Journal of Agriculture and Ecology Research International

23(3): 45-59, 2022; Article no.JAERI.86749
ISSN: 2394-1073

Performance of *Brassica rapa* and *Brassica oleracea* under Shade net within Coastal Environment

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2022/v23i330223

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/86749

Original Research Article

Received 25 February 2022
Accepted 04 May 2022
Published 09 May 2022

ABSTRACT

Cabbages are important for income generation, human nutrition, and health promotion. Its production in the tropics is constrained by soil moisture stress and high temperatures. Sustainable production requires the adoption of technologies that modify growth environment. A study was conducted to evaluate the performance of *Brassica rapa* and *Brassica oleracea* under shade nets within coastal environments. Randomized complete block design, with three replications, was used. Treatments were: 0%, 50% and 70% shading, using black shade net. Data collected include plant height, stem diameter, crown diameter, leaf chlorophyll, number of open leaves and quality heads, and fresh head weight. Data obtained were subjected to ANOVA and means separated using Tukey's test at 5%. 70%, and 50% shading significantly increased plant height than open field by 7.1cm and 5.3cm respectively. Number of open leaves and leaf chlorophyll content in both cabbages decreased with increase in shading intensity. *Brassica rapa* under 70% and 50% shading had 55% and 47.5% more yield than open field respectively, while *Brassica oleracea* under 70% and 50% shading had 62.5% and 53% more yield than open field respectively. *Brassica rapa* under 70% shading had 0.8 kg more fresh weight per plant than open field while 50% had 1 kg. *Brassica oleracea* had 1 kg more fresh weight per plant than open field in both 70% and 50% shading. Therefore, black shade net of 50% and 70% shading favoured cabbage production in a coastal environment and they can be used in areas with similar ecological conditions.

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Keywords: Cabbages; shade nets; coastal environment.

1. INTRODUCTION

Cabbage is an important vegetable that is widely consumed in Kilifi county and in Coastal region of Kenya as a whole. It provides fibre, minerals ions, such as calcium, iron, sodium, zinc, magnesium, phosphorus, potassium, and vitamins A, C, E, K that are crucial in human nutrition [1]. They also have phenolic and glucosinolates that are anti-carcinogenic, prevent type 2 diabetes, cardiovascular diseases, and inflammation of digestive systems [2,3]. Despite the high rate of consumption, local cabbage production has been constrained by the hot coastal climate, drought and poor soils, mainly aggravated by global warming [4,5,6,7].

However, studies have shown that it is possible to cause production of cabbages in areas with such harsh climatic conditions as Kilifi through use of appropriate technologies that modify the production microclimate [8,9,10,11]. Therefore, this study was conceived to assesses the effects of black shade net on performance of *Brassica rapa* and *Brassica oleracea* in Kilifi county.

2. MATERIALS AND METHODS

2.1 Site Description

The study was conducted at Pwani University farm from July 2020 to September 2020 and from December 2020 to February 2021. The farm is located at 39.85°E and 3.62°S in Kilifi County, which lies 30 m above sea level. The area experiences average annual rainfall of 900 to 1100 mm, with long rains distributed from April to June, and short rains from October to December. It also experiences average minimum and maximum temperatures 29 to 32 ^{o}C [12]. The dominant soils within the area are ferralic and dystric cambisols containing low levels of carbon [12].

2.2 Materials

Black shade nets of 50% and 70% light reduction were sourced from Graduate Farmers Ltd-Eldoret, Kenya. *Brassica oleracea* (white cabbage) seeds (cv. Rossy F1) and *Brassica rapa* Chinese cabbage (cv. Nice F1) seeds were sourced from Continental seed company, Nairobi. These seed varieties were convenient because of their fast growth and maturity ranging from 60-70 days after transplanting.

2.3 Nursery Establishment

White cabbage (*Brassica oleracea*) and Napa cabbage (*Brassica rapa*) nursery beds were established using standard nursery preparation methods as described by KALRO, [13]. The land was cleared by cutting the bush using a machete and cultivated to a fine tilth. The measurements of the nursery beds were 1 m by 2 m. 200 g di-ammonium phosphate fertilizer (of grade DAP: 18% N: 46% P_2O_5: 0% K) was broadcasted on both nursery beds and mixed with soil. Small drills were made using a stick at an interval of 10 cm then seeds were evenly placed into the drills and covered with light soil. Dry grass mulching was applied, and a shade was erected. Twenty litres of water was applied to nursery beds daily in the evening. All other recommended nursery management practices were carried out including; weeding, pest control, and hardening off when deemed necessary.

