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RESEARCH ARTICLE

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

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ABSTRACT

In Sri Lanka the demand for fresh vegetables has been increasing all over the country. Therefore, up country vegetable cultivation should be promoted in low and mid country areas. However, there is no proper fertilization pattern to enhance the growth and yield of cabbage grown in the low country. Thus, an experiment was performed in a protected house located in the low country wet zone of Sri Lanka from October 2021 to January 2022 to evaluate the effect of the rate and split application of Albert's fertilizer on the growth and yield parameters of Cabbage (*Brassica oleracea* L. var Green Coronet). The study was carried out in a two-factor factorial (2 x 3) Completely Randomized Design with four replicates. The two factors tested were, the rate of fertilizer; A_1 (1.0 g/plant/day), A_2 (1.5 g/plant/day), A_3 (2.0 g/plant/day) and the number of split applications of fertilizer; F_1 (1 time/plant/day), F_2 (2 times/plant/day), F_3 (3 times/plant/day). Treatments were applied daily. The average day temperature inside the protected house was 32.5 °C and the average night temperature inside the protected house was 27 °C. As growth parameters plant height, the number of loose leaves per plant and canopy diameter were measured once a fortnight while cabbage heads and total biomass yield were measured as yield parameters, 100 days after transplanting. Measured data were analyzed using ANOVA. Subsequently, means were separated by least significant difference (LSD) at 5% probability level. There is no significant effect of the split of Albert's fertilizer and no interaction effect between the rate and split of fertilizer. Plant height, the number of loose leaves per plant and canopy diameter were significantly influenced by the rate of fertilizer. 2.0 g/ plant/day treatment gave significantly higher values for the above growth parameters with compared to the treatments of 1 and 1.5 g/plant/day. Even though, no significant difference was recorded in total biomass yield, the significantly highest head yield was recorded in 1.0 g of Albert's fertilizer/plant/day treatment. When considering the economic yield, it can conclude that the treatment of 1.0 g/plant/day is the best fertilizer rate for cabbage grown under protected houses in the low country wet zone of Sri Lanka. Also, fertilizer application at once a day can be recommended when considering energy use efficiency since there is no significant effect of split application of fertilizer.

Keywords: Albert's fertilizer, Cabbage, Fertilizer rate, Protected house, Split application

INTRODUCTION

Sri Lanka is a tropical country with highly praising conditions for crop cultivation. Vegetables grown in Sri Lanka can be broadly categorized into two categories as up country vegetables and low country vegetables considering the agro-ecological adaptability (Nuskiya 2019). Up country vegetable cultivation contributed to 70.3% of the Maha season and 74.1% of the Yala season. Up country vegetable cultivation is the most popular among farmers in central highlands of Sri Lanka (Nuskiya 2019). But majority of the vegetables produced in up country are transported to the Colombo and other parts of the country. Due to long distance transportation, improper handling and perishable nature of

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the vegetables, about 40% is wasted. Due to these transportation difficulties and post-harvest losses, consumers in other parts of the country may not be able to obtain high quality up country vegetables for affordable prices.

In addition, the market supply of up country vegetables suffers heavily during prolonged rainy periods causing price hikes (Wijerathne and Weerakkody 2017). They stated that up country vegetable cultivation should be promoted in mid and low country areas in Sri Lanka as a means of national priority in agriculture to ensure national food security in vegetables. Moreover, the demand for high quality fresh vegetables has been fast blooming in all over the country with the rapid expansion of the tourism industry emphasizing the requirement of the promotion of up country vegetable cultivation in alternative production regions (Wijerathna *et al*. 2014).

Furthermore, vegetable supply for the local market from open fields has been experiencing severe fluctuations due to adverse weather conditions, pest and disease incidences in recent times (Wijerathna *et al*. 2014). Also, food production should be increased with the increasing demand for foods due to the continuous increment of the population. Thus, future food production has to be intensified with available land and other agricultural inputs. These circumstances welcome protected agriculture as an intensive crop production strategy (Wijerathna *et al*. 2014). Protected agriculture ensures a sustainable supply of vegetables against the seasonality of production. Therefore, it should be promoted as a means of the sustainable production method for vegetable farmers in the long term (Kumara *et al*. 2015).

