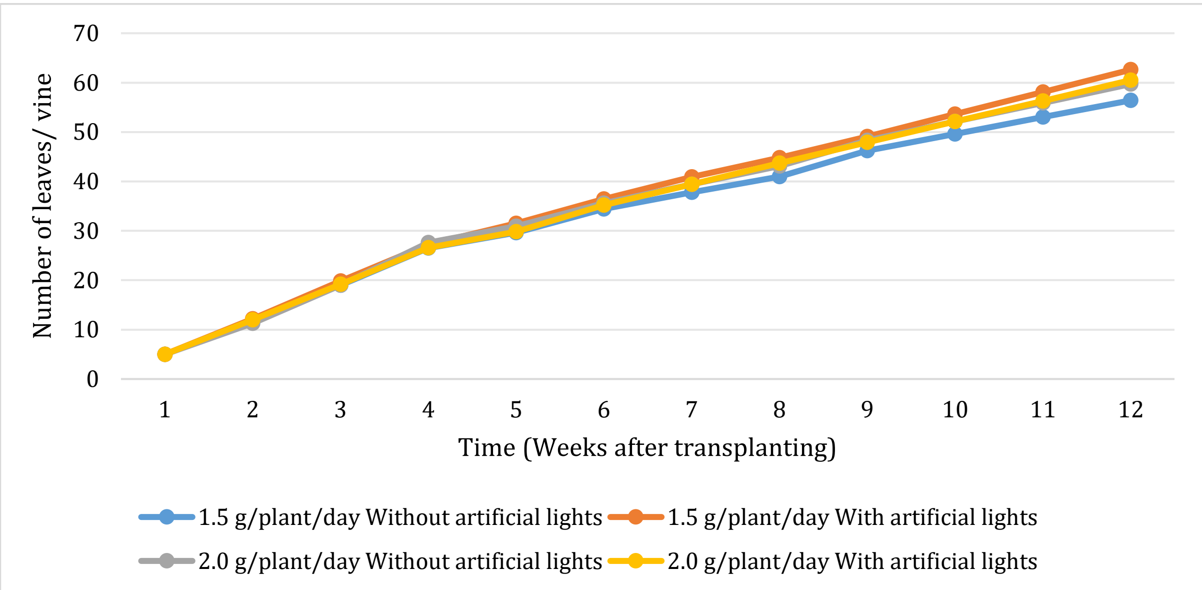

Figure 2: Number of leaves of salad cucumber plants at different weeks after transplanting as affected by fertilizer rate and artificial lighting

Artificial lighting and fertilizer rate significantly interact to influence the number of leaves per salad cucumber vine ($P < 0.05$). The highest leaf count per vine was observed in plants treated with the 1.5 g per plant per day of Albert fertilizer combined with artificial lighting (Fig. 2) from the 6th week after transplanting. Solar radiation is the primary environmental factor regulating photosynthesis, plant survival, growth, and adaptability (Zervoudakis et al. 2012). Insufficient light conditions can substantially slow down plant growth and development. Dorais (2003) reported that supplemental lighting enhances the vegetative growth of salad cucumber plants, including leaf number Additionally, Dyśko and Kaniszewski (2021) found that supplementary lighting in salad cucumber cultivation greatly influenced plant development and further reported that control plants without supplementary lighting produced significantly fewer leaves.

Table 1: Growth and yield parameters of salad cucumber plants as affected by artificial lighting

Parameter	**Without artificial lights**	**With artificial lights**
Length of 21st Internode	3.2182^{A}	2.7343^{B}
Leaf Area (7th Leaf)	556.62^{B}	648.30^{A}
Leaf Area (14th Leaf)	521.26^{B}	674.49^{A}
Leaf Area (21st Leaf)	304.89^{B}	409.21^{A}
Fresh Weight of Fruits per Vine	3.67^{B}	4.40^{A}
Number of Fruits per Vine	29.10^{B}	33.65^{A}

Mean values designated by the same letter are not significantly different at 5% probability level.

Table 2: Growth and yield parameters of salad cucumber plants as affected by fertilizer rate

Parameter	**1.5 g per plant per day**	**2.0 g per plant per day**
Leaf Area (21st Leaf)	392.92^{A}	321.18^{B}
Number of Days Taken for First Flowering	24.25^{A}	22.10^{B}
Fresh Weight of Fruits per Vine	4.36^{A}	3.71^{B}
Number of Fruits per Vine	34.55^{A}	28.20^{B}

Mean values designated by the same letter are not significantly different at 5% probability level.

