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The Impact of Shading on Growth and Yield of Cabbage (*Brassica oleracea* L.) in the Low Country Dry Zone, Ampara, Sri Lanka

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Abstract

Shade level is a predominant factor that greatly influences growth, quality and yield of exotic vegetables that are grown in low and mid country dry zone areas. Accordingly, a field trial was conducted to investigate the impact of shading on growth and yield of cabbage var. "Green Coronet" in Ampara District of Sri Lanka during the period of July to November 2020. The experiment was laid out in Completely Randomized Design (CRD) with four replicates. Levels of shades were defined in two treatments as open field condition (40% shade) and 70% shade levels. The growth measurements, plant height, the number of leaves and diameter of rosette were recorded at six and eight weeks after transplanting and Analysis of Variance was performed to determine significant differences among treatments ($p < 0.05$). Further, the head weight and yield were recorded at the harvesting stage and the results revealed that the cabbage plants grown at

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70% shade level showed significantly ($p<0.05$) better performance in the measured growth parameters *viz*. plant height, diameter of rosette, number of leaves especially after 50 days of transplanting (8WAP) and yield parameters, average head weight and final yield. The lowest performance was observed in plants grown at open field conditions with 40% shade level. It can be concluded that the plants grown at 70% shade level would obtain high growth and yield with the modified temperature, relative humidity level and optimum light intensity in the protected environment. These findings will be beneficial for the farmers to grow cabbage in low country dry zone at commercial scale to obtain higher yields rather than cultivating in open field conditions.

Keywords: *Growth, Light intensity, Relative humidity, Shade levels, Yield*

Introduction

Cabbage (*Brassica oleracea* L. *var. capitata*) is one of the most important high nutritive leafy vegetables belonging to the family Brassicaceae. It is a herbaceous biennial species originated from the South and Western part of Europe (DOA, 2018). Prior to cultivation, cabbage was mainly used for medicinal purposes as it prevents constipation, increases appetite, speeds up digestion and is very useful for diabetic patients (Silva, 1986). Due to its nutritional value (Diputado, 1989) and delicious taste, cabbage is highly popular and is extensively grown in hill country of Sri Lanka as a year-round crop. It is one of the most important and an economical and rotational vegetable crop and is mainly grown in Badulla, Nuwaraeliya and Kandy districts.

Climate is a vital factor that is reported to have a greater influence on cabbage production. Pornsuriya & Teeraskulchon (1997) have revealed in their studies that exotic vegetables such as cabbage and broccoli can be planted in hill areas where the climatic condition is cool or in lowlands during the cool season. The optimum temperature for growth and development of cabbage is 15^0C to 20^0C and the required amount of water per crop vary from 380 mm to 500 mm based on environmental conditions.

Therefore, high light intensity, high temperature and low humidity levels in the low country are problems to produce cabbage. Unfavorable or dry atmospheric environments lead to impaired quality of head, poor yield and trigger the increase of pest in cabbage cultivations. The findings of Jeong et al. (2009) and Vendrame et al. (2004) concluded that light intensity can affect plant canopy, flowering, leaf size and color in herbaceous species. Due to that, yield contributing characteristics are highly affected by extreme external environmental conditions during the growing period.

In the Sri Lankan context, to reduce the crop damages from heavy rainfall and high light intensity, cabbage and other exotic vegetable crops are grown under shade nets. Shading is an important method to create suitable environment for higher growth and high yields of vegetable crops (Sampet, 1993). Wheeler (2008) stated that plant growth and productivity can be controlled by modifying the light quantity. Cabbage is a cool seasonal crop (Decoteau, 2000), and growing of cabbage under shade condition is crucial in dry zone of Sri Lanka to improve the productivity. Also, it is pertinent to note that there are limited studies conducted in low country dry zone in relation to cool seasonal crops under different shade levels. Considering the above facts, the present experiment was undertaken with the objectives of evaluating the impact of shading on growth and yield parameters of cabbage in low country dry zone of Ampara District.

