Original Research Article

Black shadenet effects on soil properties and cabbage water use efficiency in humid coastal environment

ABSTRACT

Cabbage is a popular vegetable grown in Kenya for food and income generation.Despite the important role played by the crop within the country, current climate change effects and population pressure pose a need for increasing production through utilization of available resources.A study wastherefore conductedto evaluate the effects of black shade net on soil properties and cabbage water use efficiency in humid coastal environment.Black shade nets of 0%, 50% and 70% shading intensityand two cabbage types(*Brassica rapaand Brassica oleracea)*were evaluated in Randomized complete block design with three replications.0% represented open field. Data collected included: soil chemical characteristics, soil moisture content, air temperature, fresh head weight, dry matter weight,and water use efficiency. Data obtained were subjected to analysis of variance using general linear model SAS Computer package version 9.1and means separated using Tukey's test at 5%. From the findings obtained, the use of black shade net of 70% and 50% shading significantly increased soil moisture content by 5.1% and 2.6% than open field. Maximum air temperature in 70% and 50% shade nets was lower than open field by4.6^{o}C and 1.8^{o}C respectively while minimum air temperature under 70% and 50% shade nets was higher than open field by 2.7^{o}C and 1.6^{o}C respectively. *Brassica rapa*from 70% shading had 35% more fresh weight per plant than open field while those from 50% had 30%. *Brassica oleracea*from both 70% and 50% shading had 44% and 29% more fresh weight per plant respectively than those from open field. Although shade nets did not have significant effect on availability of nutrients within soil solution, *Brassica rapa*under 70% shading recorded 49% higher water use efficiency than open field while, 50% shading recorded 50% more WUE than open field. *Brassica oleracea* under 70% shading recorded 41% higher water use efficiency than open field, while 50% shading recorded 25%increase than open field. Owing to the fact that shade nets did not have significant effect on available nutrients within the soils but significantly influenced WUE, there is need for further studies to understand the effects of shade nets on cabbage nutrient use efficiency under the same environment.

Key words: Shade net, water use efficiency and cabbages

1.0 INTRODUCTION

Cabbage is among the crucial leafy vegetableconsumedall over the world. Itis rich infibre and minerals ions, which include: calcium, iron, sodium, zinc, magnesium, phosphorus, and potassium which are essential in human nutrition [1]. It is a good source of vitamin A, C, E, and K. It alsocontains phenolics and glucosinolates that are anti-carcinogenic and effectively reducescancer-related diseases, prevents type 2 diabetes, cardiovascular diseases, and inflammation of digestive systems [2]. It is a cool and humid crop, and if the temperature is above 24^{o}C, number of leaves increases leading to the formation of loose heads or head formation failure [3&4]. Water requirements vary from 380 mm to 500 mm per crop throughout the growing period [5]. The ideal soil pH ranges from 5.5 to 6.5, and where the soil pH is above 6.5, leaves turn dark, and leaf margins dieback, while pH below 5.5 causesleaf chlorosis and retarded growth [6]. Its production in the tropics is constrained by climatic factors and edaphic factors which include soil moisture stress, high soil and air temperatures, high evapotranspiration, and unbalanced nutrition [7,8&9]. With the recent increase in global warming, the production of cabbage is further threatened [10].

Enhancing its production in various parts, therefore,calls for the adoption of technologies that can improve ecological conditions hence ensuring effective water use efficiency by increasing crop water productivity and a reduction of water losses from the plant rooting zone [11&12]. Water-use efficiency which is a relationship between either yield or biomass to either transpiration or total water provided to the crop, including precipitation and the amount of water provided by irrigation can be enhanced by the use of shade nets [13]. Thus, practices that increase water use efficiency can be important for sustainable cabbage production [12]. Soil and soil water management, crop management, spacing, genetic characteristics, and climatic/weather characteristics improve crop water use efficiency in return improving the crop yield [14].