3.3 Length of Internodes

There was no significant interaction or main factor effect ($P \geq 0.05$) on the length of the 7th and 14th internodes. However, the length of the 21st internode was significantly influenced ($P \leq 0.05$) by artificial lighting. In the absence artificial lighting, the 21st internode recorded the highest length (Table 1). Treatments had no significant effect on the 7th and 14th internodes, as the plants were still immature and had not yet adapted to the treatments. However, by the time the 21st internode was developing, plants had sufficient time to adjust to the applied treatments.

In the present study, salad cucumber plants grown without artificial lighting exhibited significantly longer 21st internodes. This elongation may have resulted from plants attempting to absorb more light energy under low light conditions. According to Cross and Ruiter (2021), longer internodes are an indicative sign of low light levels. If internode length is shorter and the vine length is longer, more leaves and fruits can be developed per unit length of vine. Therefore, salad cucumber plants exposed to artificial lighting can produce more leaves and fruits per unit of vine length, indicating a higher potential yield.

3.4 Leaf Area

The leaf area of the 21st leaf was significantly larger ($P \leq 0.05$) under both artificial lighting and fertilizer rate treatments independently. The 21st leaf exhibited a significantly higher leaf area when treated with Albert fertilizer at a rate of 1.5 g per plant per day and supplemented with artificial lighting (Table 1 and 2).

However, only artificial lighting had a significant impact ($P < 0.05$) on the leaf area of the 7th and 14th leaves (Table 1); while fertilizer application rate had no measurable impact. This may be due to the young leaves not having sufficient time to respond to treatments. According to Aydin et al (2015), plants exposed to artificial lighting developed the largest leaf area, while those without artificial lighting recoded significantly smaller leaf area. Similarly, Sallam et al (2021) reported that greater leaf area enhances light interception. They also recorded that fertilizer application significantly affected leaf area of cucumber plants.

Furthermore, Sallam et al (2021) highlighted that the excessive use of inorganic fertilizers to maximize yields has had negative effect on human health and the environment in recent years. Thus, optimizing fertilizer application rates to ensure a balanced nutrient supply would be highly beneficial. Additionally, a larger leaf area is essential for optimal light absorption, which enhances photosynthesis and increases assimilate translocation to the storage organs, ultimately improving crop yield and productivity (Sallam et al. 2021).

3.5 SPAD Reading

Table 3: Chlorophyll content of salad cucumber leaves as affected by fertilizer rate and artificial lighting

Treatment Combination	Mean values
1.5 g per plant per day without artificial lighting	43.6
1.5 g/plant/day with artificial lighting	54.40
2.0 g/plant/day without artificial lighting	49.01
2.0 g/plant/day with artificial lighting	49.52

Chlorophyll content in salad cucumber leaves exhibited a significant interaction effect ($P \leq 0.05$) between artificial lighting and fertilizer rate. The highest chlorophyll content was observed in plants treated with the 1.5 g per plant per day of fertilizer combined with artificial lighting (Table 3). Chlorophyll content in leaves serves as a crucial indicator of plant nutritional status. In the present study, the 1.5 g per plant per day fertilizer rate recorded higher chlorophyll content, suggesting that this amount may be optimal for maximizing chlorophyll levels with artificial lights.

According to Jones-Baumgardt et al (2019), higher nitrogen levels under increased light intensity usually lead to higher photosynthetic rates. Additionally, Gajc-Wolska et al (2021) reported that cucumber plants grown under LED lighting exhibited higher chlorophyll contents in their leaves. Similarly, Yang et al (2022) found that cucumber leaves subjected to longer photoperiods contained higher levels of carotenoid and chlorophyll compared to those exposed to shorter photoperiods. This study also showed that extending the photoperiod from 7 to 16 hours per day increased pigment content in cucumber seedlings.

Furthermore, Ajdanian et al (2020) reported that cress (*Lepidium sativum*) plants grown in natural light exhibited the lowest chlorophyll index, whereas plants cultivated with a combination of red and blue LED lights at varying ratios had significantly higher chlorophyll index. Thus, blended LED lighting offers considerable benefits for various commercial greenhouse crops, especially high-value cash crops.

