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Growth and Yield Performances of Cabbage Grown under a Protected House in Low Country Wet Zone of Sri Lanka as Affected by Artificial Lights and Rate of Albert Fertilizer

U D T Perera[1*] , S Subasinghe[1], K K L B Adikaram[2], H K M S Kumarasinghe[1], M K D K Piyaratne[2]

[1] Department of crop science Faculty of Agriculture University of Ruhuna
[2] Computer Unit Faculty of Agriculture University of Ruhuna

ABSTRACT

A study was conducted in two automated protected houses at Faculty of Agriculture, University of Ruhuna, Sri Lanka to investigate the effect of artificial light supplementation (using LED light source) and rate of Albert fertilizer on growth and yield of Cabbage. The experiment was conducted in a two-factor factorial (2 x 2) Completely Randomized Design with five replicates. The tested two factors were light (with and without artificial lights) and rate of Albert fertilizer(1.0 g/plant/day and 2.0 g/plant/day). These two fertilizer rates were selected based on the best performed fertilizer rates, reported in a previous study. Thus, present study aims to find the effect of previously selected two fertilizer rates and artificial lights on growth and yield of Cabbage. Growth and yield parameters were measured and collected data were analyzed using ANOVA. Subsequently, means were separated by least significant difference (LSD) at 5% probability level. Results revealed that there is no interaction effect between rate of fertilizer and artificial lights on growth or yield parameters of cabbage. However, both growth and yield parameters of cabbage were significantly affected at least by one main factor. Plant height and canopy diameter were significantly increased by artificial lights. Significantly highest number of loose leaves per plant was recorded by 2.0 g/plant/day. 1.0 g/plant/day fertilizer rate and artificial lights recorded significantly highest total above ground biomass yield, cabbage head weight and head perimeter. Therefore, greater yields from cabbage can be obtained by applying Albert fertilizer 1.0 g/plant/day and artificial light enhanced the yield of cabbage.

Key words: Albert fertilizer, artificial light, automated protected house, Cabbage

pereradinusha707@gmail.com

INTRODUCTION

Cabbage (*Brassica oleracea* L.) is one of the most vital and nutritious vegetables belonging to the family Brassicaceae. Due to its nutritional value and delicious taste, cabbage was highly popular and it was extensively grown in hill country of Sri Lanka as a year-round crop (Pavithira, 2022). Nowadays, cabbage is growing in low country of Sri Lanka with promising yields (Perera *et al*., 2023). According to Pavithira (2022), cabbage can be successfully grown in protected houses by manipulating the climatic conditions at their optimum levels (Pavithira, 2022).

Light is essential to plant life and it determines the photosynthetic rate (Avercheva *et al*., 2009). Many stages of plant growth are significantly influenced by light. Additionally, it serves as the cornerstone of a plant's energy metabolism. When there is insufficient light for plant growth, the capacity of plants to absorb and assimilate CO_2 declines. As a result, there are fewer photosynthetic products produced, which eventually results in slower crop growth (Wang *et al.,* 2021). Zervoudakis *et al*. (2012) mentioned that solar radiation is the most important environmental component that controls photosynthesis and, as a result, the survival, growth, and adaptation of plants. Furthermore, they stated that in any ecosystem, light intensity fluctuates geographically and over time (diurnally and seasonally), having an impact on plant development and yield. Although numerous studies have been conducted to determine the ideal light intensity for plant growth, there are still studies that need to be conducted on crop specific and location specific.

Although natural light is frequently utilized in agriculture, it has the disadvantage of being easily diverted by fog, clouds, or even the cover of the greenhouse. Consequently, production of biomass by plants in natural light might be unpredictable (Saapilin *et al*., 2022). In Sri Lanka the sky in the wet zone is overcast and cloudy on most days of the year restricting adequate sun light penetration to the ground (The morning, 2020). Therefore, application of artificial lights for crop production where natural light is insufficient could be helpful to obtain maximum crop productivity.

Moreover, Both (2000) stated that when the amount of light provided by sunshine falls short of the necessary amount, the difference can be made up using an additional lighting system. It is possible to control such a lighting system only with the aid of computer software to provide precisely the same amount of light every day of the year. Recent software advancements have made it possible for the computer to maintain track of the amount of light received since dawn. The computer decides when to activate the lighting system by comparing the received light to the required amount of light (Both, 2000).