However, in Sri Lanka, protected agriculture is mainly practiced in areas with higher elevations of the country. According to Wijerathna *et al*. (2014), the prevalence of favourable climatic conditions for protected agriculture in the Central province could be the reason for this situation. Kumara *et al*. (2015), also stated that protected agriculture is not much popular in the low country due to the prevailing environmental conditions in the low country.

According to the literature there is no much evidences of growing up country vegetables in low country areas of Sri Lanka. Cabbage can be successfully cultivated in the cool climatic condition in the upcountry area (DOA 2022). But in the low country cabbage cultivation is not much popular. This might be due to the prevailing climatic condition especially higher temperature.

As mentioned by Wijerathne and Weerakkody (2017), chemical pesticide application is relatively high in cabbage cultivation. Continuous production of up country vegetables with increasing use of agro-chemicals has badly affected the environment. Eutrophication due to the application of excessive fertilizer and building up resistance in pests due to the usage of hazardous and restricted pesticides are some of the issues known for long term (Weerakkody *et al*. 2009). Thus, if cabbage could be successfully grown in protected houses, hazardous pesticide application would be able to minimize by restricting pest entrance into the protected house. Therefore, the present study was focused to see the possibility of cultivation of Cabbage (*Brassica oleracea* L. var Green Coronet) in a protected house in the low country.

As stated by Kumaragamage (2010), improper application of nutrients may lead on adverse effects on the environment, and negative cost-effectiveness of fertilizer applications. Thus, supplementation of plant nutrients at an adequate level is a key aspect in increasing crop productivity along with environmental sustainability. He also mentioned that eutrophication is a considerable issue in the wet zone of Sri Lanka due to the application of higher input of fertilizers with low fertilizer use efficiency. Wu *et al*. (2020) also mentioned that excessive use of water and fertilizer during agricultural production has become standard practices to ensure higher yields but, these practices lead to lose nutrients through leaching from surface soil to deep layers of soil, reducing water and nutrient use efficiency. Therefore, understanding the response of crop growth and yield performances to water and fertilizer is helpful to improve their management and nutrient use efficiency.

Therefore, split application of N fertilizer is one of the methods to nourish crops better by improving nutrient uptake while protecting the environment from the hazardous effects of chemical inputs along with cost effectiveness (Belete *et al*. 2018). Albert fertilizer solution is the most applied fertilizer for protected house cultivations (Ranasinghe and Weerakkody 2006; Iqram and Seran 2016) which contains most of the essential nutrients required for plant growth and it can be successfully provided for plants via the drip irrigation system that is used in most protected houses (Debnath and Mohiuddin 2020). Therefore, the effect of split application of fertilizer for optimization of growth and yield performances of cabbage grown in protected houses in low country wet zone of Sri Lanka requires further investigation. Wu *et al*. (2020), also stated that at present, research on cabbage has been mainly accomplished in the open fields and research on cabbage planting in protected houses is less frequently reported. Thus, in order to support for filling the research gap this research was conducted in a protected house to study the growth and yield performances of cabbage for different fertilization patterns in the low country wet zone of Sri Lanka.