Materials and Methods

A field experiment was carried out in agro-ecological region of DL 2b in the Ampara District of Sri Lanka to investigate the impact of shading on growth and yield of cabbage in low country dry zone during July to November 2020. Geographically, it is located at latitude of 07° 17′ 51.14″ N and longitude of 81° 40′ 55.27″ E at an elevation of 30 m above mean sea level. The soil of the experimental site is sandy loam. The annual mean temperature of the area is 30°C and it receives most of the rainfall from the Northeast Monsoon. Experimental design was laid out in Completely Randomized Design (CRD) with four replicates. The variety Green Coronet was selected for the study as it is a widely cultivated hybrid in most of areas and develops a good crop stand. It comprised of two treatments namely: T1: Open field condition with 40% shade and T2: 70% shade levels. For both treatments, cabbage seedlings were raised using nursery tray with rooting media (top soil and compost at the ratio of 1:1). Cabbage seeds were planted in every cell of the tray. After 30 to 35 days, healthy seedlings were transplanted in 3m x 1m size raised bed according to recommended spacing of 50cm x 40cm as an open field condition with 40% shade level. Conversely, seedlings were planted in 50-60 cm height and 25-30 cm width poly bags for raising plants and kept those in 70% shade level of net house and poly bags were arranged at the spacing of 50cm x 40cm. All other management practices were carried out as recommended by the Department of Agriculture. Growth parameters; namely plant height, diameter of rosette and the number of leaves per plant were taken at two weeks interval commencing from 6 weeks after transplanting. At harvesting (90 days from transplanting), the head weight and the yield of cabbage were measured. Statistical differences between the treatments under study were determined by analysis of variance (ANOVA) using Statistical Analysis System (SAS) software package and the mean separation was undertaken using least significant difference (LSD) at $P = 0.05$ probability level.

Results and Discussion

Plant growth parameters

Plant height

Mean values for growth parameter of plant height under different shade levels are shown in Table 1. It is revealed that weeks after transplanting, there was a significant difference ($P<0.05$) (Figure 1 and Figure 2) between the treatments. The result agrees with Israt Jahan et al. (2020) who reported that statistically non-significant variation was obtained in terms of plant height at the transplanting stage of cabbage whereas significant variations were noted in plant height at 50 days after transplanting.

Accordingly, the highest plant height was obtained in T2, in which the cabbage plants were treated with 70% shade level whereas the lowest was recorded in the plants which were grown under open field conditions with 40% shade level. Therefore, it was observed that different shades levels or different climatic conditions will impact the growth of cabbage a cool seasonal crop immensely. Findings of the study is supported by Abey et al. (2002), that the performance of any vegetable crop could be linked to environmental influences including climatic conditions.

Table 1. *Mean values of Plant height (cm)*

	Days after Planting	
Treatments	6 WAP	8 WAP
T1	21.9 ± 0.4	23.3 ± 0.7
T2	24.9 ± 0.7	26.7 ± 0.6
P-value	P<0.05*	P<0.05*
$LSD_{0.05}$	1.92	2.2

Values are means with ± standard error of the mean.