Light-emitting diodes (LEDs) are the most appropriate artificial light source because they can produce a precise spectrum with close illumination, a constant spectrum distribution, and higher photosynthetically active radiation (PAR) efficiency for favorable crop production. Numerous studies have shown that LEDs can positively increase crop yield, initiate the synthesis of specific metabolites, and improve fruit and vegetable quality (Saapilin *et al*., 2022).

In addition, it is essential to enhance nutrient usage efficiency by comprehending how fertilizer affects crop development and yield performances. The knowledge on optimum fertilizer amount on the growth and yield of cabbage grown under artificial light condition is still lacking. Therefore, this research was conducted to evaluate the effect of artificial lights and rate of Albert fertilizer on growth and yield performances of cabbage grown in protected houses in low country wet zone of Sri Lanka.

MATERIALS AND METHODS

This study was conducted in two automated protected houses at Faculty of Agriculture, University of Ruhuna, Sri Lanka to investigate the effect of artificial light supplementation on growth and yield of cabbage for the best performed fertilizer rates found in a previous research. Therefore, 1.0 g/plant/day and 2.0 g/plant/day fertilizer treatments and two levels of artificial light (with artificial lights and without artificial lights) were used for the current study. Artificial lights were fixed in one protected house. Therefore, two levels of artificial light were used in two protected houses providing two fertilizer levels for both protected houses.

Uniform cabbage (Var: Green Coronet) plants were transplanted in coco peat grow bags as one plant per bag after 28 days of nursery period. They were placed on the floor of the protected house with the spacing of 40 x 50 cm (DOA). The experimental design was two-factor factorial (2 x 2) Completely Randomized Design with five replicates. The tested two factors were light; L_0 (without artificial lights), L_1 (with artificial lights) and rate of Albert fertilizer; R_1 (1.0 g/plant/day), R_2 (2.0 g/plant/day). Treatments were applied daily.LEDs (60 W) of white colour were used for artificial light supplementation and they were placed 1 foot above the crop canopy. LEDs were automatically turned on when the lux level inside the protected house became less than 3000 lux from 6.00 a.m. to 6.00 p.m. Additionally, they were automatically turned off when the lux level inside the protected house became greater than 3000 lux from 6.00 a.m. to 6.00 p.m. Therefore, a minimum level of 3000 lux was maintained inside the protected house from 6.00 a.m. to 6.00 p.m. through IoT (Internet of Things) based automation system. During the night time from 6.00 p.m. to 6.00 a.m., no artificial light was supplied to facilitate the dark reaction of photosynthesis.

Two rates of Albert fertilizer solutions were prepared and they were applied to plants at one time per day. 200 ml of Albert fertilizer solution with 1.0 g and 2.0 g concentrations as assigned in two treatments was applied each plant per day. After application of fertilizer, 800 ml of water/plant/day as three splits was applied via drip irrigation system as 300 ml of water at 8.00 a.m., 300 ml of water at 11.00 a.m. and balance 200 ml of water applied at 2.00 p.m. Management of pests and diseases were done according to the recommendations of the Department of Agriculture, Sri Lanka (DOA). Harvesting was done 90 days after transplanting (DOA).

As growth parameters; plant height, number of loose leaves per plant and canopy diameter were measured at two weeks interval. As yield parameters total above ground biomass yield, fresh weight of head and perimeter of head were measured at harvesting after 90 days from transplanting. Collected data were statistically analyzed using Analysis of Variance (ANOVA) from Statistical Analysis System (SAS) 9.1.3 version. Subsequently, means were separated from Least Significant Difference Test (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Results revealed that there is no interaction effect between rate of fertilizer and artificial lights on growth and yield parameters of cabbage. However, both growth and yield parameters of cabbage were significantly affected at least by one main factor. Results show that the plant height and canopy diameter were significantly influenced by artificial lights. Significantly highest values for these parameters were recorded with artificial lights. Significantly highest number of loose leaves per plant was recorded by 2.0 g/plant/day. Total above ground biomass yield, cabbage head weight and head perimeter were significantly affected by main factors individually. 1.0 g/plant/day fertilizer rate and use of artificial lights recorded significantly highest total above ground biomass yield, cabbage head weight and head perimeter.