MATERIALS AND METHODS

This experiment was done in a protected house at the Faculty of Agriculture, University of Ruhuna (low country wet zone) from October 2021 to January 2022. Uniform cabbage (Var: Green Coronet) seedlings were planted in coir grow bags as one plant per bag after twenty-eight days of nursery period. According to the recommendation of the Department of Agriculture, Sri Lanka grow bags were placed with the spacing of 40 x 50 cm. The study was carried out in a two-factor factorial (2 x 3) Completely Randomized Design and there were four replicates. In addition, two plants per replicate were maintained. The two factors were the rate of fertilizer; A_1 (1.0 g/plant/day), A_2 (1.5 g/plant/day), A_3 (2.0 g/plant/day) and the number of split applications of fertilizer; F_1 (1 time/plant/day), F_2 (2 times/plant/day), F_3 (3 times/plant/day). Farmers usually practise 2.0 g of Albert's fertilizer 1 time/plant/day (Karunarathne *et al.* 2022). The fertilizer application was done manually. As the growing media was soilless coir media Albert's solution was used as the fertilizer since it is the best fertilizer used in soilless cultivations in Sri Lanka. Different amounts of Albert's fertilizer solutions were prepared as assigned in different treatments and they were applied to plants at three different times. In F_1 treatment, 200 ml of the relevant Albert's solution was applied to plants at 7.00 a.m. In F_2 treatment 100 ml of the relevant Albert's solution was applied to plants, each time at 7.00 a.m. and 10.00 a.m. In F_3 treatment 66.7 ml of the relevant Albert's solution was applied to plants, each time at 7.00 a.m., 10.00 a.m. and 1.00 p.m. After the application of fertilizer, irrigation was done using the drip irrigation system. 300 ml of water was applied at each time of 8.00 a.m. and 11.00 a.m. while 200 ml of water was applied at 2.00 p.m. Thus, 800 ml of water was applied per plant per day. The average day temperature inside the protected house was 32.5 ° C and the average night temperature inside the protected house was 27 °C. Though cabbage can be successfully grown in the cool climatic condition in up country (DOA 2022), in the present study cabbage was grown in the prevailing environmental conditions in the low country without applying any cooling practices to reduce the temperature inside the existing top vent protected house.

Plant height, number of loose leaves per plant and canopy diameter were measured at two weeks interval as growth parameters. Total above ground biomass yield, fresh weight of head and perimeter of head were measured after 100 days from transplanting. Collected data were statistically analyzed using Analysis of Variance (ANOVA) from SAS 9.1.3 version. Subsequently, the Least Significant Difference Test (LSD) at 5% probability level was used to separate significant means.

RESULTS AND DISCUSSION

Results revealed that there is no interaction effect between the rate and split of fertilizer and no significant effect of the split of fertilizer on growth and yield parameters of cabbage grown under the protected house in low coun-

try wet zone of Sri Lanka. However, growth parameters (plant height, number of loose leaves per plant and canopy diameter) were significantly influenced by the rate of fertilizer. 2.0 g/plant/day gave significantly higher values for above mentioned growth parameters with compared to 1 and 1.5 g/plant/day treatments. According to Figure 1, from 6th week after transplanting onwards 2 g/plant/day Albert's fertilizer treatment has the highest significant effect on average plant height of cabbage.