Using shade nets made of polyethylene woven threads with specialized UV treatment can be one of the practices that can promote the effectiveness of water use efficiency in agriculture.These shade nets further protect crops by cutting off excessive solar radiation, improving thermal climate, increasing relative humidity, sheltering crops from wind, hail, and pests [15,16&17]. They are designed for different light reduction percentages (30%, 40%, 50%, and so on) depending on the purpose. They are classified as either coloured-colour nets (red, yellow, green, and blue) and they can screen-specific spectral bands of the solar radiation (Ultraviolet) and transform direct light into scattered light or they are neutral-colour nets (black, pearl, white, and grey) that cannot change the spectral composition of light [18&19]. Mostly, black coloured nets are used compared to other nets because they have been attributed to be the most convenient neutral density filters and more efficient in reducing diurnal temperature than all other coloured nets [20&21]. However, there is limited information on the production of cabbage under shade nets in the coastal environment. This study therefore aimed at assessing the effect of black shade net on *Brassica rapa* and *Brassica oleracea*grown in the humid coastal environment.

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 Kenya, which is 3 m above sea level. The area receives average annual rainfall of 900 to 1100 mm distributed within the months of April to June (long rains) and October to December (short rains). It also experiences average daily temperature of between 21 to 28^{o}C and soils are dominated by ferralic and dystric cambisols containing low levels of carbon [22& 23].

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* (Napa cabbage) seeds (cv. Nice F1) 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, [24]. The land was prepared by bush clearing using a machete followed by cultivation to a desirable tilth. Nursery beds measuring 1 m by 2 m were prepared followed by broadcasting 200 g diammonium phosphate fertilizer of grade DAP: 18% N: 46% P_2O_5 :0% Kand thorough mixing of the fertilizer with soil. Small drills were then made using a stick at an interval of 10 cm where seeds were evenly placed and covered with light soil. Dry grass mulching was applied, and a shade was erected. Twenty litres of water were 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; each variety was to occupy one half. Metallicframes were erected at the 50% and 70% shading net treatments, 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 bySaha&Muli [25].

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 as recommended by Burt [26]. Ten grams (10 g) of DAP fertilizer was placed in every hole before seedlings were transplanted at a rate of 250 kg/ha [27]. 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 [28]. Topdressing was at the total rate of 215 kg ha^{-1} using calcium ammonium nitrate (CAN) per plant using two spoonfuls as recommended by Muleke[4], when crops started forming heads. Weeds, pests, and diseases were monitored and controlled regularly.

2.6: Data collection

Soil chemical characteristics; was determined at the beginning of the experiment before planting and after every crop harvest by taking soil samples randomly from ten points using soil auger at 0 to 15 cm soil depth in all three treatments. The samples were dried and thoroughly mixed and a 0.5 kg composite sample for each treatment was packed and taken to Kenya Agricultural research and livestock organization National Agricultural Research Laboratories (KARLO NARL) in Nairobi for chemical analysis. The soils were analysed for $pH_{(water)}$, total nitrogen (N) and exchangeable phosphorus (P), potassium(K), calcium (Ca), Magnesium (Mg), Zinc (Zn), Copper (Cu), and manganese (Mn) following the procedures described by Okalebo [29].

Soil moisture content; commenced three days after transplanting and involved sampling soil moisture within the topsoil 0-20 cm depth where feeder roots are found.This was done using the gravimetric method as described by Reynolds [30]. Four soil sampling points were randomly selected in a zigzag manner. Once the samples were collected from each treatment a 50g sample was weighed using an electronic weighing balance (Model PM 200, Mettler Instrument Limited, Switzerland) before placing it in petri dishes. Thereafter the petri dishes were placed in an oven for drying at 105^{o}C for 48hrs. Oven-dried soil samples were later weighed. The percentage soil moisture content on a dry-weight basis (θdw) in each sample was calculated using the following formula:

$$\theta dw = \frac{weight\ of\ moist\ soil - weight\ of\ oven\ dried\ soil\ x\ 100}{Weight\ of\ oven\ dried\ soil}$$

Other subsequent data collection on soil moisture content were done at an interval of three (3) days during mid-day before watering in the evening.

Air temperature; was determined at an interval of 3 days, beginning from the first week after transplanting. The thermometers were suspended in the air throughout the growing period using wooden poles at the level of crop height in every treatment and temperature readings recorded.