Plant Height

Significantly higher ($p < 0.05$) plant height was recorded when artificial lights were used (Figure 1) than without artificial lights from 4th week after transplanting to end of the crop. Several other researchers also recorded higher plant height under artificial light supplementation over natural light. Cavallaro and Muleo (2022) stated that stem elongation of crop plants is a growth and development function of the control activity of light. Sutulienė *et al*. (2022) recorded significantly taller basil and lettuce plants under 150 and 250 µmol m^{-2} s^{-1} with compared to the plants cultivated in natural light. Nguyen *et al*. (2019) also observed that increasing plant height with increasing light intensity of spinach plants when red and blue LED lights are used in conjunction. Environmental conditions have a profound influence on the growth and development of plants. Light intensity is the most important of growth and development of a plant (Nguyen *et al*., 2019). Therefore, supplementation of artificial lights during inadequate natural light conditions may support plant growth.

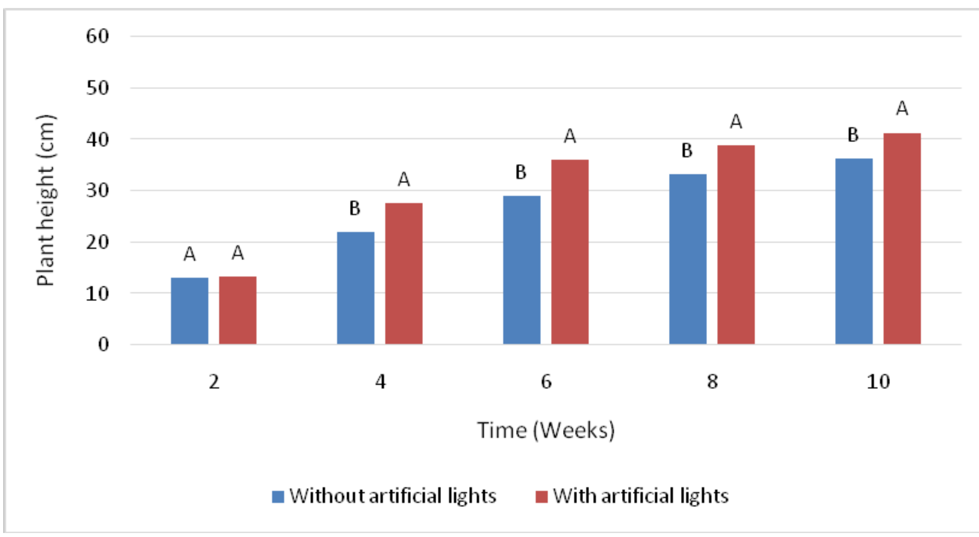

Figure 1: Mean plant height of cabbage plants during crop growth and harvesting as affected by artificial lights

Canopy Diameter

Canopy diameter of cabbage plants was significantly affected by artificial lights. Significantly higher ($p < 0.05$) canopy diameter was recorded with artificial lights (Figure 2) than without artificial lights from 4th week after transplanting onwards. Saapilin *et al*. (2022) recorded higher growth rate of Chinese cabbage (*Brassica rapa* var. chinensis) plants in high light intensity than plants grown in low light intensity. They reported unequal leaf distribution in plants grown under natural light conditions as a result of the variable light intensity received by cabbage plants during the day. With contrast to these plants, cabbage plants grown under constant artificial lights resulted consistently grown leaves across the crown. He *et al.* (2019) resulted rapid leaf area development in Chinese broccoli cultivated under red(R) : blue(B) -LED ratio of 84:16. Therefore, artificial light supplementation can increase leaf area which then leads to higher canopy diameter of plants in Brassicaceae family. Hence, providing artificial lights as a complement to natural light conditions may boost plant growth.