2.4 Experimental Design and Treatments

The experiment was laid in randomized complete block design and replicated three times. The treatments included: three (3) levels of shading intensity using black nets (70% shading, 50% shading, and open field) and two (2) cabbage species *Brassica oleracea* (white cabbage) and *Brassica rapa* (Napa cabbage). Each experimental block measured 4 by 4 m and was then divided at the centre, where each half was planted *Brassica oleracea* and the other *Brassica rapa.* At the edges of the two treatments designated for 50% and 70% shading, metallic frames were erected, and cross ties were fixed on top from one metal pole to another. The black shade nets were then placed on top and sideways of each metallic frame. A small entrance was made on one side. The plots under treatment were cultivated manually using a hoe. After one week, farmyard manure was applied in every treatment and thoroughly mixed with soil at a rate of 2.5 t ha^{-1} before transplanting as recommended by Saha [14].

2.5 Transplanting

After the seedlings had attained a recommended height of 10 to 12 cm, they were transplanted. The transplanting exercise was conducted in the evening when temperatures were low. Each nursery was watered with 5 litres of water 30 minutes before transplanting to minimize root damage. During transplanting, holes were dug at a spacing of 40 cm by 40 cm. From the margins, 30 cm was left as guard rows, resulting in five (5) rows and ten (10) plants per row amounting to 50 plants per cabbage type in every block. Ten grams (10 g) of DAP fertilizer was placed in every hole before seedlings were transplanted at a rate of 250 kg/ha [15]. After transplanting, watering was done. In subsequent watering, the amount of water applied in every treatment was uniform. Grass mulching of 15 cm thick was applied one month after transplanting as recommended by Kelley et al. [16]. Topdressing was at the total rate of 215 kg ha^{-1} using calcium ammonium nitrate (CAN) per plant using two spoonfuls when the crops started forming heads. Weeds, pests, and diseases were monitored and controlled regularly as recommended.

2.6 Data Collection and Parameters Measured

Seven (7) days after transplanting, 5 plants in each plot were randomly selected and tagged from each of the 3 middle rows, giving a total of fifteen (15) plants per cabbage type. These plants were used for data collection every week, beginning from the second week after transplanting until maturity, to determine plant height, stem diameter, crown diameter, number of leaves, leaf chlorophyll content, quality of head formation, and fresh head weight. Air temperature, was determined throughout the growing period in every treatment using thermometers suspended using wooden poles at the level of crop height, at an interval of 3 days. Plant height, was determined from the tagged plants by measuring their height from the base of the plant to the tallest leaf using a tape measure. Stem diameter, was determined by twinning a string around the stem circumference, immediately below the base of the first leaf, then stretching it on the tape measure to determine the length of the circumference and then dividing the outcome by pie, (π = 3.14) to obtain stem diameter. Crown diameter, was determined by measuring the diameter of the foliage using a tape measure. The number of leaves, were determined by physically counting the number of open leaves on the tagged plants. Leaf chlorophyll, was determined as described by Rodriguez [17], using a chlorophyll meter (Model: SPAD-502-Plus, Decagon devices), from the most recent open leaves of the tagged plants. Quality of cabbage heads, was determined by i) visually assessing the compactness of the cabbage heads, in terms of being compact, fairly compact, loose heads and leafy head or no head formation; ii) by assessing the firmness of the cabbage heads by hand pressing and iii) through density determination. Density determination was done by weighing the harvested cabbage heads using an electronic weighing machine (Model PM 200, Mettler Instrument Limited, Switzerland), then divided the volume of the cabbage which was determined by tightly covering the head of each harvested cabbage from every treatment with a pre-determined cap of rubber and immersing it into the water in a displacement can. The volume of the displaced water was equivalent to the volume of the cabbage head. Finally, the quality of the cabbage head was determined using the formula described by Pearson [18].

$$QH = \frac{\text{Weight of heads (Kg)}}{\text{Volume of water} - \text{Volume of rubber cap}}$$

Fresh head Weight**,** was determined by cutting the heads of the tagged crops from the stem and obtaining their fresh weight using an electronic balance.

2.7 Data Analysis

Data collected was then subjected to ANOVA using the GLM procedure of SAS Version 13. The means obtained were compared using Tukey's honest significant difference (THSD) test at 5% level of significance.

3. RESULTS AND DISCUSSION

It is important to note that, during the study period, in the season one (July to September), air temperature was relatively low than in the season two (December to February). Therefore in the season two, the transplanted seedlings in the open field all dried by the third week due to high ambient temperatures, despite adequate watering. *Brassica rapa* had a shorter maturity period than *Brassica oleracea*.

3.1 Prevailing Weather Conditions in the Research site during the Experimental Period

During the first season, the average maximum and minimum atmospheric air temperature experienced in Kilifi at the study site was 29.7^{o}C and 23.7^{o}C respectively while in the second season it was 31.7^{o}C and 24.5^{o}C respectively.

The average amount of monthly rainfall experienced during season one was 23.5 mm while in season two, there was no rain (Table 1). Cabbage's optimum temperatures for growth and development range from 15°C to 20 °C, while water requirement varies from 380 mm to 500 mm per crop throughout the growing period [19,20]. Thus, from the data obtained the ecological conditions within the site were not favourable for cabbage production.