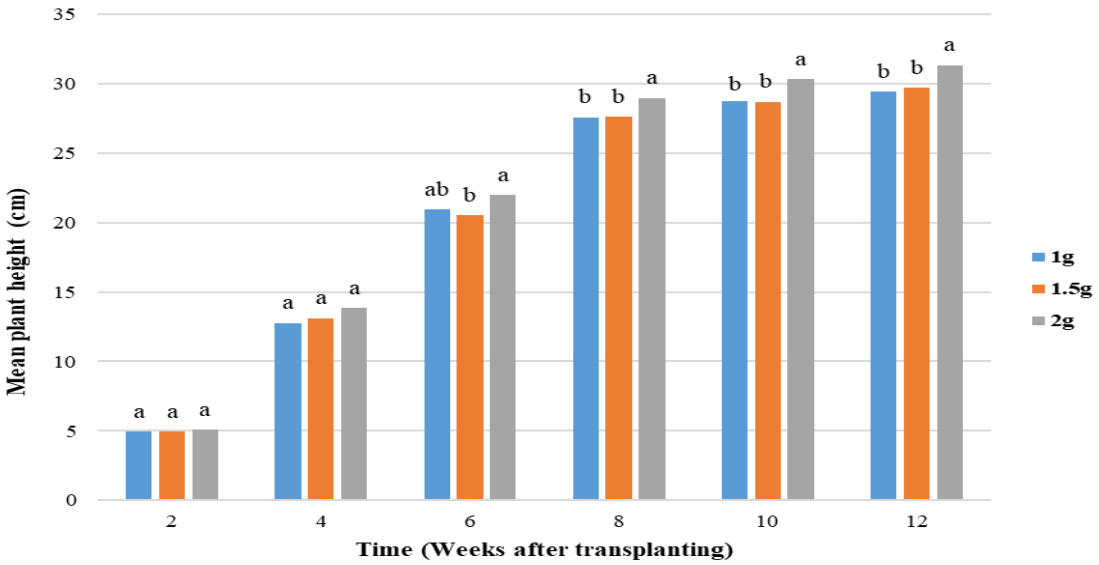

Figure 1: Mean plant height at different weeks after transplanting

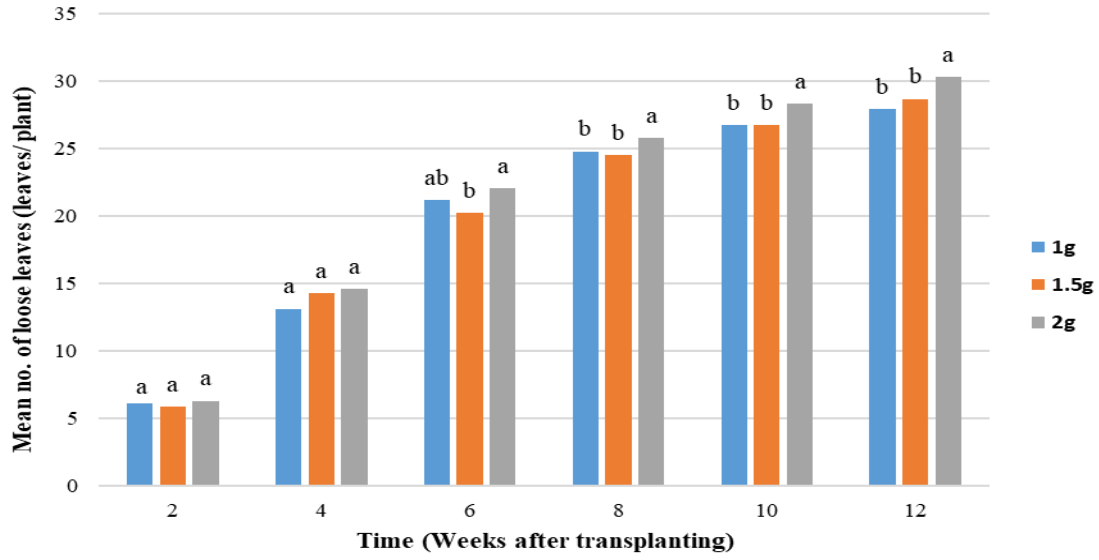

Figure 2: Mean number of loose leaves at different weeks after transplanting

In addition, 2 g/plant/day Albert's fertilizer treatment recorded a significantly highest number of loose leaves per plant from 6th week after transplanting onwards (Figure 2).

Figure 3 shows that 2 g/plant/day Albert's fertilizer treatment has reported a significantly highest average canopy diameter of cabbage plants from 6th week after transplanting onwards. However, it is not significantly different from 1 g/plant/day Albert's fertilizer treatment at 10 and 12 weeks after transplanting.