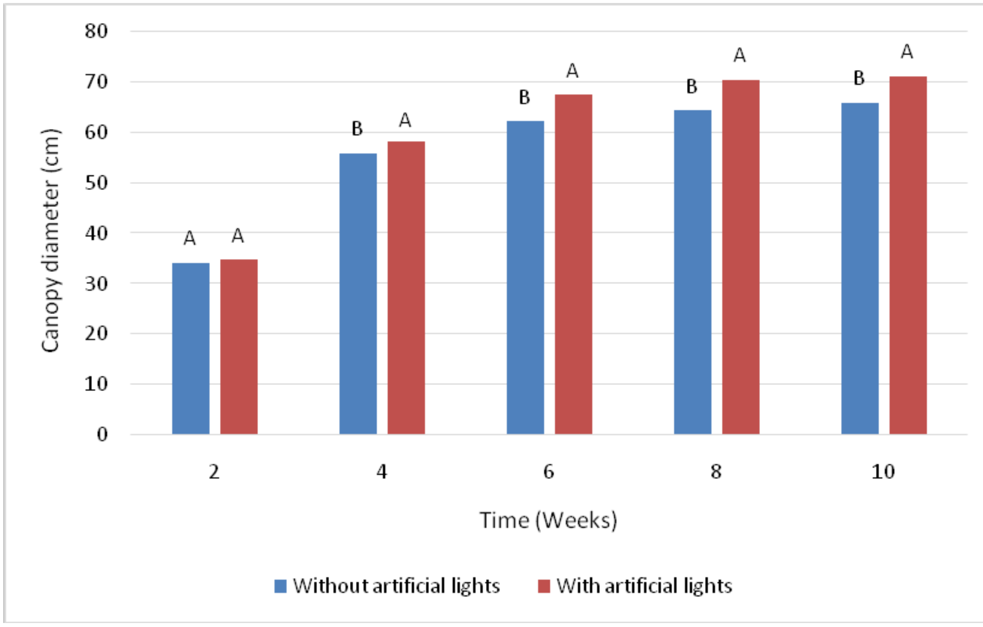

Figure 2: Mean canopy diameter of cabbage plants during crop growth and harvesting as affected by artificial lights

Number of Loose Leaves per Plant

Number of loose leaves per plant was significantly affected by rate of fertilizer. Significantly higher ($p < 0.05$) number of loose leaves per plant was recorded by application of 2.0 g of fertilizer /plant/day (Figure 3) over 1.0 g of fertilizer /plant/day from 8th week after transplanting to harvest. According to Laczi *et al*. (2016), number of leaves in cabbage is a crucial parameter since their function in light absorption affects transpiration, photosynthesis, and crop yield. They observed significantly increased number of leaves by application of horse manure under protected conditions where low values were achieved by unfertilized cabbage plants. In addition, as cited by them Easmin *et al*. (2013) reported that the amount of fertilizer used directly affected the number of leaves on Chinese cabbage. They applied 0, 160, 200, and 250 kg N/ha, and the number of leaves increased steadily with nitrogen fertilizer application. In 250 kg N/ha, they obtained 55.51 leaves of Chinese cabbage, which was the significantly highest. In that experiment, the application of 200 kg N/ha and 160 kg N/ha produced statistically same results, which were lower than the results of 250 kg N/ha. The lowest number of Chinese cabbage leaves (42.96) was recorded at 0 kg N/ha. Therefore, results of the present experiment are in agreement with past findings which the number of loose leaves in cabbage plants is directly affected by the amount of fertilizer applied.

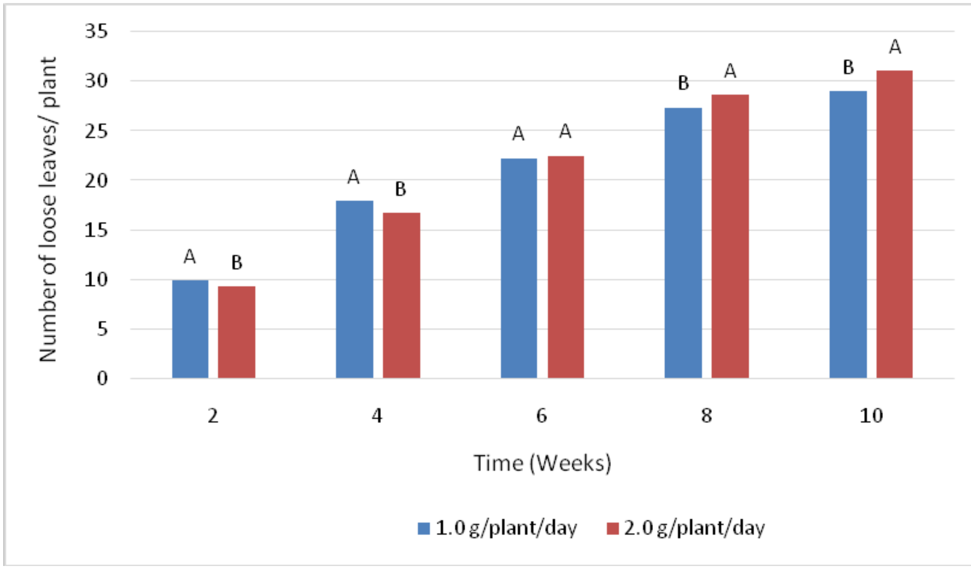

Figure 3: Mean number of loose leaves per cabbage plant at different weeks after transplanting as affected by rate of fertilizer