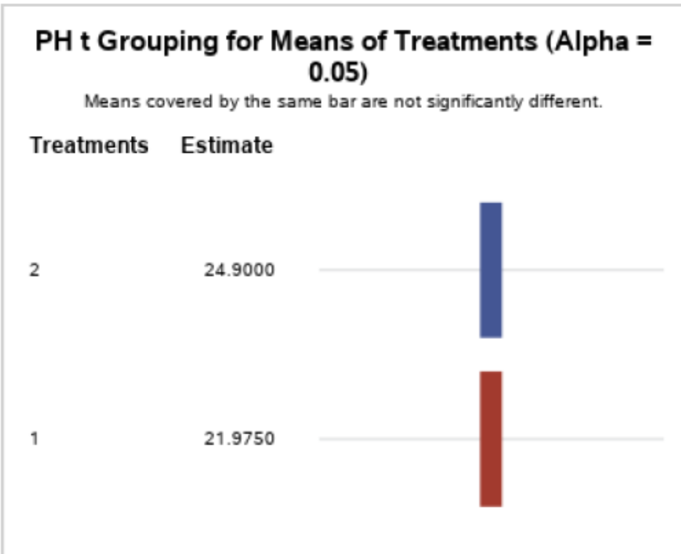


Figure 1. *Plant Height (cm) (6WAP)*

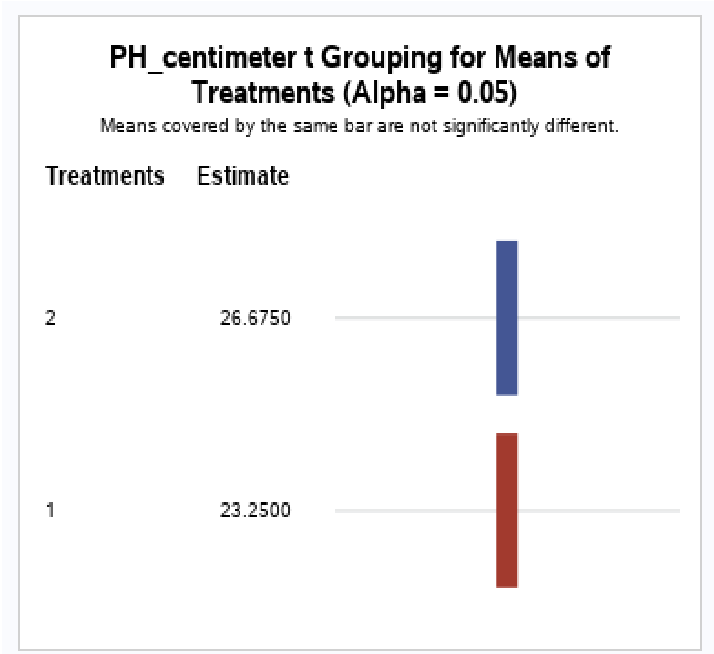


Figure 2. *Plant Height (cm) (8WAP)*

PH: Plant height
Means covered by the same bar are not significantly different by Duncan's post-hoc test at P< 0.05.

Number of leaves

Statistically significant variations (P<0.05) (Figure 3 and Figure 4) were observed among the treatments in terms of number of leaves per plant throughout the cultivation period (Table 2). These results were like that of Sajib et al. (2015). The highest number of leaves was noted in plants which were treated with 70% shade level compared with plants treated with open field conditions (40% shade level).

The reasons for the observed variations can be that shade nets play a vital role in controlling the light intensity, temperature and increase the relative humidity level in the specified micro environment. As a result, the nets provide the required favorable climatic conditions for the growth and development of cabbage to gain the maximum yield. It is also the fact that the photosynthesis is the key physiological process which determines the expected yield of any economical crop like cabbage. As already proven, the leaves are the primary source of photosynthesis. It is revealed that

70% shade level has created favorable micro climatic conditions significantly increasing the photosynthetic process and the leaf count of cabbage. Similar, results were recorded by Teshome (2019) stating that varying environmental conditions influence the expression of crop growth characters.

Table 2. *Mean values of number of leaves*

	Days after Planting	
Treatments	6 WAP	8 WAP
T1	18 ± 0.2	20 ± 0.6
T2	20 ± 0.5	23 ± 0.5
P-value	P<0.05*	P<0.05*
$LSD_{0.05}$	1.7	2.4

Values are means with ± standard error of the mean.