3.2 Effects of Black Shade net on Cabbage Height

Brassica oleracea and *Brassica rapa* heights were significantly influenced by the shading intensity of the black shade net (Fig. 1). *Brassica rapa* under 70% shading recorded the highest height, while open field recorded the lowest. A similar trend was observed on *Brassica oleracea* however, the height of the crops under 70% shading and 50% shading were not significantly different. An increase of cabbage height in shade nets can be attributed to the ability of shade nets to intercepts light waves thus lowering light intensity [21]. Low light intensity in return stimulates the synthesis of gibberellin (GA) which accelerates elongation of nodes, internodes and cells expand more to receive light for photosynthesis [22].

Potter et al. [23] reported increased gibberellin contents with decreasing light intensity from 500 to 25μmolm-2 s-1 in stems of *Brassica napus* seedlings which considerably increased plant height. Lower light intensity also induces shoot and stem elongation as a shade avoidance mechanism causing plants to grow taller to increase their light interception and to facilitate the photosynthetic processes [24]. In a similar study, Muleke et al. [25] assessed the use of eco-friendly nets on sustainable cabbage seedling production in Africa and noted seedlings that were grown under nets grew taller compared to seedlings under open nurseries. Similarly, Bandara et al. [21], carried out research in Sri Lanka noted too, that the use of shade nets regardless of colour increased the height of *Brassica oleracea* seedlings as compared to the open experiment. Equally in an experiment conducted using black and green shade nets on tomato and intercropping tomatoes with maize and sunflower, green and black shade net produced the highest significant plant height as opposed to open field [26]. Lang'at et al. [27], after using grey, yellow, blue, white, and multi-coloured shade nets, also noted longer internodes length and longer stems of tomatoes as opposed to open field.

3.3 Effect of Black Shade net on Cabbage Crown Diameter

The use of black shade net didn't significantly influence cabbages crown diameter throughout during season one however in season two it significantly influenced. *Brassica rapa* was significantly influenced in weeks 1 and 2 during season one, while in season two it was significantly influenced throughout the season (Table 2). On the other hand, *Brassica oleracea* was insignificantly influenced in weeks 1, 4, and 5 during season one, while in season two it was significantly influenced in week; 1, 2, 3, 7, and 12 (Table 3).

A significant increase in crown diameter in the shade nets in the first weeks after transplanting was in line with, Muleke et al. [25] who obtained that use of eco-friendly nets improved the Brassica seedlings' vigour. Shade modify the crop growing environment thus providing a conducive environment for vigorous plant growth [28, 29].

Table 1. Average monthly temperature (^{o}C) and rainfall at Pwani University, Kilifi

Year	Month	Maximum Temperature (^{o}C)	Minimum Temperature (^{o}C)	No. of rainy days	Rainfall (mm)
2020	August	29	23	10	22.9
2020	September	29	23	9	36.3
2020	October	31	25	3	11.2
2020	November	31	25	0	0
2020	December	31	25	0	0
2021	January	30	24	0	0
2021	February	32	26	0	0
2021	March	32	26	0	0
2021	April	33	26	0	0

Source: Pwani University Agrometeorological weather station, Kilifi

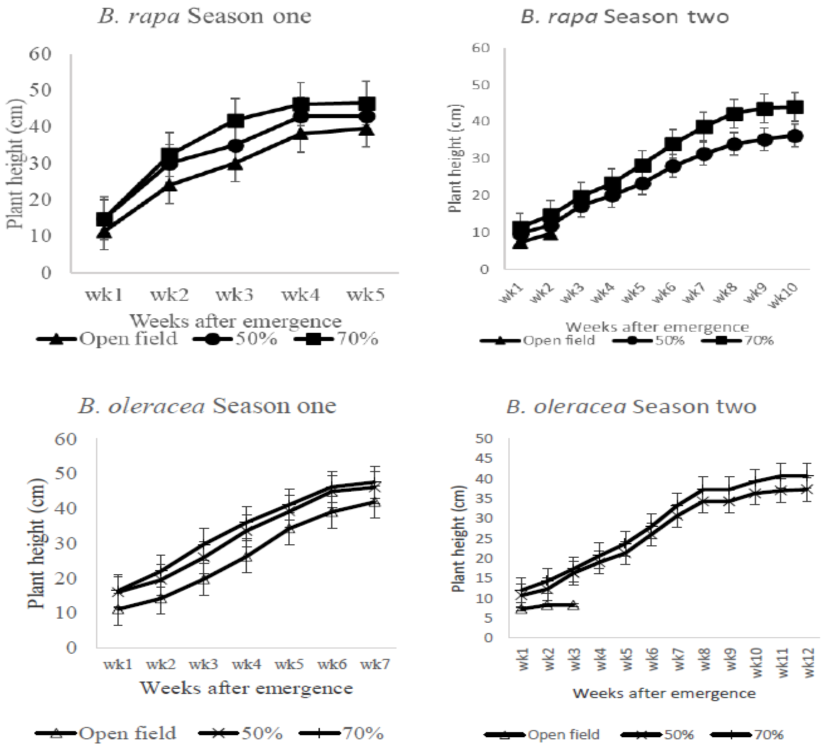

Fig. 1. *Brassica rapa* and *Brassica oleracea* plant height (cm) as influenced by black shade net during season one and two at Pwani University farm. Data was not collected from open field treatment during the season two due to failure of seedrings to survive after transplanting because of high air temperature

This micro-climate modification consequently improves plant physiological activities [16]. Abul-Soud et al. [30] and Iglesias [31] suggested that the use of nets reduced plant water stress, increased photosynthesis, and availability of carbohydrates leading to an increase in plant vigour. However, during the last weeks of harvesting open fields had the highest crown diameter compared to shade nets. As noted, high temperatures increase vegetative growth and the number of leaves of cabbages [32].

