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Combining Kitchen Waste and Cow Dung Bio-slurry have Synergistic Effects on Growth and Yield of Shade Net Grown Swiss Chard

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AM and EOG designed the experimental study, performed the statistical analysis, wrote the protocol, and All the authors wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to evaluate the effect of bio-slurry fertilizer source feedstock on the growth and yield of Swiss Chard. The experiment was conducted using a randomized complete block design with three replications at the Pwani University integrated biogas unit in Kilifi County. Treatments include a control (no fertilizer), 100% DAP+100% CAN, 100% kitchen waste bio-slurry, 100% cowdung bio-slurry, 50% DAP+50% CAN+50%kitchen waste bio-slurry, 50% DAP+50% CAN+50% cowdung bio-slurry and a combination of 50%kitchen waste bio-slurry and 50% cowdung bio-slurry. Data were analyzed using ANOVA at a 5%significance level. The results indicated that 100%

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kitchen waste bio-slurry led to the highest values in most growth parameters, while 100% inorganic fertilizer resulted in the highest chlorophyll content. Notably, the combination of 50%kitchen waste bio-slurry and 50% cowdung bio-slurry significantly increased leaf length (55.3%), plant height (58.9%) and yield (140.4%) compared to other treatments. The study concludes that a 50% kitchen bio-slurry and 50% cowdung bio-slurry mix is an effective alternative to inorganic fertilizers for growing Swiss chard.

Keywords: Bio-digester feed stock; bio-slurry; organic agriculture.

1. INTRODUCTION

Worldwide, leafy vegetables play an important role in providing vitamins, minerals and proteins needed in human diet [21]. Swiss chard (*Beta vulgaris* L.) is a leafy vegetable and belong to the Chenopodiaceae family that takes two season to complete its growth cycle. Swiss chard is widely consumed in various parts of the world, including Africa, due to its high nutritional value and low production costs. Swiss chard leaves are endowed with fiber, sodium, magnesium, and vitamin C, at the same time the stems are rich in potassium [19]. Swiss chard also has health-promoting phytonutrients like carotenoids and flavonoids, which are antioxidants that are needed to reduce the problem of malnourishment to human [9]. Generally, Swiss chard is usually grown and plays an important role in improving the nutritional requirement of rural households where the leaves and petioles are usually cooked and served as part of the staple foods. Swiss chard thrives well in cool climates with temperature of 16 -24ŸC [17].

Large amounts of kitchen waste, resulting from unused food, can have negative environmental impacts if not properly managed [8]. Approximately 97% of global kitchen wastes is disposed up in landfill, where it decomposes and this create environmental problems like odor, leachate pollution of underground waters, and gas emissions. Anaerobic fermentation of food waste for methane and solid digestate can help to recover plant nutrients from waste resources [60]. The use of bio-slurry derived from kitchen waste presents advantages compared to the inorganic nitrogen fertilizers due to available macro and micronutrients.

Application of kitchen bio-slurry result to higher increase of organic carbon compounds and nitrogen, which play a significant part in increasing the soil carbon balance [37] and yield [2]. Even though inorganic fertilizers are readily accessible by the plants and have large amounts of nutrients as compared to organic fertilizers, but organic fertilizers contain growth-stimulating agents, which make them play an important role for soil fertility improvement as well as crop productivity [1].

The soils in Kilifi County are mostly ferralsols, which have low organic matter content, and nutrients [34]. They also have low water holding capacity and high rates of drainage, this soil conditions force farmers to depend on inorganic fertilizers for increased crop yields. As a result, continuous use of inorganic fertilizers results to a weakened soil structure and loose soil aggregates resulting to an increased leaching of nutrients and consequently acidification [7]. This in turn, leads to stunted crop growth and reduced yields. Thus, continued use of chemical fertilizers deteriorates soil physico-chemical properties and cause water resource contamination. Population density, like in other towns, is increasing, and consequently, food waste generation is on the rise [3]. The food waste is commonly disposed on landfills or dumping sites, which usually causes environmental problems. However, landfilling is costly, requires space, and may have a negative impact to the environment if not well managed (Baawain, 2017).

