

Original Research Article

EFFECTS OF BLACK SHADE NET ON YIELD OF *Brassica rapa* AND *Brassica oleracea* CABBAGES IN KILIFI COUNTY

ABSTRACT

Cabbage is an important vegetable to humans since it provides crucial nutrients such as fiber, minerals, and vitamins. They also help manage cancer, cardiovascular diseases, prevent type 2 diabetes, and inflammation of the digestive systems. However, its production in the tropics is constrained by climatic and edaphic factors that include soil moisture stress, high soil and air temperatures, high evapotranspiration, and unbalanced nutrition. Due to the above challenges, sustainable cabbage production requires adoption of technologies that can modify the growth environment with minimal environmental effects. A field study was conducted at Pwani University Crop Science farm, Kilifi County, to evaluate the effects of black shade net on yield of *Brassica rapa* and *Brassica oleracea*. A randomized complete block design experiment with three replications was set. The treatments included: 50%, 70% black shade net intensity and open field as control. Data collected included, leaf chlorophyll content, fresh head weight, and dry matter weight. The data obtained was subjected to analysis of variance using General Linear Model (GLM) SAS Computer package version 9.1. The results indicated that, shading resulted in decreased chlorophyll content, and that use of 50% and 70% black net shading intensity significantly resulted in 55% and 47.5% respectively, more number of cabbage heads for *Brassica rapa* than open field, while in *Brassica oleracea*, 70% shading and 50% resulted in 60% and 52% more cabbage heads than open field respectively.

Keywords: Shade net, cabbage yields *Brassica oleracea*, *Brassica rapa*, Coastal Kenya

1.0 INTRODUCTION

1.1 Background information

Cabbage is one of the crucial vegetables widely consumed in the world and which is in high demand, especially in the Coastal region of Kenya where it is second in importance after Amaranthus [1]. It is consumed in most households for its nutritional benefits such as the supply of fiber, minerals ions such as calcium, iron, sodium, zinc, magnesium, phosphorus, potassium, and a good source of vitamins A, C, E, and K. It also contains glucosinolates and phenolics that are anti-carcinogenic and prevent type 2 diabetes, cardiovascular diseases, and inflammation of digestive systems [2, 3, 4].

Despite the high demand and important role played by this vegetable, its local production is limited by fluctuating ecological factors such as temperature, relative humidity, soil moisture, as well as unreliable and erratic rainfall that are modulated by global warming and climate change [5]. Since cabbage is sourced from other distant up-country regions of Kenya into the coastal region, increased demand in these other counties has resulted in scarcity and high prices, making it unaffordable to the majority of the rural poor. It is in this regard that this study was conceived to evaluate technologies such as the use of black shade net that have been used elsewhere to modify the plant growing environment for successful cabbages production [6, 7].

2.0 Materials and Methods

2.1 Site description

The study was done at Pwani University Crop Science farm for two trials, during the period July 2020 to September 2020 and from December 2020 to February 2021. The farm lies about 30 m above sea level (ASL) and is located at 39.85°E and 3.62°S in Kilifi County. The area experiences a bimodal type of rainfall, amounting to 900 to 1100 mm per annum, with long rains occurring from April to June and short rains occurring from September to December. The temperature ranges between 29°C to 32°C [8]. The soils are predominantly sandy loam, specifically ferralic and dystric cambisols characterized by low organic matter, poor nutrients, and low water holding capacity [9].

2.2 Materials

The black shade nets used were of 50% and 70% light reduction and were sourced from Graduate Farmers Ltd-Eldoret, Kenya. The cabbage seeds used were *Brassica oleracea*

(white cabbage, cv. Rossy F1) and *Brassica rapa*, (Chinese cabbage, cv. Nice F1) and were sourced from Continental seed company, Nairobi. These cabbage varieties were chosen because of their fast growth and early maturity ranging from 60-70 days after transplanting.