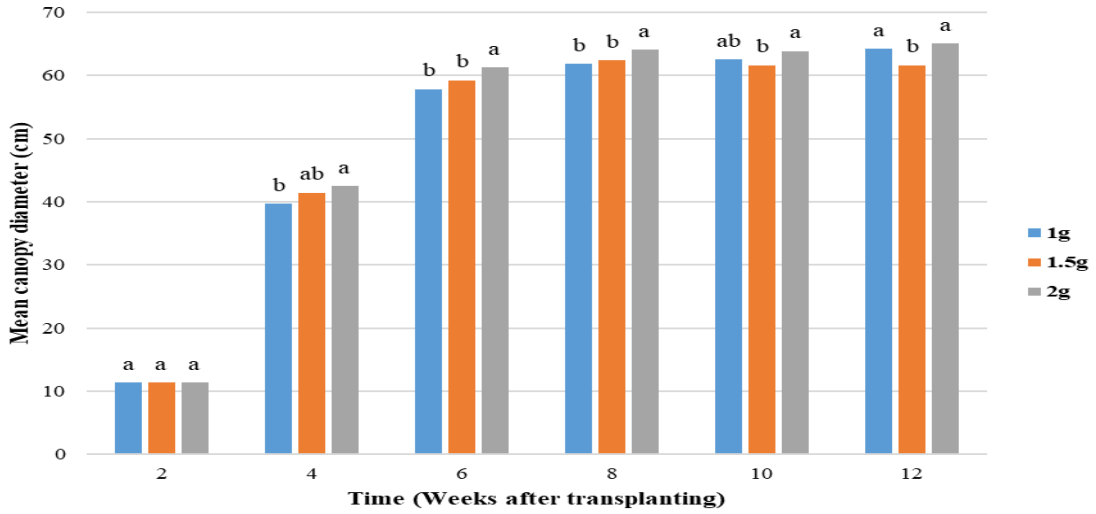

Figure 3: Mean canopy diameter at different weeks after transplanting

The results of growth parameters of the present study agree with the results of Haque *et al*. (2015). They reported that the application of adequate fertilizer is vital to improve cabbage production and they mentioned that sufficient nitrogen assists robust vegetative growth. They further stated that insufficiency of nutrients causes pale foliage and reduced growth, which the ultimate result is restricted production. They also obtained significantly higher values for plant height, number of loose leaves per plant and spread of canopy for the highest N amount. Therefore, similarly in this research remarkably increased values for growth parameters were obtained from the highest amount of fertilizer application, which might be a result of increased amounts of nutrients accepted by the plants. Then higher nutrition uptake by plants might have facilitated praising conditions for greater growth than those of others. As mentioned by Samarakoon *et al*. (2006) N, P, K and Ca uptake rates in plants increased with increasing concentration of Albert's solution.

As cited by Haque *et al*. (2015), Hadfield (1995) mentioned that sufficient nitrogen promotes robust vegetative growth because N is vital for the formation of chlorophyll and a constituent of proteins while inadequate N results in spindly slow growth and pale leaves which concluding limited yields. Furthermore, Haque *et al*. (2015) reported height of the cabbage plant at different days after transplanting increased with increasing the amount of N fertilizer from 0, 150, 250, 350 kg/ha respectively. These results are also in line with the recordings of Pramanik (2007) who discovered that the plant height of cabbage increased with larger dose of N up to 260 kg/ha and P up to 120 kg/ha. Further, Ogedegbe and Law-Ogbomo (2013) obtained the tallest height of cabbage plants for 150 kg N ha^{-1} treatment than the treatment without fertilizer, poultry manure 20 t ha^{-1}, 50 and 100 kg N ha^{-1} treatments. Moreover, as cited by Tehulie and Belete (2021), Sardana and Verma (1987) recorded highest application of nitrogen, phosphorus and potassium fertilizers increased the plant height of cabbage. Increase in plant height is an indicator of plant nutrient status (Kumarasinghe *et al*. 2019). Better nutrient status in plants leads to vigorous plants which subsequently give higher yields.

Haque *et al*. (2015) reported that the number of loose leaves per cabbage plant was significantly affected by nitrogen. They obtained the highest number of loose leaves per plant for the highest level of nitrogen. Similar results were obtained from Meena and Paliwal (2003) who obtained a maximum number of leaves for cabbage plant from the highest amount of N fertilizer while the minimum number of leaves from without applying N fertilizer. In addition, Pramanik (2007) obtained the highest number of loose leaves per plant with the dose of N 260 kg/ha and P 120 kg/ha while

the minimum was obtained with 0 kg/ha N and P fertilizers. Number of leaves in plants affect to the rate of photosynthesis, which is a main metabolic activity that affects growth and yield.

Haque *et al*. (2015) reported that canopy diameter was remarkably higher in the highest level of nitrogen. They further mentioned that higher amount of N perceived by plants provided praising conditions for leaf creating which ultimately results broader canopy. As well, Pramanik (2007) observed maximum plant spread with the dose of N 260 kg/ha and P 120 kg/ha while the minimum was observed with 0 kg/ha N and P fertilizers.