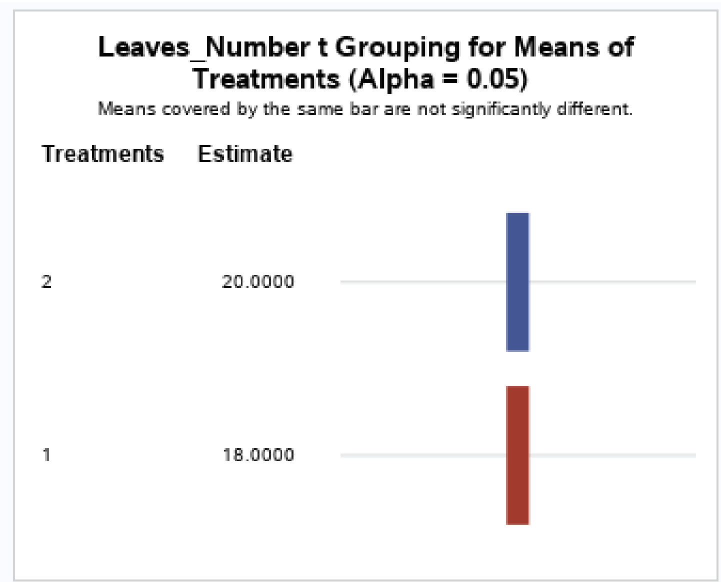


Figure 3. *Number of leaves (6WAP)*

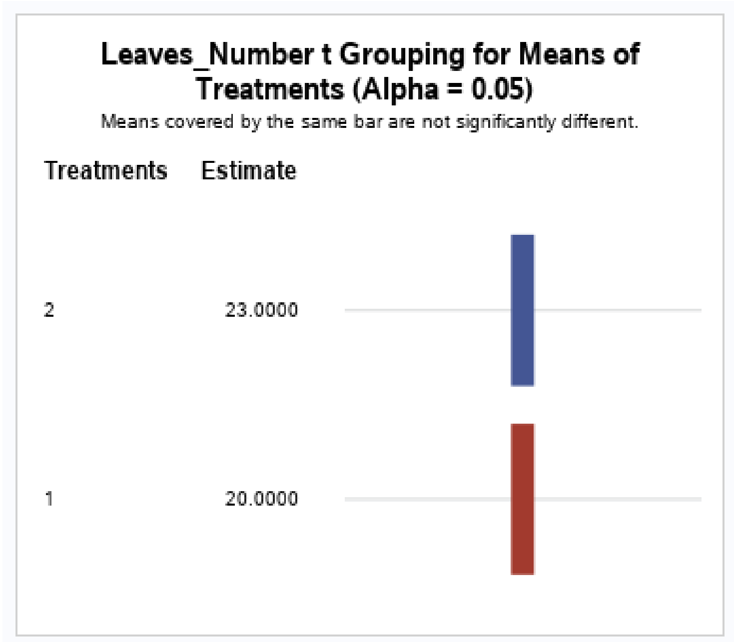


Figure 4. *Number of leaves (8WAP)*

Means covered by the same bar are not significantly different by Duncan's post-hoc test at P< 0.05.

Diameter of rosette

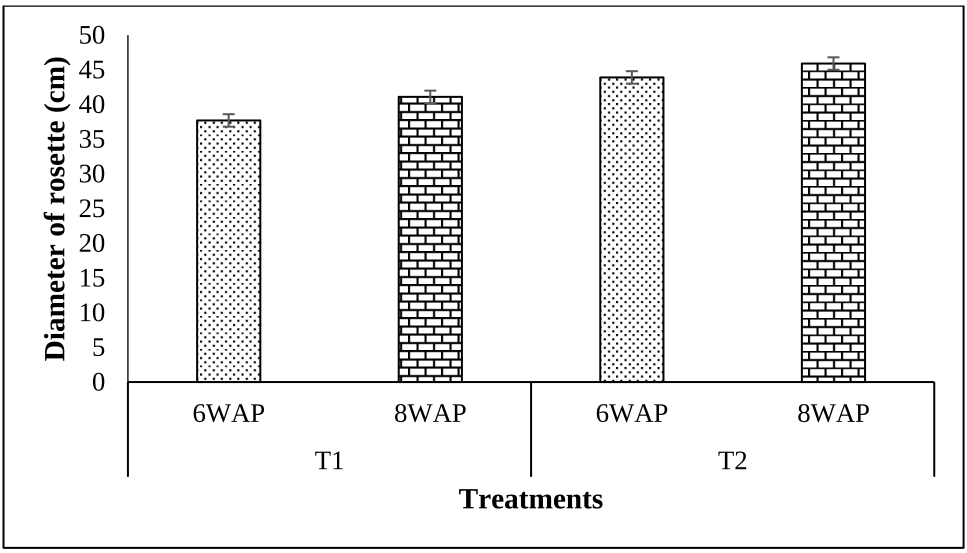
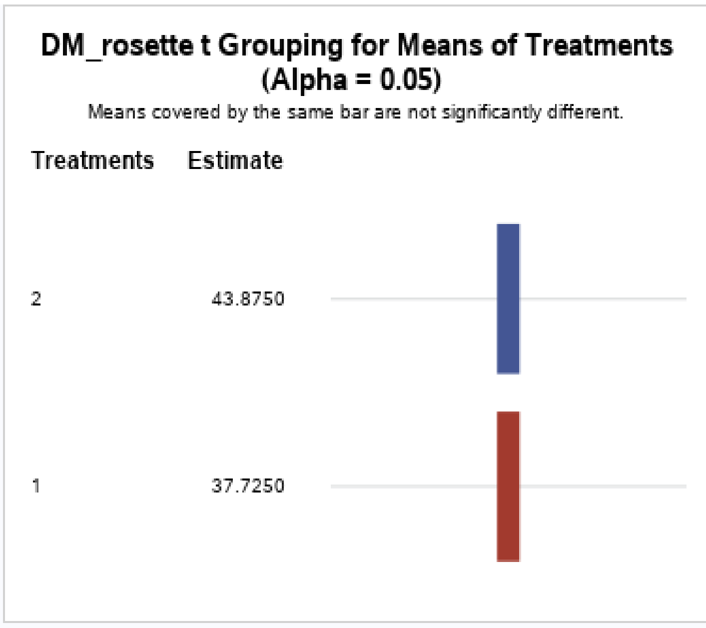