Fresh Weight of Heads

There was no interaction effect on fertilizer rates and artificial light but fresh weight of cabbage heads was significantly affected by main factors separately. 1.0 g/plant/day fertilizer rate and artificial lights application recorded significantly highest ($p < 0.05$) fresh weight of heads (Figure 4 and 5). The significantly highest fresh weight of cabbage heads was recorded in 1.0 g/plant/day fertilizer rate than 2.0 g/plant/day fertilizer rate. Although previous research have revealed that increased amounts of fertilizer resulted larger cabbage heads (Kumar and Rawat, 2002; Pramanik, 2007; Choudhary *et al*., 2009; Tehulie and Belete, 2021), in the present experiment significantly highest cabbage head weight was recorded in the lowest amount of fertilizer. That might be due to the high temperature in low country where cabbage was grown. The temperature in low country was not optimum for better cabbage head development.

However, artificial supplementation of light has significantly improved crop yield where natural light is not adequate. According to Saapilin *et al*. (2022), artificial light could increase the effectiveness of Chinese cabbage production. Yasoda *et al*. (2018) reported no curd formation in cauliflower grown in dry zone of Sri Lanka under 75 % shade level and they stated that it might be due to the inadequate light intensity and subsequently low photosynthetic activity. In addition, Sutulienė *et al*. (2022) reported the fresh and dry weight of basil plants cultivated in the growth chamber increased with illumination intensities of 50, 150, 300, and 600 $\mu molm^{-2}s^{-1}$. Additionally, they claimed that when considering the environmental aspects in agriculture, the two most essential elements for plant growth are light and nutrition. In addition, light intensity has a direct impact on plant metabolism and development. Furthermore, as mentioned by them although additional lighting may be required in greenhouses to enhance plant growth, it is only necessary when the daily light integral is naturally low. Therefore, maintaining a minimum lux level of 3000 lux from 6.00 a.m. to 6.00 p.m. was supportive to enhance cabbage head yield where natural sunlight was not sufficient.

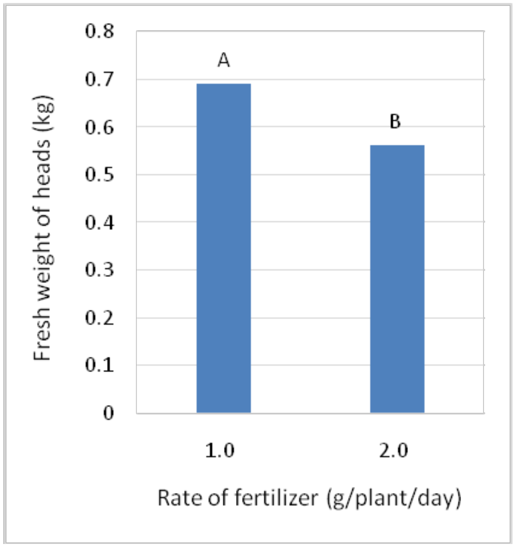

Figure 4: Mean fresh weight of cabbage heads as affected by rate of fertilizer

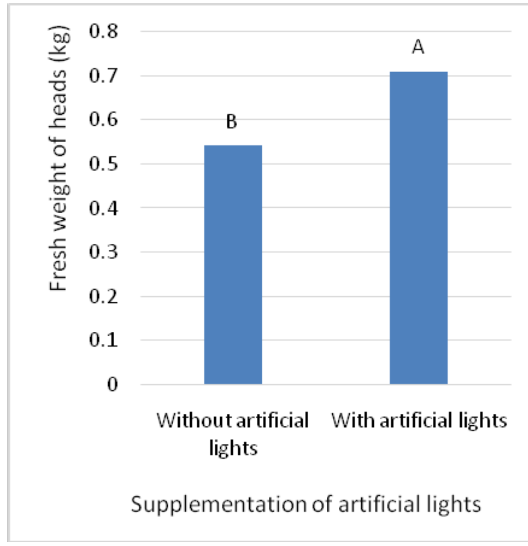

Figure 5: Mean fresh weight of cabbage heads as affected by artificial lights

Perimeter of Head

Perimeter of cabbage heads was also significantly affected by main factors separately. 1.0 g/plant/day fertilizer rate and artificial lights application recorded significantly highest ($p < 0.05$) perimeter of head (Figure 6 and 7).