As cited by Ogedegbe and Law-Ogbomo (2019), Choudhary and Choudhary (2005) mentioned that the vegetative parameters of cabbage plants increased significantly with increasing nitrogen amounts and this implies that additional application of fertilizer may uplift the growth and yield of cabbage. Furthermore, Atanasova *et al*. (2007) stated that head cabbage is a plant with higher demand of N as well as K and P since it gathers large vegetative biomass comparatively in a short time period.

When considering the yield parameters significantly highest fresh weight (0.9743 kg) and perimeter of cabbage heads (45.7167 cm) were recorded in 1.0 g of Albert's fertilizer/ plant/day treatment with compared to 1.5 and 2 g/plant/day Albert's fertilizer applied treatments (Figure 4 and 5).

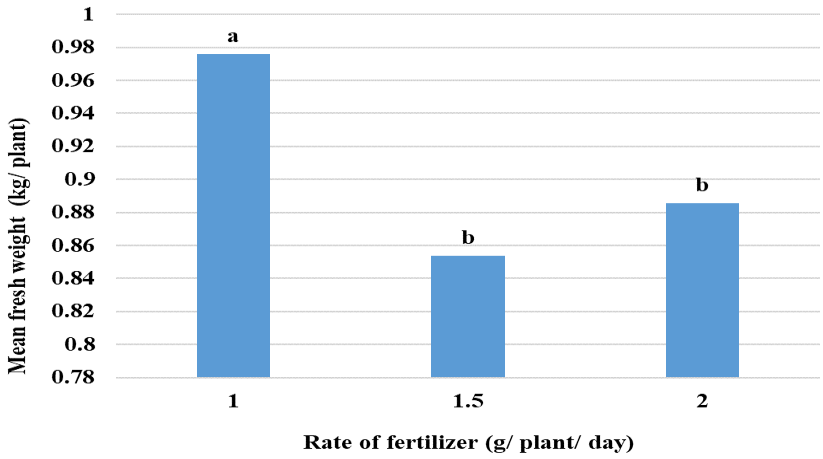

Figure 4: Fresh weight of cabbage heads at different rates of Albert's fertilizer solution at harvesting

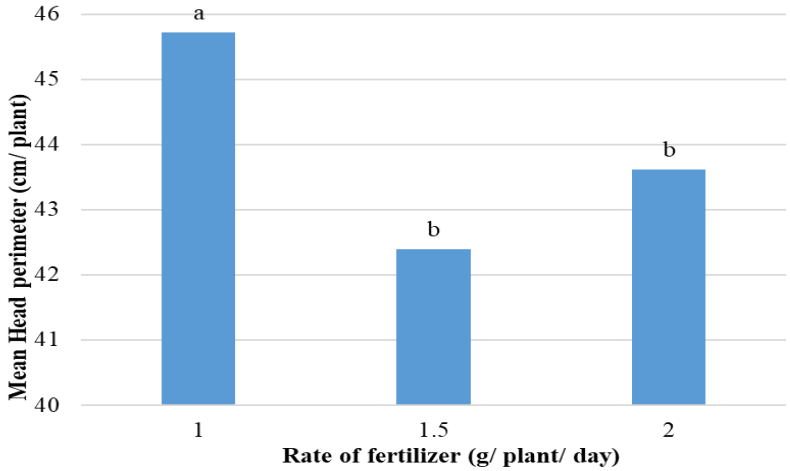

Figure 5:Mean head perimeter at different rates of Albert's fertilizer solution at harvesting

However, total above ground biomass yield at harvesting (biomass yield) has no significant effect with rate of fertilizer.