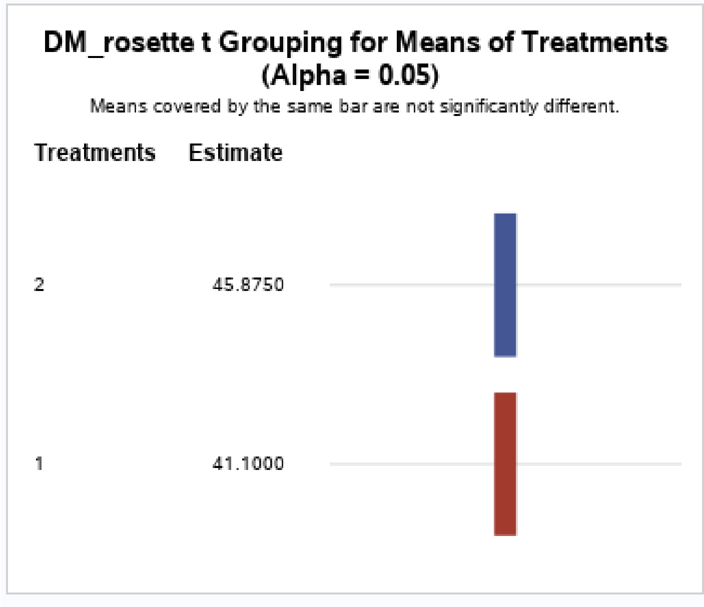
Figure 5. *Diameter of rosette (cm)*

The effect of different shade levels on mean diameter of rosette was found (Figure 5) as statistically significant ($P<0.05$) (Figure 6 and 7). The highest mean diameter of rosette was measured as 45.9 cm from T2 at approximately after 50 days of transplanting (8WAP). However, the lowest result was recorded in T1 as 41.1 cm. Dry atmospheric environmental conditions may negatively impact the outcome of a cool seasonal crop like cabbage, which may lead to drop in growth and yield attributes. In order to grow cabbage in a challenging environment, the condition has to be modified to obtain the maximum return by using the shade nets. Therefore, the growing of an upcountry vegetable in an unfavorable environmental condition such as low country dry zone under the shade nets will significantly influence on its agronomical parameters like diameter of rosette.



$LSD_{0.05} = 3.08$

Figure 6. *Diameter of rosette (cm) (6WAP)*



$LSD_{0.05} = 3.2$

Figure 7. *Diameter of rosette (cm) (8WAP)*

Means covered by the same bar are not significantly different by Duncan's post-hoc test at P< 0.05.