2.3 Nursery establishment

The nursery beds of the *Brassica oleracea* and *Brassica rapa* cabbages were established using standard nursery preparation methods as described by KALRO [10]. The land was cleared, ploughed, and harrowed to a fine tilth, using a panga, Jembes, and rakes respectively. The nursery beds dimensions were 1 m by 2 m. 200 g Diammonium phosphate (DAP) fertilizer (grade: 18% N: 46% P₂O₅: 0% K) was broadcasted on both nursery beds, thoroughly mixed with the soil, and drills were done using a stick, at intervals of 10 cm then seeds were evenly placed into the drills and covered with some soil. Dry grass mulch was applied on the surface of the seedbed, and an overhead shade was erected. Watering to field capacity was done and maintained in the morning and evening each day until germination and establishment. All other nursery management practices were carried out as recommended including, weeding, pest control, and hardening.

2.4 Transplanting

On attaining a height of 10 to 12 cm, the seedlings were transplanted during the evening when temperatures were low. Each nursery was watered with 5 litres of water 30 minutes before transplanting to minimize root injury and shock. During transplanting, a spacing of 40 cm by 40 cm was adopted. 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 as recommended by Burt *et al.* [11]. Ten (10) grams or a rate of 250 kg/ha of DAP fertilizer was applied to every hole before the seedlings were transplanted after which watering was done [12]. Grass mulch 15 cm thick was applied one month after transplanting as recommended by Kelley *et al.* [13]. Topdressing was done using calcium ammonium nitrate (CAN) when bolting started, at a rate of 215 kg ha⁻¹ or two teaspoonfuls per plant as recommended by Muleke *et al.* [5] (2014). Weeds, pests, and diseases were monitored and controlled regularly, as they appeared.

2.5 Experimental design and treatments

A completely randomized block design experiment replicated three times was set. The treatments included: i) three levels of shading intensity at 70%, 50% (using black shade

nets), and open field; and ii) two cabbage types, namely, *Brassica oleracea* (white cabbage) and *Brassica rapa* (Napa cabbage) (Table 1 and Figures 1 and 2).

Table 1: Treatment and levels

Treatments (shading factor)	Cabbage species	
Open field	<i>Brassica oleracea</i>	<i>Brassica rapa</i>
50% shading	<i>Brassica oleracea</i>	<i>Brassica rapa</i>
70% shading	<i>Brassica oleracea</i>	<i>Brassica rapa</i>

Each experimental block measured 4m by 4m and was then divided at the centre, where each half was planted with *Brassica oleracea* and the other with *Brassica rapa* (Figures 1 and 2). 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 Jembe. After one week, farmyard manure was applied to every treatment plot and thoroughly mixed with soil at a rate of 2.5 t ha⁻¹ as recommended by Saha & Muli [14] before transplanting was done.

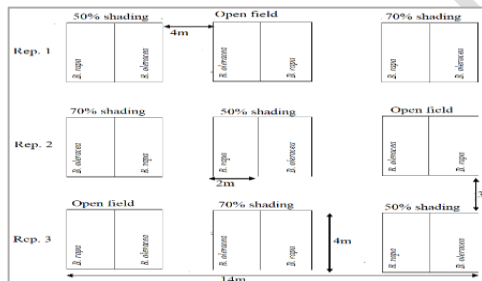


Figure 1: Experimental plot layout.

Figure 2: Black shade nets, 70% and 50% growing.

2.6 Sampling and Data collection

After transplanting, five plants per plot were randomly selected from which data was collected every week, until harvesting when final cabbage fresh and dry weights were determined. Other parameters measured included chlorophyll content (using chlorophyll meter, model SPAD 502 PLUS, Decagon devices, as described by Rodriguez & Miller [15]), and the number of fully-formed cabbage heads per plot. At the harvest stage, final fresh and dry matter head weights for each treatment were determined using an electronic

weighing balance (Model PM 200, Mettler Instrument Limited, Switzerland). The dry matter was obtained by cutting the cabbage into smaller pieces and drying at 105°C, until constant dry weight.

2.7 Data analysis

The collected data was then subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of SAS, 13th Edition. The means so obtained were compared using Tukey's honest test for significant difference (THSD) at a 5% level of significance.