Seven (7) days after transplanting, 5 plants in each plot for all treatments were randomly selected and tagged from each of the 3 middle rows, giving a total of fifteen (15) plants per cabbage type. These crops were used to determine fresh head weight, dry matter, and water use efficiency.

Fresh head Weight;the tagged crops were harvested by cutting the heads from the stem. Their fresh weight was then determined using a weighing electronic balance and recorded in Kilograms.

Dry matter; after harvesting the tagged plants and their fresh weight determined, they were then cut longitudinally into six (6) pieces and dried in the oven at 70^{o}C for 5 minutes, and placed on the sun. This activity took place for one week while weighing their weight after every day until a constant weight was attained. Later their total dry matter was determined by weighing using a digital weighing machine to enable the estimation of water use efficiency (WUE) as recommended by Sharma[13].

Water Use Efficiency (WUE); water used in every watering time per treatment was recorded and the rain gauge was placed at the site throughout the study period to determine the amount of rainfall received. This was essential in the determination of WUE as shown in the equation below.

Water Use Efficiency = $^{\text{Total dry matter}}/_{\text{Total amount of Water Used (m}^{-3}\text{ ha}^{-1}\text{)}}$ [13].

2.7: Data analysis

Data collected was then subjected to analysis of variance (ANOVA) using the GLM procedure of SAS at $P \leq 0.05$. *Means* for significant treatments, at the F test, were separated using Turkey's honestly significant difference (THSD) test at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

N/B- All the cabbage plants grown in the open field during the second trial wilted and dried due to temperature stress. The open field temperatures recorded then were 39^{0}C, which was far beyond the ceiling temperatures for physiological and biochemical reaction for cabbage plants, given that cabbages are temperate plants in nature.

3.1: Effect of shade net on soil chemical properties

Soils within the research site were slightly alkaline (pH 7.4 - 7.8) (Table 1). The soils had adequate levels of exchangeable P, K, Ca, Mg, Mn and low levels of Total Nitrogen, organic carbon, exchangeable copper, iron, and zinc. Although shade nets did not significantly affect the availability of most of the nutrients, exchangeable phosphorus, copper, iron, zinc, and sodium were observed to increase graduallyin all treatmentseach season. Most nutrients were equally noted to be slightly lower under the open field as compared to 50% and 70% shade net. Soil pH was also observed to reduce gradually each season.

The gradual increase of exchangeable phosphorus, copper, iron, zinc, and sodium over the cropping seasons can be attributed to either cumulative effect of nutrients overtime due to improved soil moisture retention and temperature regulation under shade net environment. According to [31&32], improved soil moisture and temperature regulation creates favourable conditions for soil biota to thrive leading to increased microbial activities that have a positive impact on the release of nutrients from the colloidal structures into the soil solution. Similarly, presence of regulated soil moisture and temperature creates favourable environment for nutrients mineralization and solubility leading to increased availability of nutrients in the exchange complex [32, 33&34]. Owing to the fact that nutrients such as copper, iron and zinc are immobile in nature, the observed increase over the cropping seasons could be attributable to cumulative effect within the exchange complex over time.

The observed gradual soil pH decrease in all soils over the two cropping seasons can be attributed to either improved soil buffering capacity or reduced concentration of salts. As a factor of alkalinity and acidity levels of soils, accumulation of salts contributes immensely to the increased pH levels in dry land environment [35]. Irrigation on the other hand leaches out most soluble salts down the profile while plants utilize some through uptake [36], leading to reduced salt concentration hence low pH value. The observed continuous increase in available P over the cropping seasons can be attributed to the continuous pH reduction as well as improved moisture and temperature regulation. According to Weil and brady [32] and Muindi, [34] phosphorus is an immobile mineral whose availability in soils negatively affected by soil reaction, organic matter levels as well as biotic activities. Owing to the fact that all soils were provided with adequate moisture through irrigation while shade nets promoted soil temperature regulation leading to improved soil buffering capacity and biotic activities, favourable conditions might have been availed for retention of exchangeable P within the exchange complex.