Average weight of head and yield

Table 3.

Mean values of cabbage head weight and yield

Treatments	Head weight per Plant(Kg)	Yield (Kg/m^2)
T1	0.9 ± 0.03	4.5
T2	1.4 ± 0.04	7.0
P-value	P<0.05*	P<0.05*

Values are means with ± standard error of the mean.

As given in Table 3 and Figure 8, there was a significant difference (P<0.05) in average head weight and cabbage yield among the treatments under varying shade levels. The factors may have contributed to a significantly higher (P<0.05) yield due to contribution of vegetative, reproductive characters and higher rate of photosynthetic process took place under the shade net conditions in T2 whereas the lowest was recorded in the T1.

Generally, under a shading net, the growth and quality of crop is affected both by light quantity and quality. When a shading net is used in agricultural crop production, the quality and quantity of light within the shade should be considered. These optimum environmental conditions encourage photosynthesis and partitioning of photo-synthesis rate into economic parts of the plant. Hence, it could be concluded that the yield of cabbage head was influenced greatly by light intensity, temperature and relative humidity and increased number of leaves per plant leading to increased average weight of cabbage head. It is in par with the statement of Meena et al., (2010) that yield and its component characters are polygenic in nature, thus influenced by the environmental factors. Further, Sundstorm & Story (1984) also found that growing season influenced head development as well as temperature had a significant effect on cabbage head shape as average head length/width ratios.

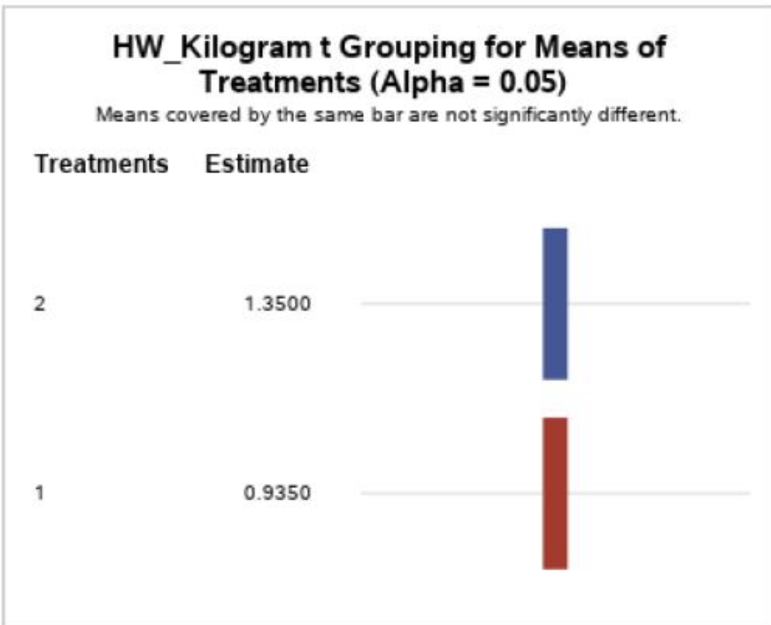


Figure 8. *Average Head weight (Kg)*

Means covered by the same bar are not significantly different by Duncan's post-hoc test at P< 0.05.

Conclusions

In Sri Lanka, particularly in the dry zone, shade nets are specified to provide protected environmental conditions for successful growth and development of exotic vegetables like cabbage against extreme external environmental conditions. Growth and physiology of a crop can vary due to environmental factors which ultimately result in high or low yield. Accordingly, results stated that, there was a significant difference among treatments in the growth parameters of plant height, the number of leaves per plant and the diameter of rosette with different shade levels throughout the cultivation period. The highest results were recorded with the treatment of 70% shade level compared to open field conditions with 40% shade level especially after 50 days of transplanting. Thereby, head weight and yield could be improved further by modified environment and eventually the overall impact of the photosynthetic capacity. As cabbage is a nutritional crop and generates high yield to farmers, it is suggested to grow cabbage under shade nets in low country dry zone like Ampara District to harness better benefits.

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