3.0 Results

It is important to point out that, during the experimentation period, the first trial which ran from July to September, was fairly wet and cooler than the second trial from December to February, which was hot and fairly dry. Also during the second trial, the transplanted seedlings in the open field all dried during the third week due to high ambient temperatures, despite adequate watering. However, those planted under shade nets survived to harvest.

3.1 Effect of black shade net on leaf chlorophyll content of *Brassica rapa* and *Brassica oleracea*

Black shade net had significant effects on leaf chlorophyll content of *Brassica rapa* and *Brassica oleracea* during seasons first and second trial. Open field *Brassica rapa* cabbages maintained higher chlorophyll content of about 6.4% throughout the growing period compared to cabbages under 50% shading. On the other hand, 50% shading had about 6.0% higher chlorophyll content than 70% shading throughout the growing period in the first trial (Table 2). During the second trial, 50% shading resulted in higher chlorophyll content compared to 70% shading during the first three weeks, and during the 6th, 8th, and 10th weeks. For *Brassica oleracea* during the first trial, open field cabbages had on average, 5.3% significantly more leaf chlorophyll content than 50% shaded cabbages during the 2nd, 3rd, 5th, 6th, and 7th weeks. 50% shading on the other hand resulted in an average 6% higher chlorophyll content than 70% shading during the 2nd, 4th, 6th, and 7th week of the first trial (Table 3). During the second trial, *Brassica oleracea* under 50% shading, maintained significantly more chlorophyll content averagely 9.7% than 70% shading throughout the growing period.

rapa
 Table 2: Effects of 50% and 70% shading and open field on Leaf chlorophyll content of *Brassica* in first and second trials at Pwani University farm

Weeks after emergency	First trial									
	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10
	Leaf chlorophyll content (mg/g/FM ⁻¹)									
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	0.0026	0.0045	0.0016	0.0001	0.0018					
CV%	3.8	1.5	1.2	0.8	1.2					
	Second trial									
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	0.0048	0.0061	0.0466	0.0628	0.0946	0.0425	0.0580	0.0222	0.0553	0.0318
CV%	2.1	2.5	3.6	3.9	3.0	2.2	1.9	1.3	1.9	1.9

Means followed by the same letters within a column are not significantly different according to Tukey's Honestly Significant Difference Test ($P \leq 0.05$). ** -Missing data. Crops during the first trial matured than in the second trial due to an increase in air temperature during the second trial