Although the effect of bio-slurry (animal dung bio-slurry) on crop performance is well vast studied including Kilifi County, that of bio-slurry from different source feedstock is under-researched and more so on Swiss chard. This study therefore, was conducted to evaluate the effect of bio-slurry from different source feedstock on growth and yield of shade net grown Swiss The study's hypothesis was that bio-slurry from the different source feed stock do not affect growth and yield of Swiss chard

2. MATERIALS AND METHODS

2.1 Study Site

The study was carried out during the 2021/2022 and 2022/2023 growing seasons at. [38] The

Pwani University Integrated Biogas research unit, located at 39°44' East and 3°50' South, 30 meters above sea level, lies in the coastal belt of Kenya, 60 km north of Mombasa.. The region experiences low, bimodal rainfall, ranging from 600 to 1,000 mm annually, with the long rains, the more dependable season, occurring from March to June [20]. The most dependable rainy season is the long rains, which extend from March to June. Temperatures in the region range from a minimum of 23°C to a maximum of 30°C, with an average relative humidity of 80%. The soils are ferralsols that are predominantly sandy loam Generally, Kilifi County is nearly all ranching Zone (CL 6), apart from the moist or irrigated areas along the riverbanks and higher rainfall areas, which receive an average annual rainfall of more than 1000 mm near the coast in the southeast. The region also has a Coconut-Cassava Zone (CL 3). Within the CL3 zone, however, large sections of the soil are not suitable for this crop production due to seasonal flooding or water logging [40] And Pwani University lies in agro ecological zone 3.

2.2 Experimental Materials

2.2.1 Swiss chard seed

Swiss chard is a leafy vegetable extensively cultivated for its early maturity, making it an excellent crop for food security [32]. There is a high demand for Swiss chard since it is commonly consumed yet it is not commonly grown in Kilifi and therefore there is a need to demonstrate its suitability in terms of its performance under the prevailing shade net conditions. [27].

2.2.2 Feed materials used

2.2.2.1 Kitchen waste

Kitchen waste was composed of uncooked cabbage, uncooked kales, uncooked tomatoes, potato peels, cooked potatoes; tarmarine, cooked bones with flesh, sieved tealeaves, and cooked beans cooked rice and 50 % of this waste contained cooked Ugali and rice waste. Kitchen waste bio-slurry is rich in nitrogen and potassium [44]. This kitchen waste, which included both pre-cooked and cooked food items, was primarily leftover from the student-catering unit and University staff quarters.

2.2.2.2 Cow dung

Cow dung is the undigested remains of feed material consumed by cattle, primarily composed of feces and urine in a 3:1 ratio.. It consist majorly of lignin, cellulose and hemicelluloses. It also has 24 minerals such as nitrogen, potassium and trace of elements like Sulphur, iron, magnesium, copper, cobalt and manganese. Cow dung contain different species of bacteria, protozoa and yeast [29]. Cow dung was collected while fresh from Pwani University dairy unit, where the cows feed on grass material and other leafy plant under free range grazing system.

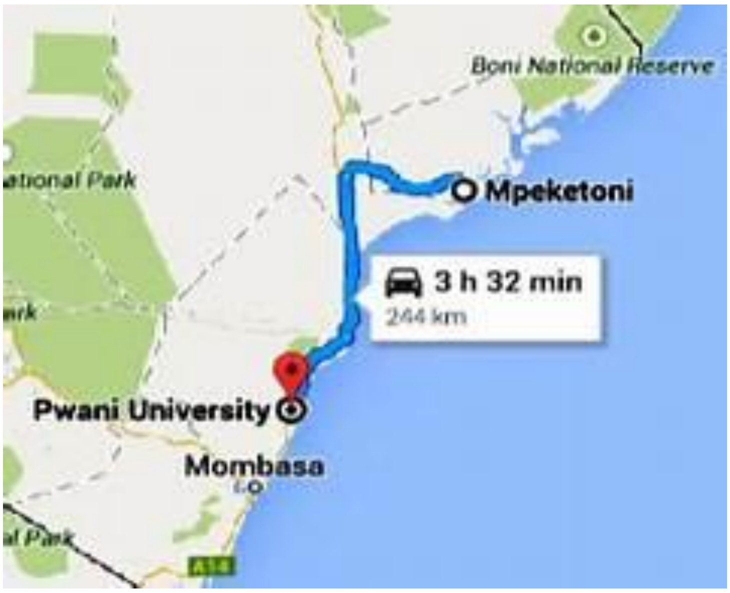

Fig. 1. Experimental study area source: kenyayote.com

2.2.3 Flexi biogas system

The Flexi biogas system was used to digest the materials (Fig. 2). Flexi biogas digester is moveable and elastic. It consists of a flexible digester bag, which is housed in a fabric tunnel. The tunnel serves as an insulator, which absorbs heat and maintains the temperature between 25 ^{o}C to 36 ^{o}C. The tunnel and the elastic bag increase the volume of gas production and decreases the retention time, ensuring a faster rate of fermentation and gas release. It is then piped via PVC pipe connected to a stove for cooking. The Flexi biogas digester does not require an agitator; it is a simple 6 m x 3 m envelope made of PVC canvas, housed in a fabric tunnel [46]**.**