In this study, wider crown diameter recorded under open field during the last days of maturity could therefore be as a result of high temperature experienced outside the nets which let leaves open up covering a wider area as compared to the netted area. Increased light intensity has for long been known to result in thickening of cells and therefore shortening of internodes in most plants, while decreased light is known to result in elongation of cells, and therefore elongation of internode length and therefore increased plant height [33].

3.4 Effects of Black Shade net on Cabbage Stem Circumference

Cabbages stem circumference was not significantly influenced by shade net intensity consistently (Fig. 2). *Brassica rapa* recorded higher stem diameter under 70% shading and the lower diameter under open field, on the other hand, *Brassica oleracea* showed higher stem diameter under 50% shading and lowest under the open field. The current research, therefore, differs from other research work Aied et al*.* [34], while working on "Growth response of eggplant (*Solanum melongena*) to shading and cultivation inside a greenhouse in a tropical region" found stem diameter of eggplant subjected to shading being smaller in size compared to those under the open field. On the other hand, stem diameter was found to be small in the unshaded treatment compering compared to shaded crops [35]. Qiao et al*.* [36] and Saka [37], argued that the low light density experienced in the shade nets caused etiolation leading to a decrease of stem girth in plants**.** However, Semida et al. [38] reported contrary results where stem diameter increased with an increase in shade level.

Table 2. Crown diameter of *Brasicca rapa* as influenced by black shade net

				Season one						
Weeks after emergency	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk5**	**Wk6**	**Wk7**	**Wk8**	**Wk9**	**Wk10**
0% shading	20.9b	28.3b	49.8a	54.7a	54.8a					
50% shading	26.4a	38.4a	54.5a	55.2a	55.4a					
70% shading	28.1a	41.7a	51.6a	53.2a	53.4a					
p_{Value}	0.0121s	0.0023s	0.1620ns	0.1949ns	0.1892ns					
CV%	6.4	5.3	4.6	2.1	2.0					
				Season two						
Open field	11.5c	15.2c	**	**	**	**	**	**	**	**
50% shading	19.5b	31.8b	37.0b	42.0b	45.8b	52.3a	54.3a	55.4a	56.1a	57.1a
70% shading	22.5a	34.7a	42.8a	46.4a	49.2a	52.2a	53.9b	54.9b	55.6b	55.8b
p_{Value}	0.0001s	0.0001s	0.0033s	0.0028s	0.0243s	0.05s	0.0494s	0.0494s	0.0263s	0.0135s
CV %	1.6	1.5	1.0	0.6	1.4	0.1	0.3	0.2	0.2	0.3

***-Missing data, s- significant and ns-not significant. Crops in the season one matured faster than in second trial due to increase in temperature in season two. Means followed by same letters within a column are not significantly different according Tukey's Honestly Significant Difference Test (P≤0.05)*

Table 3. Crown diameter of *Brasicca oleracea* as influenced by black shade net

						Season one						
Weeks after emergency	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10	Wk11	Wk12
Open field	6.2b	17.4b	23.2b	34.2b	45.3a	49.8a	51.3a					
50% shading	14.2ab	27.0a	32.9a	41.0a	47.5a	52.5a	52.8a					
70% shading	15.2a	27.8a	34.5a	41.9a	46.3a	45.6b	45.8b					
p_{Value}	0.0718ns	0.0061s	0.0148s	0.0632ns	0.3974ns	0.0166s	0.0007s					
CV%	31.0	8.5	9.3	7.6	3.8	3.4	1.5					
						Season two						
Open field	5.5c	11.9c	10.9b	**	**	**	**	**	**	**	**	**
50% shading	11.2b	19.6b	30.2a	37.5a	42.4a	45.9a	49.6a	52.5a	56.6a	54.4	55.0a	54.9a
70% shading	15.3a	24.4a	29.5a	35.7a	40.0a	44.0a	46.0b	50.8a	52.6a	53.9	54.3a	54.4b
p_{Value}	0.0001s	0.0001s	0.0001s	0.0766ns	0.0518ns	0.0549ns	0.0150s	0.0637ns	0.1360ns	0.0820ns	0.1086ns	0.0390s
CV%	3.7	2.6	3.3	1.8	1.7	1.3	1.1	1.1	1.1	0.3	0.6	0.2