Table 1: Soil chemical properties taken before planting cabbages at Pwani University Agricultural farm and after the harvest of first and second trial

	Initial soil analysis before planting		Soil analysis after first trial						Soil analysis after first trial			
Field			70%		50%		Open field		70%		50%	
Parameters	Value	Class	Value	Class	Value	class	Value	Class	Value	class	Value	
Soil pH - H_2O	7.44	Slightly alkaline	7.08	Neutral	7.06	Neutral	7.07	Neutral	6.79	Neutral	6.77	Neutral
Exch N%	0.05	low	0.05	Low	0.05	low	0.06	Low	0.07	low	0.05	Low
Org. Carbon %	0.41	low	0.51	Low	0.53	low	0.50	Low	0.36	low	0.34	low
Exch P ppm	29.00	adequate	42.2	Adequate	42.4	adequate	41.3	adequate	44.45	adequate	43.55	adequate
Exch K me%	1.10	adequate	0.90	Adequate	0.88	adequate	0.87	adequate	0.98	adequate	0.97	adequate
Exch Ca me%	2.40	adequate	3.6	Adequate	3.4	adequate	3.7	adequate	2.0	adequate	2.2	adequate
Exch Mg me%	2.01	adequate	1.35	Adequate	1.37	adequate	1.36	adequate	1.95	adequate	1.96	adequate
Exch Mn me%	0.48	adequate	0.37	Adequate	0.35	adequate	0.36	adequate	0.56	adequate	0.55	adequate
Exch Cu ppm	0.7	low	0.8	Low	1.0	low	0.7	Low	0.96	low	0.92	low
Exch Fe ppm	9.4	low	16.8	Adequate	16.5	adequate	16.6	adequate	20.3	adequate	19.7	adequate
Exch Zn ppm	2.32	low	4.14	Low	4.17	low	4.15	Low	5.46	adequate	5.65	adequate
Exch Na me%	0.27	adequate	0.37	Adequate	0.38	adequate	0.36	adequate	1.02	adequate	1.03	adequate
Elect.Cond. mS/cm	0.48	adequate	1.06	Adequate	1.05	adequate	1.07	adequate				

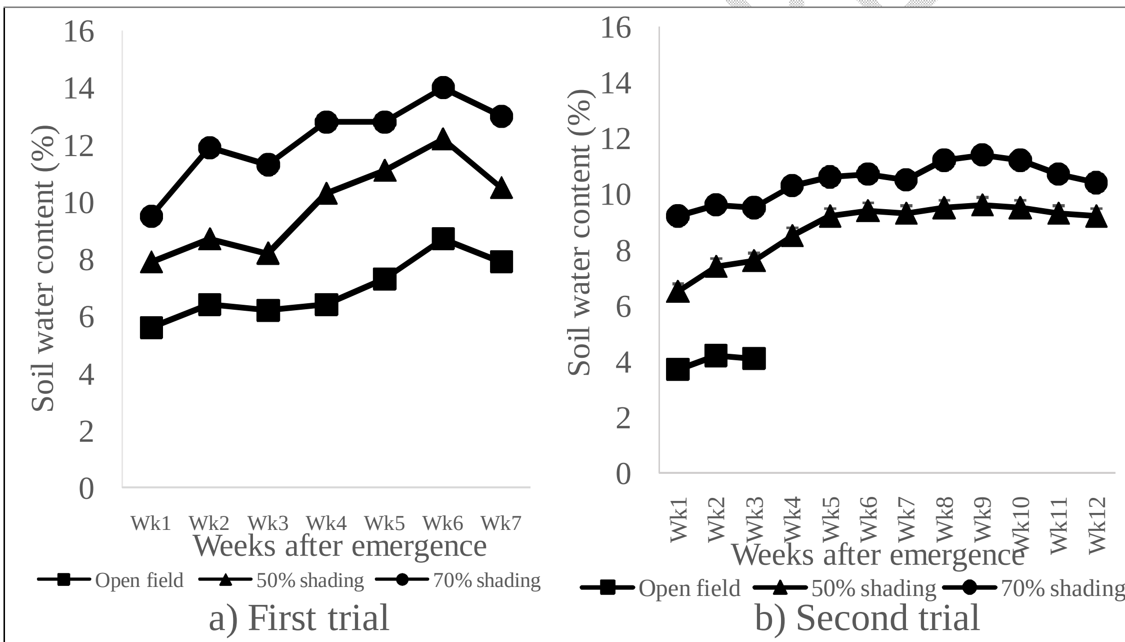
Key: **Exch. -** exchangeable

Org.- organic

Note: Data was not collected from open field treatment during the second trial due to failure of seedlings to survive after transplanting because of high air temperature