As cited by Kolota and Chohura (2015), White and Forbes (1976) recorded level of nitrogen fertilization is an influencing factor for the crop yield of cabbage and they obtained favorable yields for higher nitrogen amounts. Haque *et al*. (2015), stated that the optimum amount of nitrogen may secure better growth of plants with greater leaf area resulting in the highest fresh weight of head plant^{-1}. Kumar and Rawat (2002) and Pramanik (2007) also reported higher yields of cabbage with increased rate of Nitrogen fertilizer. Akand *et al*. (2015) recorded significant variations on head diameter from different levels of nitrogen fertilizer. He observed a maximum head diameter from 200 kg ha^{-1} N fertilizer treatment whereas the minimum was observed in 0 kg ha^{-1} treatment. In addition, Man and Sandhu (1956) obtained larger heads from 168 kg/ha N fertilizer treatment while Hossain (1998) recorded maximum head diameter of 250 kg N/ha than lower amounts of fertilizer. Ogedegbe and Law-Ogbomo (2019) obtained maximum yields with 150 kg N ha^{-1} treatment over the treatment without fertilizer, poultry manure 20 t ha^{-1}, 50 and 100 kg N ha^{-1} treatments. As cited by Tehulie and Belete (2021), Parmar *et al*. (2009) revealed that increased level of N fertilizer helps to induce better yields in Brassica vegetables. Similarly, Khadir *et al*. (2002) demonstrated that cabbage head yield increased with increasing the amount of N fertilizer. Cabbage being a massive consumer of nutrients (Choudhary *et al*. 2009) maximum cabbage head yields were observed from the largest amount of fertilizer treatment.

Table 1: Mean above ground biomass yield at different rates of Albert's fertilizer solution at harvesting

Rate of Albert fertilizer (g/ plant/ day)	Mean Values (kg/ plant)
1	1.24356[a]
1.5	1.18143[a]
2	1.20117[a]

However, in the present study significantly higher values for cabbage head yield was obtained for the lowest amount of fertilizer (1.0 g/plant/day) applied treatment. That may be due to the higher temperature in the low country. According to the Department of Agriculture, cabbage can be successfully grown in cool climate areas in the up country (DOA 2022). In addition, Muleke *et al*. (2014) has mentioned that cabbage is a cold weather food crop which can thrive moderately to low optimum temperatures between 15 to 20 ℃ which cabbage heading can be greatly reduced under high temperatures. Moreover, Hara and Sonoda (1982) mentioned that environmental conditions influence cabbage head formation. They further mentioned that temperature is the most significant factor among the environmental factors, through its effect on producing and consuming carbohydrates by plants. They revealed that a balanced relationship between nitrogen assimilation and carbohydrate production of cabbage plants is essential for head development. They further stated that the effect of temperature on cabbage-head formation is considerable in the case of a higher supply of N than lower supply of N. Moreover, they mentioned that decreasing head yield of cabbage and carbohydrate amounts can be described in terms of genetical susceptibility of cabbage plants to higher temperatures and utilization of carbohydrates for plant respiration. Ryle *et al*. (1976) reported respiration for the maintenance of plant rises with high temperatures and loss of carbohydrates for respiration results depletion of carbohydrate content.

Barrett *et al*. (2015) stated that air temperature affects the growth and harvest of cabbage. Furthermore, da Silva *et al*. (2020) reported that optimum air temperature for cabbage growth is between 59 and 70 °F (between 15 to 21.11℃). Paranhos *et al*. (2016) mentioned

that cabbage yield is maximized at an air temperature of 64 °F (17.778 °C). According to Gardner and Ehling (1965), high temperatures lower the water potential of cabbage leaves thereby reduce leaf thickness, which will be then caused head formation more difficult. As a result, loose heads form and cabbage head yields may reduce. Rasanjali *et al*. (2020) resulted low marketable yield and low total yield of cabbage due to increased temperature.

Therefore, these results imply that temperature more than 25°C will result in decreased development of cabbage heads. Energy deprivation through transpiration is more severe in leafy vegetables with broad leaves than in vegetables with small leaves (Hara and Sonoda 1982). In this study day temperature exceeds the optimum temperature and it was more than 30 °C. Therefore, when plant growth is high, a higher amount of produced carbohydrates might have used for the maintenance of the plant resulting low yield in cabbage heads. However, the total biomass yield (fresh weight of total above ground parts of the plant) of cabbage was not influenced by the amount of fertilizer since plants with higher vegetative features yielded lower head yield and plants with lower vegetative features yielded higher head yields which indicates the balanced photosynthate partitioning. As mentioned by Oh *et al*. (2015), the optimum temperature for photosynthesis of cabbages is below 25°C . Under low temperatures the photosynthetic rate of cabbage increased with increasing temperature, but decreased when temperatures were over 25°C.