First trial

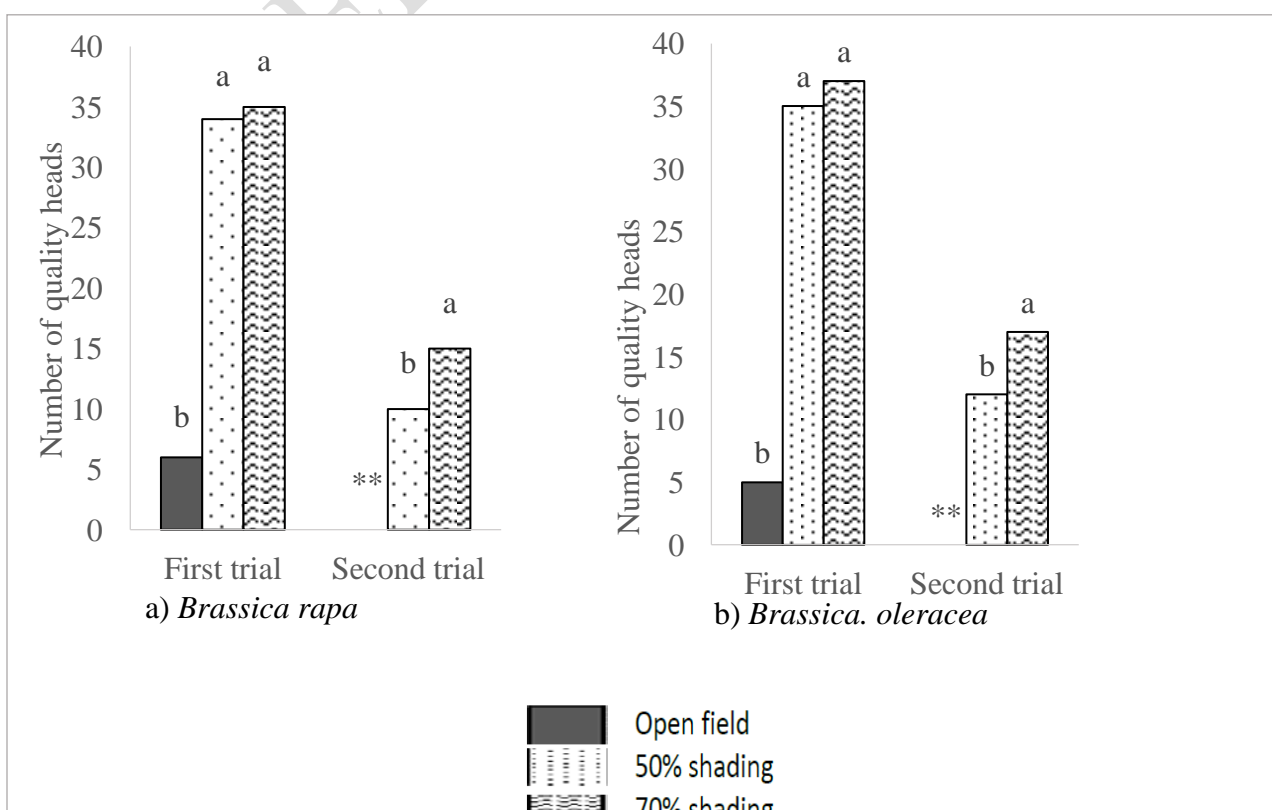
Table 3: Leaf chlorophyll content of *Brassicca oleracea* as influenced by two levels of black shade net at Pwani University farm during the first and second trials.

Wks after emergency	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10	Wk11	Wk12
	Leaf chlorophyll content (mg/g/FM ⁻¹)											
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}	0.1571	0.0001	0.001	0.004	0.182	0.001	0.001					
VC%	3.5	1.5	1.6	1.6	5.5	1.1	1.8					
	Second trial											
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	47.2b	47.4b	46.9a	45.6b	43.0a	42.5b	41.8b
P-Value	0.2475	0.0649	0.0014	0.082	0.060	0.008	0.000	0.063	0.063	0.013	0.006	0.007
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

Means followed by the same letter in a column are not significantly different at 5% level of significance Honestly Significant Difference Test ($P \leq 0.05$). ** - Missing data. Crops in the first trial matured faster than in the second trial due to an increase in air temperature in the second trial

3.2 Effects of Black shade net on the number of cabbage heads formed

For *Brassica rapa*, the use of 70% black shade net resulted in 73 % more cabbage heads than the open field during the first trial, while the use of 50% black shade net resulted in 26 % more cabbage heads than the open field. For *Brassica oleracea*, the use of 70% and 50% black shade net during the first trial resulted in 92% and 88% more cabbage heads, respectively, than in the open field (Figures 3).



*Figure 1: Effects of black shade net on the number of cabbage heads formed for Brassica rapa and Brassica oleracea during the first and second trials, at Pwani University farm. NB: **- indicates missing data; Second trial crop in the open field failed after transplanting due to high air temperatures.*

During the second trial, only the cabbage crop grown under shade nets survived. However, there were no significant differences in the number of cabbage heads due to the use of 50% and 70% shading. The use of 70% shading on *Brassica rapa* recorded an insignificant 10% and 15% more cabbage heads than in 50% shading during the first and second trials, respectively. Despite the high air temperature experienced during the second trial, the performance of the cabbages were remarkable (Figure 4).



Figure 4: Brassica rapa under 50 % black shade net and Brassica oleracea harvested from 50% black shade net field at Pwani University farm.