3.2: Effect of shade net on soil moisture content

Shade nets were observed to significantly improve soil moisture availability throughout the cropping period (Figure 1). Although 70% shading recorded the highest soil moisture percentage and open field the lowest, percentage moisture content between 70% and 50% shade nets in both first and second trials was not significantly different. The available moisture content in open fields in second trial were observed to be very low (less than 3%) during the first 4 weeks when data was collected. These differences could be attributed to the shade nets ability to reflect solar radiation, reducing the radiant flux reaching the soil, and regulating microclimatic temperatures [37&38]. Similar findings have been reported by Gogo [15], who suggested that reduced transpiration losses from the crop under net covers could as well minimize water uptake by plants leading to an increase in moisture retention in the soil within the nets.Additionally, Díaz-Pérez [39], revealed that the use of shade nets increased soil water content with an increase in shading intensity, which was similar to the current study where 70% shading had the highest soil moisture content, followed by 50% shading and lowest under open experiment.



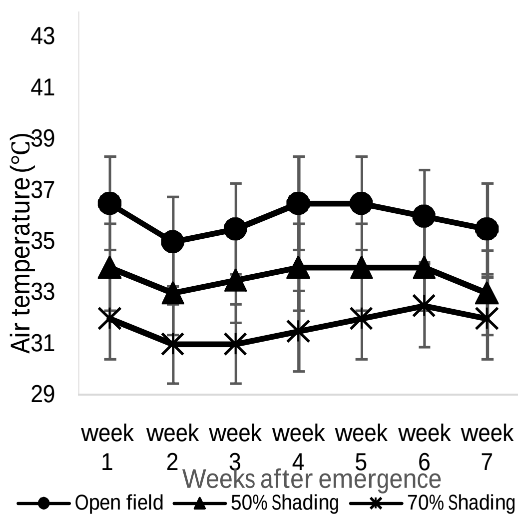
Wk - represent weeks after transplanting

Figure 1: Soil moisture content (%) as influenced by black shade net during first and second trial at Pwani University farm. **Note-** Data was not collected from open field treatment during the second trial due to failure of seedlings to survive after transplanting because of high air temperatures.

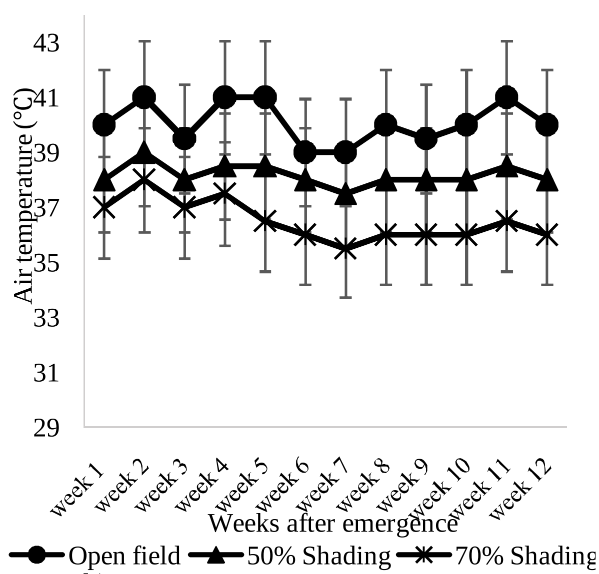
3.3: Effect of black shade net on air temperature at the immediate cabbage growing environment

The use of a black shade net of 50% and 70% shadingintensity lowered maximum diurnal air temperature (determined during mid-day) as compared to the open fields (Figure 2). Averagely, 70% shading recorded 4.5^{o}C lower maximum diurnal air temperature than open field while 50% recorded 2.7^{o}C lower temperatures than the open field. On the other hand, minimum air temperature (determined at 5:00 hours) was higher under 70% shading by 2.5^{o}Cthan open field while 50% shading had 1.4^{o}Chigher than the open field.