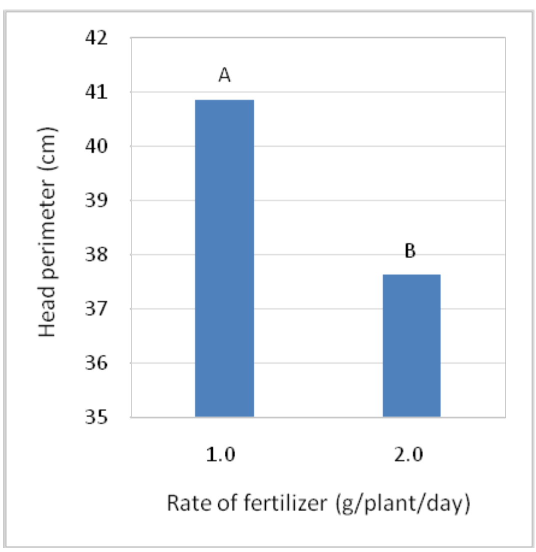

Figure 6: Mean perimeter of cabbage heads as affected by rate of fertilizer

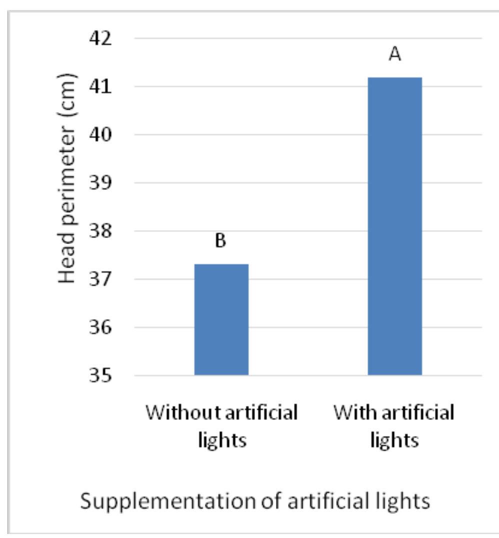

Figure 7: Mean perimeter of cabbage heads as affected by

Total Above Ground Biomass Yield

Total above ground biomass yield was significantly affected by main factors separately. 1.0 g/plant/day fertilizer rate and artificial lights application recorded significantly highest ($p < 0.05$) total above ground biomass yield (Figure 8 and 9). The growth rate and biomass of Chinese cabbage plants cultivated in high light intensity were higher than those cultivated in low light intensity (Saapilin *et al*., 2022). Similar results were observed by Duc *et al*. (2021), who also stated that protected growing facilities with the lighting conditions showed high production capacity of Chinese cabbage grown in a plant factory. Jones-Baumgardt *et al*. (2019) reported increment in fresh weight by 36% in cabbage microgreens from 100 to 600 mmol/m^2/s light intensity increment. In addition, Proietti *et al*. (2021) reported that continuous lighting in controlled environment enhanced the total fresh biomass of rocket plants (*Eruca vesicaria)*. Even though natural light is mostly utilized in agriculture, it has the drawback of being readily diverted by fog, clouds, and even greenhouse covers. Consequently, biomass generation by plants in natural light might be unpredictable (Saapilin *et al*., 2022). As well, even Sri Lanka is close to the equator, the sky in the wet zone in Sri Lanka is overcast and cloudy on most days in rainy season of the year restricting adequate sun light penetration to the canopy (The morning, 2020). Therefore, application of artificial lights for crop production where natural light is insufficient could be resulted promising yields. When considering the rate of fertilizer, 1.0 g/plant/day fertilizer application resulted significantly higher total above ground biomass yield than 2.0 g/plant/day fertilizer application. That might be attributed with greater head yields obtained from 1.0 g/plant/day fertilizer rate over 2.0 g/plant/day fertilizer rate which ultimately resulted a higher total above ground biomass yield by 1.0 g/plant/day fertilizer applied plants.