3.3 Effect of black shade net on fresh cabbage head weight

The use of black shade nets had significant effects on fresh cabbage head weight in both trials (Table 4). During the first trial, the use of 50% black shade net on *Brassica rapa* resulted in yields of 119 tonnes ha⁻¹, an increase in yield of 89 %, while the use of 70%

black shade net resulted in yields of 109.4 tonnes ha⁻¹, an increase in fresh cabbage yields of 88 % compared to the open field that yielded 12.8 tonnes ha⁻¹. A comparison of 50% and 70% shading of *Brassica rapa* during the first trial indicated that 50% shading resulted in significantly 27.4% (or 9.6 tonnes) higher yields than 70% shading, while during the drier second trial, 70% shading gave 82% more fresh weight yields of 6.7 tonnes, than 50% shading (Table 4).

Table 4: Mean fresh cabbage head weight of *Brassica rapa* and *Brassica oleracea* as influenced by 50% and 70% shade nets at Pwani University farm

Cabbage types	<i>Brassica rapa</i>		<i>Brassica oleracea</i>	
	First trial	Second trial	First trial	Second trial
	Weight (in tonnes ha ⁻¹)			
Open field	12.8c	**	7.8c	**
50% shading	119.0a	1.2b	91.9b	1.5b
70% shading	109.4b	6.7a	119.2a	6.0a
P-Value	0.0002	0.0003	0.0016	0.0003
CV%	3.6	14.4	9.6	15.6

Means followed by the same letters within a column are not significantly different according to Tukey's Honestly Significant Difference Test ($P \leq 0.05$). **Missing data due to failure of seedlings to survive after transplanting because of high air temperature, and s- significant;

Also, during the first trial, *Brassica oleracea* under 70% shading resulted in 93.5% more cabbage fresh weight (or 119.2 tonnes ha⁻¹), while 50% shading resulted in 91.9 tonnes ha⁻¹ was 91.4% more cabbage fresh weight compared to open field that yielded 7.8 tonnes ha⁻¹. During the second trial, 70% shading resulted in 75% more fresh cabbage weight yield compared to 50% shading that yielded 1.5 tonnes ha⁻¹ (Table 4).

3.4 Effect of black shade net on cabbage dry matter weight

Use of shade net on *Brassica rapa* during the first trial resulted in significant increases in cabbage dry matter yields than open field by 89.2% (or 7.14 tonnes ha⁻¹) and 88.3% (or 6.5 tonnes ha⁻¹) under 50% and 70% shading, respectively (Table 5). Thus, 50% shading resulted in more dry matter than 70% shading when compared with open field, for *Brassica rapa* in the first trial. However, in both trials, 50% and 70% shading resulted in comparable amounts of dry matter yields. For *Brassica oleracea*, open field and 50% shading resulted in comparable amounts of dry matter yields, while 70% shading resulted in significantly 93.4% higher dry matter yields than open field during the first trial. However, during the second trial, 50% and 70% shading resulted in comparable dry matter yields.

Table 5: Mean dry matter weight of *Brassica rapa* and *Brassica oleracea* as influenced by 50% and 70% black shade net at Pwani University farm

Cabbage types	<i>Brassica rapa</i>		<i>Brassica oleracea</i>	
	First trial	Second trial	First trial	Second trial
	Dry matter weight (in tonnes ha ⁻¹)			
Open field	0.77b	**	0.47b	**
50% shading	7.14a	0.072a	5.51b	0.09a
70% shading	6.56a	0.40a	7.15a	0.36a
p _{Value}	0.0017	0.0001	0.0172	0.0004
CV%	3.2	8.9	6.0	15.0

Means followed by the same letters within a column are not significantly different at ($P \leq 0.05$). **Missing data due to failure of seedlings to survive after transplanting because of high air temperature.