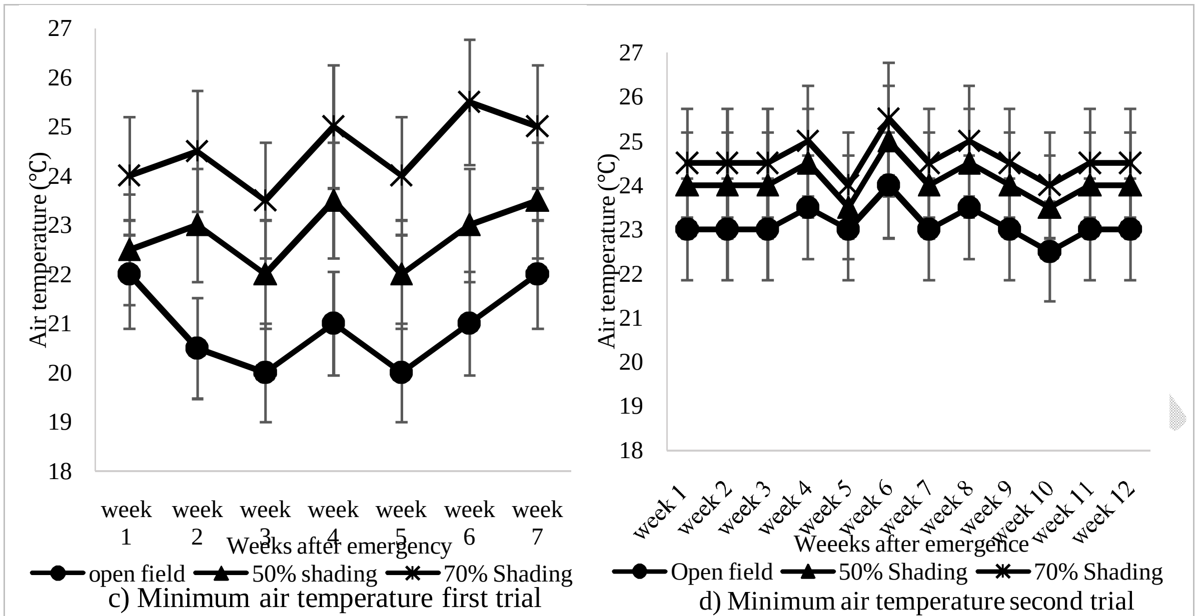
The maximum diurnal air temperature was also found to be low in the shade nets during sunny days than outside. Iglesias and Alegre [40], suggested that during the day when solar radiation is high the shade nets reduce temperature through interception, while at night, in the morning, and during cloudy time within the day, shade nets increase air temperature inside the netted area than the outside due to the reduced air movement in the net structure and slow mixing of outside air with inside air, thus reducing heat loss to the surrounding atmosphere leading to a temperature build-up. Shahak[41], similarly obtained the same findings where maximum daily temperature under shade-nets (30% PAR) was up to 3°C lower than the control. In addition, Zoratti [42], noted that the use of black shade net had a reverse change in temperature to diurnal temperature. Bandara [43], equally found that shade nets effectivelyreduced heat during the daytime while changing the spectrum. Similarly, Ilić, [44], found shading technology as confirmed in Israel generally decreased maximum daily temperature by 1–5°C and reduce heat stress.



a) Maximum air temperature first trial



b) Maximum air temperature second trial



Data points represent means ± standard deviations. Wk-represent weeks after transplanting

Figure 2: Maximum and minimum air temperature (□) as influenced by black shade within the cabbages growing environment during first and second trial at Pwani University farm. Data points represent means±standard deviations. Wk represent weeks after transplanting.