***-Missing data, s- significant and ns-not significant. Crops in the season one matured faster than in season two due to increase in temperature in season two. Means followed by same letters within a column are not significantly different according Tukey's Honestly Significant Difference Test (P≤0.05)*

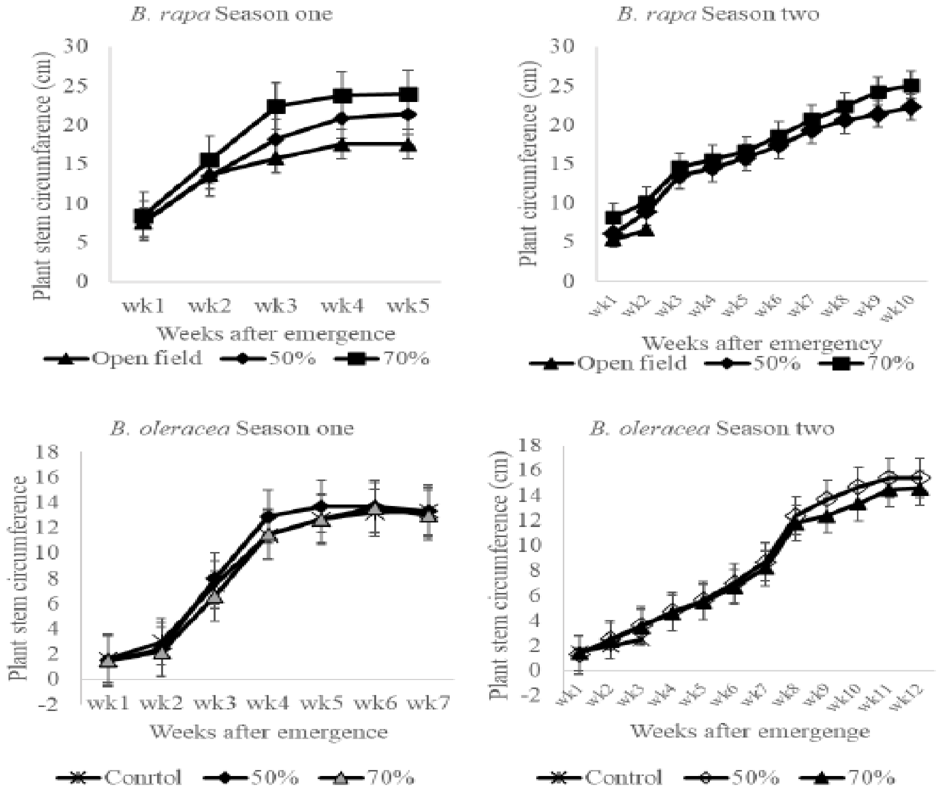

Fig. 2. *Brassica rapa* and *Brassica oleracea* stem circumference as influenced by black shade net during season one and two at Pwani University farm. Data was not collected from open field treatment during the season two due to failure of seedrings to survive after transplanting because of high air temperature

This unclear and irregular effect of shade netting on stem circumference in the current study can therefore be linked to the genetic properties of the plants to its homeostatic functions. Aied et al. [34], further suggested that genetic traits, especially at the first stages of plant growth, influence the response of stem diameter to light intensity. A similar case was as well explained in a study on different cultivars of soya beans to light intensity using shade nets, [39].

3.5 Effects of Black Shade Net on the Number of Cabbage Leaves

The number of cabbage open leaves was significantly affected by shade nets although inconsistently with 50 and 70% shade nets recording a higher number of leaves compared to open field during the first weeks in season one. During season two, *Brassica rapa* under 70% shading showed the highest number of open leaves consistently (Table 4). A similar trend was observed on *Brassica oleracea* (Table 5).

As explained by Hara [32], continuous exposure of cabbages to higher temperatures leads to leaves unfolding and this could be the possible reason for more number leaves in the open field than in the shade nets during the last days to harvesting in season one. Ayeni et al. [40], equally found more leaves per plant that were exposed to full sunlight than those grown under 75% light interception and 50% light interception respectively. Similarly, the light intensity had a significant ($P < 0.05$) effect on *Jatropha curcas* seedlings leaves, where the highest mean number of leaves were observed in seedlings without light intensity restriction, followed by seedlings covered with 40% and 60%, shade net [37]. Yasoda et al. [41], as well found the highest number of leaf formations under 50% shade level and the lowest in 75 % shade level. In contrast, Semida et al. [38], obtained the number of leaves per transplant, significantly ($P \leq 0.05$) increased with shading levels. In the current study, during the earlier weeks after transplanting, the number of leaves was more in the nets than outside possibly due to favourable environmental conditions in the shade nets than open fields [8].