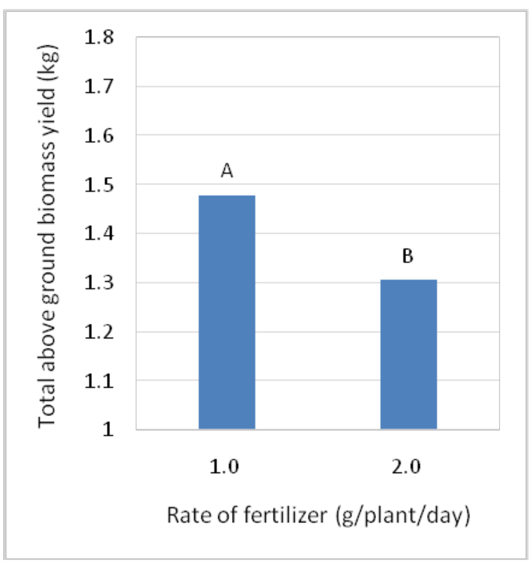

Figure 8: Mean total above ground biomass yield as affected by rate of fertilizer

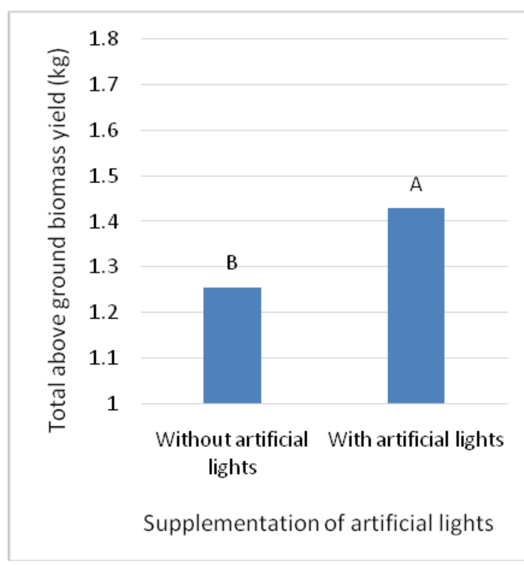

Figure 9: Mean total above ground biomass yield as affected by artificial lights

CONCLUSION

Cabbage head yield was increased when Albert fertilizer applied 1.0 g/plant/day. In addition, supplementary artificial lights enhanced growth parameters of cabbage which then helped to increase head yields. Therefore, greater yields from cabbage can be obtained by applying Albert fertilizer 1.0 g/plant/day and providing artificial lights under protected house conditions in low country wet zone of Sri Lanka.

REFERENCES

1. Avercheva, O.V., Berkovich, Y.A., Erokhin, A.N., Zhigalova, T.V., Pogosyan, S.I. and Smolyanina, S.O., 2009. Growth and photosynthesis of Chinese cabbage plants grown under light-emitting diode-based light source. *Russian Journal of Plant Physiology*, *56*, pp.14-21.
2. Both, A.J., 2000. Some thoughts on supplemental lighting for greenhouse crop production.*Bioresource Engineering. Department of Plant Biology and Pathology Rutgers, The State University of New Jersey, New Brunswick, NJ.*
3. Cavallaro, V. and Muleo, R., 2022. The effects of LED light spectra and intensities on plant growth. *Plants*, 11(15), pp.1911.
4. Choudhary, B.R., Fageria, M.S. and Dhaka, R.S., 2009. *A text book on production technology of vegetables*. Kalyani Publishers.
5. Department of Agriculture, *HORTICULTURAL CROPS RESEARCH AND DEVELOPMENT INSTITUTE,CROPS*. Sri Lanka.Available at:https://doa.gov.lk/hordi-crops/ (Accessed: 22.12.2022).
6. Duc, N.V., Chowdhury, M., Ali, M., Park, S.U., Kim, Y.J. and Chung, S.O., 2021. Effects of light conditions on growth and glucosinolate content of Chinese cabbage grown in a plant factory. In *IX International Symposium on Light in Horticulture* (Vol. 1337),pp.171-178.
7. Easmin, D., Islam, M.J. and Begum, K., 2013. Effect of different levels of nitrogen and mulching on the growth of Chinese cabbage (*Brassica campestris* var. Pekinensis). *Progressive Agriculture*, 20(1-2), pp.27-33.
8. He, J., Qin, L. and Chow, W.S., 2019. Impacts of LED spectral quality on leafy vegetables: Productivity closely linked to photosynthetic performance or associated with leaf traits?. *International Journal of Agricultural and Biological Engineering*, 12(6), pp.16-25.
9. Jones-Baumgardt, C., Llewellyn, D., Ying, Q. and Zheng, Y., 2019. Intensity of sole-source light-emitting diodes affects growth, yield, and quality of Brassicaceae microgreens. *HortScience*, 54(7), pp.1168-1174.
10. Kumar, M. and Rawat, T.S., 2002. Effect of nitrogen and spacing on the quauty and yield of cabbage (*Brassica oleracea* L. Var. capitata). *Agricultural Science Digest*, 22(2), pp.90-92.
11. Laczi, E., Apahidean, A., Luca, E., Dumitraş, A. and Boancă, P., 2016. Headed Chinese cabbage growth and yield influenced by different manure types in organic farming system. *Horticultural Science*, 43(1), pp.42-49.
12. Nguyen, T., Tran, T. and Nguyen, Q., 2019. Effects of light intensity on the growth, photosynthesis and leaf microstructure of hydroponic cultivated spinach (*Spinacia oleracea* L.) under a combination of red and blue LEDs in house. *International Journal of Agricultural Technology*, 15(1), pp.75-90.
13. Pavithira, R., 2022. The Impact of Shading on Growth and Yield of Cabbage (*Brassica oleracea* L.) in the Low Country Dry Zone, Ampara, Sri Lanka. *OUSL Journal*, 17(1), pp.35-47.