2.2.4 Inorganic fertilizer

The inorganic fertilizers used in the experiment were di-ammonium phosphate (DAP; 18% N: 46% P_2O_5: 0% K_2O) and calcium ammonium nitrate (CAN; 26% N) [25]. DAP was applied at planting, while CAN was top-dressed four weeks after transplanting [25]. The DAP was applied to the respective treatments at planting and CAN was applied as a top dress four weeks after transplanting.

2.2.5 Shade net

The shade net used was black in color, with light intensity of 55 %, relative humidity capacity of 24%. Its dimension was 20m long, 8m wide, and 8 m in height, that was sourced from Amiran Kenya in Nairobi. Fig. 3 shows Swiss chard grown under the shade net.

2.2.6 SPAD-502 chlorophyll meter

The SPAD-502 chlorophyll meter is a hand-held equipment that is used for the quick, precise and non-damaging measurement of leaf chlorophyll content. It is widely used in both research work and in agricultural applications on different plant species [16].

Fig. 2. Flexi bio digester

Fig. 3. Swiss chard under shade net

Fig. 4. Chlorophyll meter

2.2.7 Plant material (Cultivar selection)

One cultivar of Swiss chard (Ford-hook giant) is commonly consumed in the County. Swiss chard (Ford-hook giant) certified seeds was sourced from Agro vet shop. Green leaves and a white stalk characterize the Ford hook giant.

2.2.8 Organic shredder

The organic Shredder is a powerful shredder, which is 1.5hp, which rapidly and simply handles kitchen waste. The shredder has a hopper, with a protective bar and a specific opening. In addition, it has a pair of wheels and a handle, which make it portable and navigable. The shredder is easy to use. It is simply turned on with a quick switch and in a moment, the waste is turned into organic chips.

2.2.9 Fertilizers

D.A.P, C.A.N and the bio-slurry from the kitchen source feedstock and that from cow dung. Other materials include a Jembe tape measure, pesticides (belt, carbendazim), 30cm ruler, a 1-meter ruler and a pen.

2.3 Experimental Design and Treatments

The experimental design was a randomized complete block (Table 1). The size of each experimental unit was 2.1m x1.9m. The total experimental field was 127.14m^2. Plots had paths of 0.5m between them and 0.5 between the replications. Seedlings were transplanted at a spacing of 45cm by 30cm per hole. The experiment was set both under the open field as control experiment and under the shade net to evaluate the effect of bio-slurry fertilizer treatment on Swiss chard under shade net environment net.

2.4 Data Collection

2.4.1 Determination of chemical and physical properties of soil, source feedstock and fresh bio-slurry

Soil samples, kitchen waste, cow dung, kitchen waste bio-slurry and cow dung were taken to Laboratory [17] Agro Care in Nairobi for analysis.

Fig. 5. Organic shredder

Table 1. Experiment design and treatments

Treatment	Shade net			Open field		
Key	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
T1= Control(No fertilizer Applied)	T6	T3	T3	T1	T6	T4
T2=100% DAP+100 CAN	T4	T2	T2	T5	T7	T5
T3=100%Kitchen bio-slurry	T7	T5	T1	T6	T1	T3
T4=100%Cow dung bio-slurry	T5	T6	T6	T7	T4	T7
T**5**=50% DAP (18:46:0)+50% CAN+50% kitchen bio-slurry	T1	T1	T4	T2	T2	T6
T6= T5=50% DAP (18:46:0)+50% CAN+50% cow dung bio-slurry	T2	T7	T5	T3	T5	T2
T7=50% kitchen bio-slurry+50% cow dung bio-slurry	T3	T4	T7	T4	T3	T1