Table 4. Number of open leaves of *Brasicca rapa* as influenced by black shade net

					Season one					
Weeks after emergency	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk5**	**Wk6**	**Wk7**	**Wk8**	**Wk9**	**Wk10**
Open field	8.3a	13.0a	15.3a	18.0a	19.7a					
50% shading	10.7b	13.0a	16.0a	17.0a	16.3b					
70% shading	10.3b	13.0a	16.0a	15.7b	15.7b					
p_{Value}	0.0246s	1.0000ns	0.4444ns	0.0142s	0.0037s					
CV%	6.8	4.4	4.2	3.1	3.9					
					Season two					
Open field	4.0b	5.3b	**	**	**	**	**	**	**	**
50% shading	5.3a	6.7a	10.0a	12.7a	14.7a	16.0a	17.8a	18.0a	18.3a	18.3a
70% shading	5.3a	7.0a	10.3a	13.3a	15.7a	17.3a	18.3a	19.0a	20.7a	20.7a
p_{Value}	0.0567ns	0.0156s	0.4226ns	0.1835ns	0.2254ns	0.0572ns	0.2254ns	0.2254ns	0.2222ns	0.2254ns
CV%	10.8	6.4	4.0	3.1	4.7	2.4	4.0	3.8	8.4	7.3

***-Missing data, s- significant and ns-not significant. Crops in the season one matured faster than in season two due to increase in temperature in season two. Means followed by same letters within a column are not significantly different according Tukey's Honestly Significant Difference Test (P≤0.05)*

Table 5. Number of open leaves of *Brasicca oleracea* as influenced by black shade net

						Season one					
Weeks after emergency	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk5**	**Wk6**	**Wk7**	**Wk8**	**Wk9**	**Wk10**	**Wk11**	**Wk12**
Open field	5.7b	6.7b	10.7b	13.7b	14.0b	14.3ab	16.7a					
50% shading	6.7a	10.0a	13.0a	16.0a	17.0a	16.7b	10.3a					
70% shading	7.3a	9.7a	13.0a	15.0a	15.3ab	14.3a	13.0a					
p_{Value}	0.0091s	0.0005s	0.0336s	0.0500s	0.0233s	0.0316s	0.3589ns					
CV%	5.1	3.8	6.4	5.3	5.1	4.3	35.7					
						Season two						
Open field	4.0b*	4.7b*	5.3c	**	**	**	**	**	**	**	**	**
50% shading	4.3ab	5.7ab	7.0b	9.0a	10.7a	13.0a	15.0a	16.7b	18.7b	20.0a	21.3b	22.0a
70% shading	5.3a	6.7a	8.7a	10.7a	12.7a	15.3a	17.7a	19.3a	21.0a	22.7a	23.3a	24.0a
p_{Value}	0.0772ns	0.0625ns	0.0055s	0.1296ns	0.0742ns	0.1181ns	0.1462ns	0.0153s	0.0198s	0.0572ns	0.0001s	0.0742ns
CV%	11.6	12.5	8.2	8.3	6.1	7.6	5.0	2.3	2.1	3.8	0.1	3.7

***-Missing data, s- significant and ns-not significant. Crops in the season one matured faster than in season two due to increase in temperature in season two. Means followed by same letters within a column are not significantly different according Tukey's Honestly Significant Difference Test (P≤0.05)*

Table 6. Leaf chlorophyll content of *Brasicca rapa* as influenced by black shade net

					Season one					
Weeks after emergency	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk5**	**Wk6**	**Wk7**	**Wk8**	**Wk9**	**Wk10**
Open field	37.4a	34.4a	37.9a	41.3a	39.9a					
50% shading	31.1b	32.6b	35.6b	40.3b	38.3b					
70% shading	28.9b	31.4c	34.6c	36.4c	36.5c					
p_{Value}	0.0026s	0.0045s	0.0016s	0.0001s	0.0018s					
CV%	3.8	1.5	1.2	0.8	1.2					
					Season two					
Open field	30.5a	32.1b	**	**	**	**	**	**	**	**
50% shading	30.7a	34.6a	32.9a	31.3a	35.9a	39.1a	37.8a	36.1a	35.1a	37.7a
70% shading	27.3b	30.1c	28.9b	27.8a	33.3a	35.9b	35.6a	33.6b	32.9a	31.0b
p_{Value}	0.0048s	0.0061s	0.0466s	0.0628s	0.0946ns	0.0425s	0.0580ns	0.0222s	0.0553ns	0.0318s
CV%	2.1	2.5	3.6	3.9	3.0	2.2	1.9	1.3	1.9	1.9

***-Missing data, s- significant and ns-not significant. Crops in the season one matured faster than in season two due to increase in temperature in season two. Means followed by same letters within a column are not significantly different according Tukey's Honestly Significant Difference Test (P≤0.05)*

Table 7. Leaf chlorophyll content of *Brasicca oleracea* as influenced by black shade net