14. Perera, U.D.T., Subasinghe, S., Adikaram, K.K.L.B., Kumarasinghe, H.K.M.S. and Piyaratne, M.K.D.K., 2023. Effect of the rate and split application of Albert's fertilizer on growth and yield performances of cabbage under the protected house in the low country wet zone of Sri Lanka.*Tropical Agricultural Research & Extension,* 26(1), pp.52-63.
15. Pramanik, S. 2007. Effect of nitrogen and phosphorus on the growth and yield of cabbage (*Brassica oleraceae* var. Capitata L.), MS thesis, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.
16. Proietti, S., Moscatello, S., Riccio, F., Downey, P. and Battistelli, A., 2021. Continuous lighting promotes plant growth, light conversion efficiency, and nutritional quality of *Eruca vesicaria* (L.) Cav. in controlled environment with minor effects due to light quality. *Frontiers in Plant Science*, 12, pp.730119.
17. Saapilin, N.S., Yong, W.T.L., Cheong, B.E., Kamaruzaman, K.A. and Rodrigues, K.F., 2022. Physiological and biochemical responses of Chinese cabbage (*Brassica rapa* var. chinensis) to different light treatments. *Chemical and Biological Technologies in Agriculture*, 9(1), pp.1-20.
18. Sutulienė, R., Laužikė, K., Pukas, T. and Samuolienė, G., 2022. Effect of light intensity on the growth and antioxidant activity of sweet basil and lettuce. *Plants*, 11(13), pp.1709.
19. Tehulie, N.S. and Belete, S., 2021. Review on the effects of NPS fertilizer rates on growth, yield components and yield of cabbage (*Brassica oleracea* var. *capitata* L.). *South Asian Journal of Agricultural Sciences*, 1(1), pp.15-21.
20. The morning, 2020. *Solar power in SL: Reasons for slow progress.* Sri Lanka. Available at: https://www.themorning.lk/articles/107813(Accessed: 03.08.2023).
21. Wang, S., Fang, H., Xie, J., Wu, Y., Tang, Z., Liu, Z., Lv, J. and Yu, J., 2021. Physiological responses of cucumber seedlings to different supplemental light duration of red and blue LED. *Frontiers in Plant Science*, 12, pp.709313.
22. Yasoda, P.G.C., Pradheeban, L., Nishanthan, K. and Sivachandiran, S., 2018. Effect of Different Shade Levels on Growth and Yield Performances of Cauliflower.*International Journal of Environment, Agriculture and Biotechnology*, 3(3), pp.948-955.
23. Zervoudakis, G., Salahas, G., Kaspiris, G. and Konstantopoulou, E., 2012. Influence of light intensity on growth and physiological characteristics of common sage (*Salvia officinalis* L.). *Brazilian Archives of Biology and Technology*, 55, pp.89-95.