2.4.2 Determination of growth parameters

2.4.2.1 Determination of plant height, leaf length, leaf width and petiole length

Physical counting of the number of plants per experimental unit that were surviving regardless of the environment. And four (4) plants were randomly selected and tagged in each experimental unit two weeks after transplanting. Using a meter rule the height was measured from the soil surface to the highest leaf tip of the largest leaf. Moreover, average of the four plants was taken. Leaf length and leaf width was determined using a 30cm rule, on the tagged plants. The largest leaf and widest on each plant from each treatment was designated for the length and width measurement respectively. The leaf width was obtained by measuring the widest part of the leaf perpendicular to the midrib, while the leaf length was measured along the midrib, from the tip of the leaf petiole to the tip end of the leaf. Petiole length was determined by measuring from the tip of the petiole up to where is attached to the stem.

2.4.2.2 Determination of the number of leaves

The number of leaves was determined every week by physically counting the number of fully-developed leaves from the four randomly selected tagged plants from each treatment.

2.4.2.4 Determination of chlorophyll content

Chlorophyll content was determined on the largest leaf of each selected plant by using chlorophyll meter; model SPAD 502-DL meter.

2.4.2.5 Determination of leaf fresh weight

Swiss chard harvesting was started on the third week after transplanting and was done after every two weeks until the end of cropping season. Swiss chard leaves that were 15 cm or more in length was harvested. The fresh weight of the entire experimental unit was determined using digital weighing scale. Since harvesting of the leaves continued during the growing period, total yield of fresh weight was determined at the last harvest.

2.5 Data Analysis

The collected data was subjected to analysis of variance (ANOVA) using General Linear Model (GLM) of statistical analysis system for significant test. The significant means was compared using Tukey's Honest test performed at a 5% significance **level to determine differences among treatment means, due to its ability to control family wise error**. effects [13].

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Chemical composition of kitchen and cow dung raw bio-slurry used during the experiment

The results (Table 2) show the levels of bulky density, dry matter, moisture content, pH (H_2O), NH^4, NO_3, HCO_3, EC, Exchangeable phosphorus, Exchangeable potassium, Exchangeable calcium, Exchangeable magnesium, Exchangeable iron, Exchangeable zinc, Exchangeable copper, Exchangeable sodium and Exchangeable manganese.

The bulky density of the bio-slurry was recorded as (0.25± 0.02 g/cm3) and (0.52± 0.04 g/cm3) from kitchen source feedstock and cow dung source feedstock respectively. The percentage moisture content of the bio-slurry from kitchen source feedstock and cow dung source feedstock was (54.8± 3.93 % and (62.1± 4.21%) respectively. The pH (H_2O) level of bio-slurry from kitchen source feedstock was (7.2±0.90) and that of cow dung source feedstock was (6.9 ± 0.51). HCO_3 for the kitchen source feedstock was (3968.9±52.40 mg/kg) and cow dung source feedstock was (5560.3±45.72 mg/kg). NH_4 for bio-slurry cow dung feedstock was (125.5±10.91mg/kg) while that from kitchen feedstock was (110.3±10.42mg/kg). NO_3 for bio-slurry from cow dung source feedstock was (2.96±0.34) and that of kitchen source feedstock was (2.4± 0.42).

Dry matter of bio-slurry from kitchen source feedstock recorded was (45.2 ± 3.62%) and cow dung source feedstock was (37.9 ± 3.71%).The electrical conductivity of bio-slurry from kitchen source feedstock was recorded as (5.33 ± 0.32mS/cm) and that from cow dung source feedstock (6.99 ± 0.63mS/cm).