						Season one						
Weeks after emergency	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10	Wk11	Wk12
Open field	43.2a	49.0a	55.0a	53.4a	53.7a	50.8a	52.3a					
50% shading	46.4a	43.9b	49.9b	50.6a	52.4b	48.2b	46.8b					
70% shading	44.9a	39.1c	47.9b	47.8b	47.6b	46.3c	44.5c					
p_{Value}	0.1571ns	0.0001s	0.0011s	0.0038s	0.1819ns	0.0011s	0.0009s					
VC%	3.5	1.5	1.6	1.6	5.5	1.1	1.8					
						Season two						
Open field	42.0a	42.9b	42.9c	**	**	**	**	**	**	**	**	**
50% shading	44.2a	45.5a	48.2a	45.2a	44.7a	49.4a	50.4a	49.0a*	48.3a	44.7b	43.5a	43.4a
70% shading	42.5a	43.6ab	45.6b	43.9a	43.4a	47.2Sb	47.4b	46.9a	45.6b	43.0a	42.5b	41.8b
p_{Value}	0.2475ns	0.0649ns	0.0014s	0.0821ns	0.0606ns	0.0082s	0.0005s	0.0632ns	0.0632ns	0.0134s	0.0067s	0.0075s
CV%	3.3	2.2	1.4	1.1	1.0	0.5	0.2	1.4	1.4	0.6	0.3	0.4

***-Missing data, s- significant and ns-not significant. Crops in the season one matured faster than in season two due to increase in temperature in season two. Means followed by same letters within a column are not significantly different according Tukey's Honestly Significant Difference Test (P≤0.05)*

3.6 Effect of Black Shade net on Leaf Chlorophyll Content of Cabbages

Black shade net was observed to significantly influence *Brasicca rapa* leaf chlorophyll content in both seasons 1 and 2 with 70% shading recording the lowest leaf chlorophyll content followed by 50% shading while the highest leaf-chlorophyll content was observed under open field (Table 6). *Brassica oleracea* on the other hand was not significantly influenced consistently, although it was noted that chlorophyll content was more under open field and decreased with an increase in shading intensity (Table 7). Similar results were obtained by Ilić et al*.* [42] who reported significantly higher total chlorophyll content in tomato plants grown under shade nets (black and blue nets) than those grown in the open field. Bergquist et al*.* [43], equally found that the concentrations of total chlorophylls in baby spinach leaves were significantly higher under the nettings. Souza et al. [44] and Oliveira et al*.* [45] also reported significantly higher total chlorophyll content in plants grown under the blue net.

Studies that indicated an increase in the total leaf chlorophyll content in the netted area suggested that this could be due to modification of the plant leaves as a mechanism of harnessing more light energy to compensate for the light intercepted by the nets [46]. However, contrary to the above research and in line with the current study, Björkman, [47] found *Solidago virgaurea* clones adapted to light environment, had more total chlorophyll content when they were grown under high light and high temperature than those under low light and high temperature, of which they suggested, this could be due to genetic difference in carboxydismutase enzyme and natural selection where under high light, more carboxydismutase enzyme was recorded. Soybean leaves from low light and high temperatures were also found to have low total chlorophyll than leaves from high light and high-temperature micro-climate [48]. The total chlorophyll contents of purple pak-choi *Brassica rapa* were equally significantly reduced consistently after exposure to low light intensity as compared to those grown under normal light intensity. Bell [49], found that the perpetual shade caused a 38% decrease in color and etiolation of *Agrostis stolonifera,* but treatments that received 6 hours of shade and full sun treatment had more chlorophyll (46%). A Similarly case by, Crookston et al*.* [50], found that shading consistently resulted in thinner and frequently smaller leaves, thus reducing the volume of photosynthetic cells per leaf or unit leaf area in beans. Chonan [51], equally noted the thickness of mesophyll and the number of photosynthetic cells per square millimeter in leaves decreased concurrently with a decrease in light intensity. As suggested by, Björkman [52], plants occupying sunny habitats, their total chlorophyll content is greater than shade species due to carboxydismutase enzyme whose formation is induced by light energy, which in return leads to the formation of chlorophyll a. Insufficient light intensity also leads to reduced photosynthetic active radiation (PAR), and leaf chlorophyll content as suggested by Fukuoka et al*.* [53].Therefore, in the current study, a decrease in chlorophyll content in the shaded cabbages could be due to the effect of photosynthetic enzyme carboxydismutase (ribulose-l,5-diphosphate carboxylase). Also, the malondialdehyde enzyme could be another factor for low chlorophyll in cabbage under shade nets. This enzyme is believed to damage plant cells including photosynthetic cells and it increases under low light intensity, as suggested by, Zhu et al. [54].

3.7 Effect of Black Shade net on Cabbage Quality head Formation

Black shade net shading significantly influenced the quality of head formation of *Brassica rapa* and *Brassica oleracea* in both seasons (Fig. 3).