Moreover, Wang et al (2021) investigated photosynthetic pigment levels in cucumber leaves under varying durations of red and blue LED light supplementation. One hour of red and blue LED exposure significantly increased carotenoid content compared to the control treatment (no additional light). Two hours of LED exposure markedly improved total chlorophyll, carotenoids, and chlorophyll A levels compared to the control group. Additionally, three hours of artificial lighting significantly enhanced chlorophyll and carotenoid concentrations in cucumber leaves. As a result, their study suggested that increasing photosynthetic pigment content in cucumber leaves can be achieved by introducing LED lighting.

3.6 Number of Days Taken for First Flowering

The number of days required for first flowering was significantly influenced solely by fertilizer rate. Compared to 1.5 g per plant per day, the fertilizer rate of 2.0 g per plant per day resulted in a considerably shorter ($P < 0.05$) flower initiation period (Table 2). This can be attributed to rapid reaching to reproductive development stage due to the higher nutrient availability from the fertilizer treatment. Yang et al (2022) reported that cucumber is a day-neutral plant that induces flowers independent of day length. Cross and Ruiter (2021) also stated that cucumbers are day-neutral plants or photoperiod indeterminate plants which means that they do not require short- or long-day photoperiods for flower induction. Therefore, cucumber plants flower year-round, irrespective of day and night length, explaining why flower initiation was not significantly affected by artificial lighting, even though, artificial lighting was supplied to enhance the photoperiod.

3.7 Fresh Weight of Fruits per Vine

There was no interaction effect between fertilizer rate and artificial lighting on fresh fruit weight per vine. However, fresh fruit weight was significantly affected by fertilizer rate and artificial lighting independently. The 1.5 g per plant per day fertilizer rate combined with artificial lighting recorded significantly higher ($P \leq 0.05$) fresh fruit weight per vine (Table 1 and 2). This result aligns with previous studies on artificial light supplementation for salad cucumbers. Dorais (2003) stated that supplemental lighting increases the relative fruit growth rate and biomass of vegetable crops. As cited by Dorais (2003), Blain *et al*. (1987) reported a 70–80% increase in cucumber yield under supplemental lighting compared to natural lighting.

Furthermore, Marcelis (1994) stated that higher light levels enhanced dry matter allocation to cucumber fruits. Turcotte and Gosselin (1989) stated that supplemental lighting at 200 µmol m^{-2} s^{-1} increased net photosynthesis of greenhouse cucumber when natural light levels were below 280 µmol m^{-2} s^{-1}. Insufficient sunlight reduces the quality of cucumber seedlings, thereby negatively impacting the quantity and nutritional content of cucumbers (Ji et al. 2020).

When considering fertilizer rates, 1.5 g of Albert fertilizer per plant per day significantly enhanced salad cucumber yield compared to 2.0 g of Albert fertilizer per plant per day. Chand (2014) found that applying the 100% recommended dose of NPK fertigation resulted in significantly greater yield (89.06 t ha^{-1}) and higher nutrient usage efficiency for nitrogen, phosphorous and potassium (508.93, 712.50, and 296.88 kg ha^{-1}, respectively) compared to110%, 100%, 90% and 80% of the recommended dose. Hence, the highest NPK fertilizer rates do not translate into higher yields. Additionally, Wang et al (2023) highlighted that over-fertilization hampers sustainable greenhouse vegetable production and leads various planting challenges. Excessive usage of chemical fertilizers has created a number of planting obstacles in recent years. Therefore, under artificial light supplementation, 2.0 g of Albert fertilizer per plant per day treatment may have resulted a nutrient imbalance and the optimal fertilizer rate for maximizing salad cucumber yield is 1.5 g of Albert fertilizer per plant per day.

3.8 Number of Fruits per Vine

The number of fruits per vine was significantly influenced by fertilizer rate and artificial lighting independently. The 1.5 g per plant per day and artificial lighting treatments each recorded a significantly higher ($P \leq 0.05$) number of fruits per vine (Table 1 and 2). This result aligns with earlier studies that demonstrated salad cucumber yields increase when artificial light supplementation is applied in areas with insufficient natural light. Dorais (2003) stated that a greater number of cucumber fruits can be harvested under supplemental light conditions.

Furthermore, Gajc-Wolska et al (2021) documented maximum marketable cucumber production from plants illuminated by LED lights throughout the entire crop cycle. Consequently, artificial lighting is clearly beneficial for increasing salad cucumber fruit yield.