Results of the present study reveal that split application of Albert's fertilizer solution has significant effect neither for growth nor yield parameters. Da Silva *et al*. (2020) recorded that there was no difference in the total cabbage yield grown in the loamy sand soils of Georgia when using 170 to 280 lb/acre N when applied as splits between preplant and three posttransplant applications. In addition, Coolong *et al*. (2022) reported that frequent application of liquid fertilizers (calcium nitrate-based) to cabbage throughout the crop cycle did not affect the yield compared with two larger applications of granular fertilizers.

Contrary to the findings of the present experiment Belete *et al*. (2018) recorded that the usage of N three splits (¼ at sowing, ½ at tillering and ¼ at booting) resulted in more grain yield than nitrogen usage only once at tillering or as twice splits as ½ at sowing and ½ at tillering or ½ at tillering and ½ at booting in bread wheat (*Triticum aestivum* L.). As well, increased wheat grain yield was recoded when N was used as thrice splits (at planting, tillering and post-anthesis) compared with twice (at planting and tillering) and at once (at planting) by Otteson *et al*. (2007). The grain yield increment due to the thrice split application of nitrogen might be related with better matching of N availability with crop demand during the growing season. Gharge *et al*. (2020) also observed split application of N fertilizer gave better results for growth parameters on maize.

In above mentioned experiments constructive results were reported for split application of fertilizer by dividing total N fertilizer requirement into two or more splits and adding them in various growth stages. It helped to meet crop nutrient demands at different growth stages thus, enhanced plants' ability to utilize nutrients. However, contrary to those studies, small amounts of fertilizer (1.0 g/plant/day, 1.5 g/plant/day and 2.0 g/plant/day) were applied to plants as split doses in the present study. Thus, it might have no effect on fertilizer use efficiency since cabbage plants might had the ability to use more fertilizer if we feed larger amounts than used in the present study. In addition, the nutrient requirement of the crop during the different stages of growth was fulfilled according to the received amounts of fertilizer since fertilizer was applied throughout the whole growing season.

Absorption of nutrients from Albert's fertilizer solution was more efficient than other solid fertilizers since nutrients are immediately available for plant uptake in liquid fertilizers. Thus, nutrients provided by them can be most effectively utilized by plants. Liu *et al*. (2014) mentioned that liquid fertilizers have the po-

tential to increase plant growth and development. Moreover, liquid fertilizers can increase plant metabolic activities and thus help to increase growth of plants by increasing the number of leaves, plant height, dry matter content, etc (Kumarasinghe *et al*. 2019).

Speed of the metabolic reactions increases with temperature up to a certain level. Since the usual temperature of the low country is greater than the usual temperature in up country, metabolic rate of plants in the low country is speed. Then nutrient uptake also increases. Most of the times split application is useful when the plants cannot utilize nutrients with consistency to the supply rate. However, in the current study since the temperature of the microclimate is greater and cabbage being a highly nutrients demanding crop there might not have surplus fertilizer which was wasted due to the inability of absorption by plants. That may be the reason that growth and yield parameters have no significant effect from fertilizer split. In addition, coconut coir like soilless media provides more efficient use of water and fertilizer (Asaduzzaman *et al*. 2015). Thus, this media might have provided better water and nutrient holding facilities which restricted leaching and inadequacy of nutrients. However, effect of the split application of Albert's fertilizer for growth and yield parameters of cabbage grown in protected houses should be further investigated using different amounts of Albert's fertilizer solution at different stages of plant growth.

CONCLUSIONS

1.0 g Albert's fertilizer/plant/day applied as single dose is the best treatment for cabbage grown under protected houses in low country wet zone of Sri Lanka.

AUTHOR CONTRIBUTION

UDT Perera conducted the research and wrote the paper while all the other authors supervised the research and corrected the paper.

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