4.0 Discussions

4.1 Effect of black shade net on leaf chlorophyll content

Black shade net was observed to significantly influence leaf chlorophyll content in *Brassica rapa* and *Brassica oleracea* in both the first and second trials. Cabbages grown under 70% black shade net had lower leaf chlorophyll content than cabbages under 50% black shade net. The 70% shading recorded the lowest leaf chlorophyll content followed by 50% shading while the highest leaf-chlorophyll content was observed under the open field. Thus, chlorophyll content decreased with an increase in shading intensity. These findings are in agreement with similar results obtained by Bergquist *et al.* [16]; Zhu *et al.* [17] and Ilić *et al.* [18] who reported that chlorophyll content decreased with an increase in shading intensity and that, tomato and baby spinach plants grown in the open field had significantly higher total chlorophyll content than those grown under black shade nets. This could have been attributed to the fact that light energy and its intensity are responsible for inducing the formation of carboxydismutase enzyme which in turn induces the formation of chlorophyll [19]. Therefore, a decrease in light intensity would result in decreased formation of carboxydismutase enzyme and thus, low amounts of chlorophyll content, whereas an increase in light intensity as observed in the open field resulted in more chlorophyll content.

4.2 Effect of black shade net on the number of cabbage heads

In both trials, more cabbage heads were harvested from 70% shading, followed by 50% and lowest under the open field. Thus, 70% shading which recorded the lowest light intensity had the highest number of cabbage heads while open field treatment which was

exposed to maximum light conditions had the lowest number of cabbage heads. These differences in yield due to shading can be attributed to differences in light intensities and air temperatures under these treatments. Cabbage, being a temperate crop, is a cool-season crop and does well under cool or lower ambient temperatures, which were provided by the 50% and 70% shade nets environment. These findings are in agreement with those observed by Adeniji *et al.* [20] and Muleke *et al.* [5], who reported that an increase in temperature affects cabbage head formation, delays maturity of the crop by increasing vegetative growth and number of open leaves leading to the formation of loose heads or failure of head formation.

4.3 Effect of black shade net on cabbage fresh weight

From the results, cabbages under shade nets had more fresh weight yield than those under the open field. However, 50% shading during the cool first trial resulted in higher *Brassica rapa* fresh weight yields than 70% shading and open field. This suggests that 50% shading intensity appears to be the most ideal for *Brassica rapa* maximum fresh cabbage weight gain. For *Brassica oleracea*, 70% shading resulted in the highest fresh cabbage weight than 50% shading and open field during the first trial. This suggests that for *Brassica oleracea*, 70% shading was the most ideal shading intensity for maximum fresh cabbage weight gain. For the second trial and for both cabbages types, 70% shading gave the highest fresh cabbage weight, suggesting that 70% shading provided the most ideal shading intensity for maximum fresh cabbage weight gain during warm seasons. These findings are in agreement with those reported by Rekika *et al.* [21]; Muleke *et al.* [5] and Ngelenzi *et al.* [22], who obtained that shade nets enhanced heavier fresh head weight in cabbages due to reduced air temperatures and increased soil moisture that provided favourable conditions for cabbage growth.

4.4 Effect of black shade net on cabbage dry matter

From the study, cabbages grown under shade nets had more dry matter yield than those grown in the open field. However, 50% shading during the first trial resulted in higher *Brassica rapa* dry matter yields than 70% shading and open field. This suggests that 50% shading intensity was the most ideal for maximum dry matter formation for *Brassica rapa*. For *Brassica oleracea*, 70% shading resulted in the highest dry matter yields than 50% shading and open field during the first trial. This implies that for *Brassica oleracea*, 70% shading provided the most ideal shading intensity and micro-climate for maximum production of dry matter yields. During the second trial, for both types of cabbages, 70% shading resulted in the highest dry matter yields. This suggests that 70% shading provided the most ideal shading intensity and micro-climate for maximum dry matter production. These findings are in agreement with those reported by Muleke *et al.* [5] and Ngelenzi *et al.* [22], who found that cabbages grown under agro net covers accumulated more dry matter than those grown in the open field. The conducive microclimate created by the black shade nets possibly led to increased growth vigour, leading to more accumulation of total fibre and therefore dry matter yields.

5.0 Conclusion and Recommendation

The study has shown that it is possible to grow cabbages in Kilifi County and the Coastal region of Kenya as a whole or even in most Arid and semi-arid areas by using a black shade net, that moderates temperature and light intensity creating a micro-climate conducive to growth, dry matter accumulation and formation of cabbage heads, so long as soil moisture is not limiting and other factors are not limiting.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly used 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.

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