3.4: 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 trials(Table 2). During first trial*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 first trial, but in second trial, 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 first trial respectively, while in second trial, 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 [45]. Equally fresh weight of Chinese cabbage was greater under plastic row covers compared to control plants [46]. As well in research conducted on lettuce, heavier heads were obtained from plants grown under shade net cover than in open fields[47,48]. Broccoli heads grown under row cover perforated polyethylene plastic were also significantly heavier than those from the open field [49]. 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 [50]. 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.

3.5: Effect of black shade net on cabbage dry matter weight.

Cabbage total dry matter weight was significantly influenced by shade nets in all the growing trials(Table 3). *Brassica rapa* under 50% and 70% shading had 0.021 kg and 0.017 kg more total dry matter than those under open field in first trial respectively, while in second trial, 50% and 70% shading had 0.047 kg and 0.055 kg more dry weight than in open field respectively. *Brassica oleracea* under 50% and 70% shading had 0.002 kg and 0.025 kg more total dry matter than those under open field in first trial respectively, while in second trial, 50% and 70% shading had 0.056 kg and 0.07 kg more dry weight than in open field respectively.

Total dry matter was equally higher under shade nets than under open fields. The current research contradictsthe findings of Ma [51] who obtained more total biomass in plants grown under low light intensity than those grown under shade structures, where they suggested this could have been due to low photosynthetic ability in the nets which resulted inthe low growth rate. Sadek and Youssef [52]however, found more dry weight for plants grown under shades nets than those grown under open. Ngelenzi [53] as well found that dry weight was generally increased for plants grown under coloured net covering compared with those grown in the open field.Similar finds by Gaurav [54]also indicated dry weight was highest under 75% shade closely followed by 50% and lowest under open condition for cordyline. This was in line too with Muleke[4] who found cabbage grown under agronet covers accumulated more dry matter than that grown in the open field. In the current study, although the total dry matter was more under 70% shading followed by 50% shading and lowest under open field, the dry matter per unit volume was highest under open field followed by 50% shading and lowest under 70% shading. The conducive environment created by shade nets possibly could be the one that led to cabbages to grow with vigour leading to more accumulation of total fibre than the open-grown cabbages. On the other hand, higher dry matter per unit volume of cabbages grown in the open field compared to net grown cabbages could be due to unfavourable conditions which made cabbage to be hardy thus developing a lot of fibre as a mechanism to avoid water loss.

3.6: Effect of black shade net on cabbages water use efficiency

The use of shade nets for cabbages production significantly influenced water use efficiency (Figure 3). Both 50% and 70% shading were observed to have higher water use efficiency compared to open field in *Brassica rapa* plots in first and second trialand *Brassica oleracea* plots in second trial. It was however observed that WUE was not significantly different in all shade nets where *Brassica oleracea* had been established in the first trial.

The effects of shading nets on enhanced water use efficiency have been reported by different studies. For instance, Möller and Assouline [55] concluded that 30% black shading net reduced solar radiation and increased irrigation water use efficiency of bell pepper. Díaz-Pérez [38]on the other hand observed highersoil water conditions under shading nets compared with the control while Gent [56] reported an increase in soil water content under shading in greenhouse-grown tomatoes and this consequently increased water use efficiency. Similarly, studies on apricot demonstrated high WUE under shaded region than under open fields, [57]. This was in line with the research conducted on citrus where WUE under shade nets was obtained to be high than in the open field, [58]. Water use efficiency was also reported to be higher under the different colouredagro-net covers than under the control treatment, [53].

Table 2: Mean of the fresh head weight of *Brassica rapa* and *Brassica oleracea* as influenced by black shade net

Cabbage types	*Brassica rapa*		*Brassica oleracea*	
	First trial	Second trial	First trial	Second trial
Open field	1.7c	**	1.1c	**
50% shading	2.8a	0.7b	2.1b	0.7b
70% shading	2.5b	1.0a	2.6a	1.1a
p_{Value}	.0002	.0003	0.0016	.0003
CV%	3.6	14.4	9.6	15.6