Similar to fresh fruit weight, the 1.5 g per plant per day fertilizer rate produced significantly more fruits compared to 2.0 g per plant per day treatment. This may be due to a nutrient imbalance under artificial light conditions, caused by the 2.0 g of Albert fertilizer per plant day rate. Earlier studies have shown that over-fertilization may hinder sustainable greenhouse vegetable production (Wang et al. 2023). Therefore, the optimal fertilizer rate for maximizing salad cucumber fruit yield is 1.5 g of Albert fertilizer per plant per day.

3.9 Length of Fruits

There was no interaction effect ($P \geqslant 0.05$) between fertilizer rate and artificial lighting on the length of salad cucumber fruits. Additionally, fruit length was not significantly affected ($P \geq 0.05$) by either factor independently. The size and shape of salad cucumber fruits vary depending on the cultivar (Chemicals 2014). Therefore, the applied treatments had no measurable impact on fruit length.

3.10 Cost - Benefit Ratio

According to Table 4 and 6 that the total variable cost of growing salad cucumbers per square meter with and without artificial lighting was LKR 1662.16. and LKR 1311.94, respectively, when labour costs were excluded. When labour costs were considered, the variable costs were LKR 3182.43 with artificial lighting and LKR 2832.21 without artificial lighting.

The highest variable cost in both cultivations (with and without artificial lighting) was labour, accounting for 53.67% and 47.77%, respectively. The second-highest variable cost was Albert solution, which accounted for 15.02% of costs with artificial lighting and 13.37% without artificial lighting. The third-highest variable cost in salad cucumber cultivation without artificial lighting was the cost of seedlings, accounting for 8.58% of the total variable cost. However, in cultivation with artificial lighting, the third-highest variable cost was the cost of electricity, accounting for 11.74%.

According to table 5 and 7, the net return per square meter of salad cucumber cultivation without artificial lighting was LKR 1842.32 while cultivation with artificial lighting resulted a net return of LKR 2144.08.

The cost-benefit ratios for cultivating salad cucumbers per unit area of land were 1.40 without artificial lighting (Table 5) and 1.28 with artificial lighting (Table 7), when labour costs were excluded. Additionally, the cost-benefit ratios for salad cucumber cultivation per unit area were 0.65 and 0.67, with and without artificial lighting, respectively, when labour costs were included.

These results suggest that salad cucumber cultivation with artificial lights is less economical than cultivation without artificial lights, primarily due to the cost of electricity, when labour costs were excluded. However, artificial light supplementation enhances cucumber yield, potentially offsetting higher operational costs. Therefore, introducing renewable energy solutions such as solar-powered artificial lighting could reduce electricity costs, ultimately improving the economic viability of salad cucumber cultivation with artificial lighting.

Table 4: Cost of salad cucumber cultivation without artificial lighting

Cost Item		Quantity	Unit Price (LKR)	Value (LKR)
Seedlings		20	90.00	1800.00
Grow bags		20 grow bags x LKR 125.00 = LKR 2500.00 LKR 2500.00 x 1/4* = LKR 625.00	125.00	625.00
Plant training thread roll		250 m	1000.00 (for 1 km)	250.00
Fertilizer	Albert solution	35 g/ day x 90 days = 3.15 kg	1000.00	3150.00
	Crop Master			
	Nitrabor	100 ml	115.00	115.00
	30:10:10	500 g	100.00	100.00
	10:52:10	250 g	285.00	285.00
	$MgSO_4$	250 g	285.00	285.00
	Captan	500 g	100.00	100.00
Fungicides	Mancozeb	50 g	240.00	240.00
	Amistar	100 g	500.00	500.00
		50 ml	600.00	600.00
	K44			
Foliar	Calmax	100 g	100.00	100.00
sprays		200 ml	300.00	300.00
Water	25 l/ day x 30 days = 750 l + service charge (LKR 300.00 per month)** = LKR 61.50 + LKR 300.00 = LKR 361.50 For 3 months = LKR 361.50 x 3 = LKR 1084.50		82.00 (for 1000 l)**	1084.50
Electricity	0.3728 kWh/ day x 30 days + fixed charge (LKR 30.00 per month)***		2.50 (from 0–30 kWh)***	173.88
Labour	LKR 125.00 x 1 hr/ day x 90 days		125.00 (for 1 labour hour)	11250.00

Total variable cost (Excluding labour cost)	9708.38
Total variable cost per square meter (Excluding labour cost)	1311.94
Total variable cost (Including labour cost)	20958.38
Total variable cost per square meter (Including labour cost)	2832.21

*One grow bag can be used for four crop cycles (Unpublished data). Therefore, 1/4 cost of grow bags was considered.
**The Gazette of the Democratic Socialist Republic of Sri Lanka (2022)
***Public Utilities Commission of Sri Lanka (n.d.)