In general, *Brassica rapa* under 70% shading recorded 73% and 26% more cabbage heads than the open field in both seasons one and two respectively, while 50% shading recorded 70% and 16% more cabbage heads than the open field in season one and two respectively. On the other hand, *Brassica oleracea* under 70% shading recorded 92% and 32% more cabbage heads than the open field in both seasons one and two respectively, while 50% shading recorded 88% and 17% more cabbage heads than the open field in season one and two respectively. In all growing seasons, more cabbages were harvested from 70% shading, followed by 50% and lowest under the open field. This yield difference can be linked to the difference in air temperatures recorded under these treatments. Cabbages being a cool and humid crop, 70% shading which recorded the lowest air temperature had the highest number of quality heads, and open field which recorded the highest temperature had the lowest number of quality heads. As explained by Hara [32], an increase in temperature consequently hinders cabbage head formation, delaying the maturity by increasing vegetative growth and number of leaves leading to the formation of loose heads or failure of head formation. More days to maturity experienced during season two can as well be associated with high temperatures experienced in season two than in season one.

3.8 Effect of Black Shade net on Cabbage Fresh Head Weight

Shade nets were also noted to have significantly influenced cabbages fresh head weight in all growing seasons (Table 8). During season one *Brassica rapa* heads under 50% shading had 1.1 kg fresh weight than those under open field while those under 70% shading had 0.8 kg more weight than in open field during season one, but in season two, 50% and 70% shading had 0.7kg and 1kg more weight than those under open field respectively.

Brassica oleracea under 50% and 70% shading had 1 kg and 1.5 kg more fresh weight than open field in season one respectively, while in season two, cabbages under 50% and 70% shading had 0.7 kg and 1.1 kg more fresh weight than those under open field respectively. In correlation with the current study, Chinese cabbage heads grown under floating row covers of perforated polyethylene and polypropylene were heavier than those from control plants [55]. Equally fresh weight of Chinese cabbage was greater under plastic row covers compared to control plants [56]. As well in research conducted on lettuce, heavier heads were obtained from plants grown under shade net cover than in open fields [57,58]. Broccoli heads grown under row cover perforated polyethylene plastic were also significantly heavier than those from the open field [59]. It was obtained as well fresh head yield of 'Waianae Strain' green mustard cabbage 186 decreased linearly with increasing shade in both Fall 1987 and Spring 1988 [60]. The current study supports these findings with fresh head weight being enhanced under shade nets perhaps due to reduced air temperature and increased soil moisture under shade net leading to favourable conditions for cabbages.

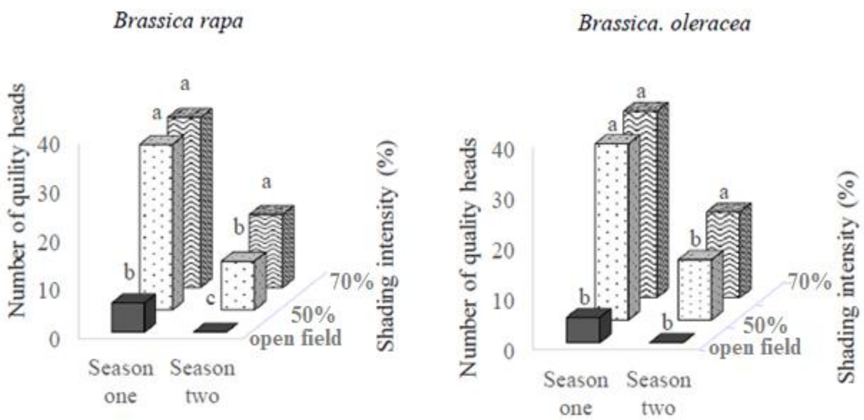

Fig. 3. Number of quality heads formed for *Brassica rapa* and *Brassica oleracea* as influenced by black shade net during the season one and two at Pwani University farm. **-Missing data; Data was not collected from open field treatment during the season two due to failure of seedrings to survive after transplanting because of high air temperature

Table 8. Mean of fresh head weight of *Brassica rapa* and *Brassica oleracea* as influenced by black shade net

Cabbage types	*Brassica rapa*		*Brassica oleracea*	
	Season one	Season two	Season one	Season two
Open field	1.7c	0.0c	1.1c	0.0c
50% shading	2.8a	0.7b	2.1b	0.7b
70% shading	2.5b	1.0a	2.6a	1.1a
p_{Value}	0.0002s	0.0003s	0.0016s	0.0003s
CV%	3.6	14.4	9.6	15.6

Means followed by same letters within a column are not significantly different according Tukey's Honestly Significant Difference Test (P≤0.05)

4. CONCLUSION AND RECOMMENDATION

Use of black shade net (50% to 70% shading intensity) decreased maximum air temperatures with increasing shading intensity, while minimum air temperatures increased with decreasing shading intensity. Cabbages under 70% shading had the highest plant height and more quality heads, followed by 50% shading and lowest under the open field. Shade nets also registered highest fresh cabbage head weight than an open field. The number of open leaves and leaf chlorophyll content was lowest under 70% shading and more under the open field. Based on the findings of this study, areas with similar climatic conditions like Kilifi should adopt the use of black shade net of 50% to 70% shading intensity for cabbage production. There is need for further studies on physico-chemical changes on composition of the cabbages and organoleptic and safety indicators.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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