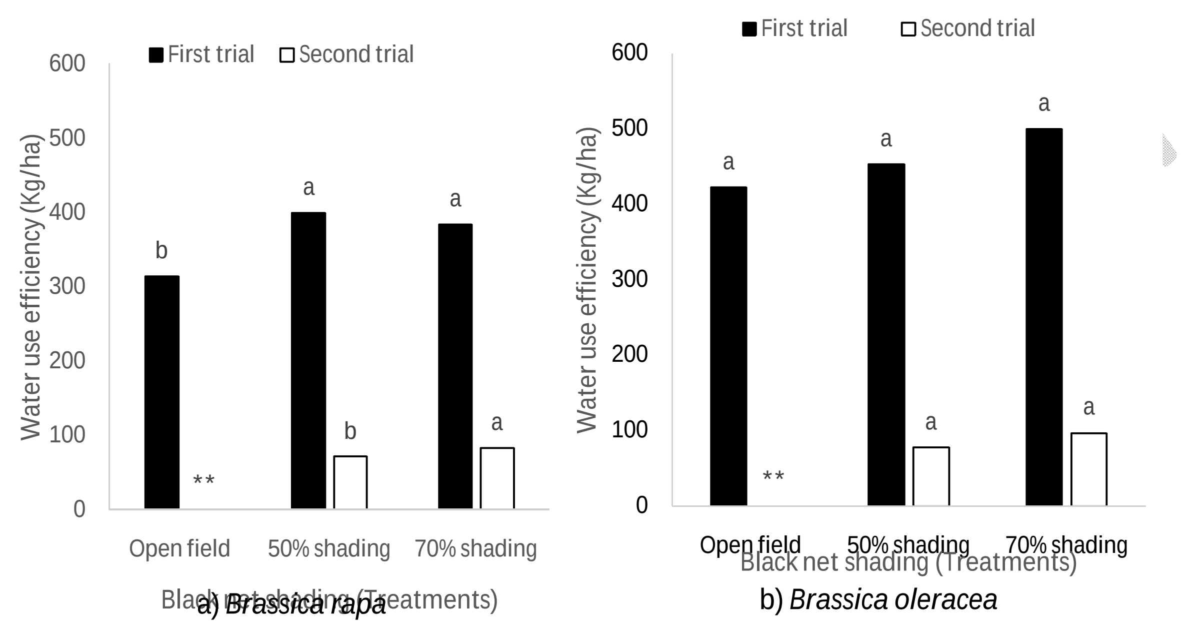
Missing data due to failure of seedlings to survive after transplanting because of high air temperature, and **s- significant; Means followed by same letters within a column are not significantly different according Tukey's Honestly Significant Difference Test ($P \leq 0.05$)

Table 3: Mean of dry matter weight of *Brassica rapa* and *Brassica oleracea* as influenced by black shade net

Cabbage types	*Brassica rapa*		*Brassica oleracea*	
	First trial	Second trial	First trial	Second trial
Open field	0.08b	**	0.10b	**
50% shading	0.1a	0.05a	0.10a	0.06a

70% shading	0.1a	0.05a	0.13a	0.07a
P_{Value}	.0017	.0001	.0172	.0004
CV%	3.2	8.9	6.0	15.0

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



Means followed by the same letters within a trial are not significantly different according to Tukey's HSD test (P≤0.05)

Figure 3: Water use efficiency (Kg/ha) of *Brassica rapa* and *Brassica oleracea* as influenced by black shade net during first and second trial at Pwani University farm. ** -Missing data due to failure of seedrings to survive after transplanting because of high air temperature

4. CONCLUSION AND RECOMMENDATION

Use of black shade net of 50% and 70% shading intensitysignificantly improved soil moisture content. Use of shade nets was however found to have insignificant effects on availability of nutrients within soil solution. Growing cabbagesunder black shade net of 70% shading and 50% shading significantly improved water use efficiency and 70% shading recorded the highest water use efficiency followed by 50% shading. Maximum air temperature decreased with an increase in shading intensity while minimum air temperature increased with a decrease in shading intensity. Based on the findings of this study, regions with similar climatic conditions like the current study site, black shade net of 50% to70% shading intensity can be used to improve cabbage water use efficiency.

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