Table 5: Net return per square meter of salad cucumber cultivation without artificial lighting

Benefit Item	Quantity (kg)	Average Unit Price (LKR)	Value (LKR)
Harvest	43.28	315.00	13633.20
Total return			13633.20
Total return per square meter			1842.32

Cost - Benefit Ratio (Excluding labour cost) = Benefits / Costs
= 1842.32 / 1311.94
= 1.40

Cost - Benefit Ratio (Including labour cost) = Benefits / Costs
= 1842.32 / 2832.21
= 0.65

Table 6: Cost of salad cucumber cultivation with artificial lighting

Cost Item	Quantity	Unit Price (LKR)	Value (LKR)
Seedlings	20	90.00	1800.00
Grow bags	20 grow bags x LKR 125.00 = LKR 2500.00 LKR 2500.00 x 1/4* = LKR 625.00	125.00	625.00
Plant training thread roll	250 m	1000.00	250.00

			(for 1km)	
Fertilizer	Albert solution	35 g/ day x 90 days = 3.15 kg	1000.00	3150.00
	Crop Master			
	Nitrabor	100 ml	115.00	115.00
	30:10:10	500 g	100.00	100.00
	10:52:10	250 g	285.00	285.00
	$MgSO_4$	250 g	285.00	285.00
		500 g	100.00	100.00
	Captan			
Fungicides	Mancozeb	50 g	240.00	240.00
	Amistar	100 g	500.00	500.00
		50 ml	600.00	600.00
	K44			
Foliar sprays	Calmax	100 g	100.00	100.00
		200 ml	300.00	300.00
Water		25 l/ day x 30 days = 750 l + service charge (LKR 300.00 per month)** = LKR 61.50 + LKR 300.00 = LKR 361.50 For 3 months = LKR 361.50 x 3 = LKR 1084.50	82.00 (for 1000 l)**	1084.50
Electricity for irrigation system		0.3728 kWh/ day x 30 days = 11.184 kWh		
Electricity for light system		60 W bulb x 10 bulbs x 4hrs/ day = 2.4 kWh/ day 2.4 kWh/ day x 30 days = 72 kWh		
Total electricity cost		11.184 kWh + 72 kWh = 83.184 kWh + fixed charge (LKR 90.00 per month)*** = LKR 921.84 For 3 months = LKR 921.84 x 3 = LKR 2765.52	10.00 (from 61-90 kWh)***	2765.52
Labour		LKR 125.00 x 1 hr/ day x 90 days	125.00 (for 1 labour hour)	11250.00
Total variable cost (Excluding labour cost)				12300.02
Total variable cost per square meter (Excluding labour cost)				1662.16
Total variable cost (Including labour cost)				23550.02
Total variable cost per square meter (Including labour cost)				3182.43

*One grow bag can be used for four crop cycles (Unpublished data). Therefore, 1/4 cost of grow bags was considered.
**The Gazette of the Democratic Socialist Republic of Sri Lanka (2022)
***Public Utilities Commission of Sri Lanka (n.d.)

Table 7: Net return per square meter of salad cucumber cultivation with artificial lights

Benefit Item	Quantity (kg)	Average Unit Price (LKR)	Value (LKR)
Harvest	50.369	315.00	15866.24
Total return			15866.24
Total return per square meter			2144.08

Cost - Benefit Ratio (Excluding labour cost) = Benefits / Costs
= 2144.08 / 1662.16
= 1.28

Cost - Benefit Ratio (Including labour cost) = Benefits / Costs
= 2144.08 / 3182.43
= 0.67

4. Conclusion

Higher yields can be achieved in salad cucumber cultivation by applying Albert fertilizer at 1.5 g per plant per day under artificial lighting. Additionally, growing salad cucumbers under artificial lights becomes more economically viable when farmers utilize their own labour rather than hired labour. Artificial lighting powered by renewable energy sources can enhance the economic viability of the growing systems, while positively impacting to growth and yield outputs.

5. Acknowledgement

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