The exchangeable phosphorus for bio-slurry from Kitchen source feedstock was (20.2±2.85 mg/kg) and that of cow dung source feedstock was (27.6± 3.45 mg/kg). The exchangeable (Ca^{2+}, Mg^{2+}, K^+, and Na^+) in the two bio-slurry samples exhibited the following pattern (K^+ > Na+ > Mg^{2+} > Ca^{2+}). The bioslurry from kitchen source feedstock and that from cow dung source feedstock had Ca^{2+} (0.42± 0.02cmolc/kg) and (0.29± 0.01cmolc/kg) respectively. For K^+ it was (3.13± 0.22 cmolc/kg) and 2.12± 0.33cmolc/kg) for kitchen source feedstock and cow dung source feedstock respectively, while for Mg^{2+} it was recorded as (0.45± 0.02 cmolc/kg) and (0.42± 0.03 cmolc/kg) for kitchen source feedstock and cow dung source feedstock respectively. Na^+ concentration in the bioslurry was (1.35± 0.15 cmolc/kg) and (1.26± 0.21cmolc/kg) for kitchen source feedstock and cow dung source feedstock respectively. The Exchangeable Copper was recorded as (0.28± 0.03mg/kg) for bio-slurry from cow dung source feedstock and (0.35± 0.04 mg/kg) for bioslurry from kitchen source feedstock. The exchangeable (phosphorus, Iron and zinc and copper) for raw cowdung bio-slurry exhibited the following trend for exchangeable phosphorus (27.6±3.45) > Exchangeable Iron (1.36±0.25) > Exchangeable sodium (1.26±0.21) > Exchangeable Zinc (0.62±0.03) > Exchangeable Copper (0.28±0.03). For kitchen waste bio-slurry followed the following trend exchangeable phosphorus (20.2±2.85) > Exchangeable sodium (1.35±0.15) >Exchangeable Iron (1.24±0.19) > Exchangeable Zinc (0.72±0.08) > Exchangeable Copper ((0.35±0.04)

Soil analysis:

3.1.2 Physical and chemical composition of soil before the cropping season

The results (Table 3) shows the levels of the soil physical and chemical properties. The standard deviations show the variants among the soil samples from the open field and that of under shade net**.** The soil pH under the shade net was (7.45±1.34 and while that of under open field was (7.25±1.24).

The bulky density for the two soil samples was (1.90±0.26 g/cm^3) and (1.85±0.21 g/cm^3) for shade net end open field respectively. The soil porosity was recorded as (17.35± 1.52%) under the shade net and (15.79± 1.57%) in the open field.

The electrical conductivity of the soil under the shade net was (0.58± 0.04mS/cm) and that of the open field was (0.47±0.02 mS/cm). The soil organic carbon for the soils was recorded as (3.10± 0.09 mg/g) and (3.43± 0.02 mg/g) for the shade net and for the open field respectively. Phosphorus level was (16.58± 2.42mg/kg) and (15.65± 1.98mg/kg) under shade net and open field respectively. The exchangeable Nitrogen level for the soil under shade net and open field was (0.34±0.02 mg/g) and (0.32± 0.01 mg/g).The Exchangeable sodium was (0.10± 0.00 cmol/kg) while that under the open field was (0.11± 0.00. cmol/kg).

The exchangeable (Ca2+, Mg2+, K+ and Na+) in the soil samples exhibited the following pattern (Ca^{2+} > K^+ > Mg^{2+}> Na+). Quantitatively, these cations were as follows; (1.13± 0.15 cmolc/kg), (1.07± 0.09 cmolc/kg), (1.22± 0.10 cmolc/kg) and (0.10±0.00 cmolc/kg) for Ca2+, Mg2+, K+ and Na+) respectively under the shade net. While that under the open field it was (1.09± 0.09 cmolc/kg) (1.05± 0.07 cmolc/kg), (1.14± 0.07 cmolc/kg), and (0.11± 0.00cmolc/kg for exchangeable (Ca2+, Mg2+, K+ and Na+) respectively. Cation exchange capacity for the soil under the shade net was (4.35±0.9 meq/100g) while that of the open field was varied (4.05±0.85 meq/100g).

3.1.3 Summary statistics

The results (Table 4) show a summary of statistical analysis on the effect of cover, treatment and interaction of cover with treatment and the coefficient variance. The p-values due to the effect of cover on; petal length, leaf length, leaf width, number of leaves per plant, plant height chlorophyll and yield are (p<.0001), (p<.0001), (p= 0.0436), (p= 0.0436) (p= 0.0108), (p= 0.0393) and (p= 0.0089) respectively. while the p–values due to the effect of treatment application on petal length, leaf length, leaf width, number of leaves per plant, plant height chlorophyll and yield were (p= 0.0426),(p= 0.0464),(p= 0.0076),(p= 0.0008), (p= 0.0125),(p< .0001)and (p= 0.0071) respectively. All the values were significant since the statistical analysis was performed at 5% level of Significance.

Interaction between cover and treatment did not have any significant effect on petal length (p= 0.9997), leaf length (p=0.9638), leaf width (p= 0.8367), number of leaves per plant (p= 0.2077), plant height (p= 0.9824), chlorophyll (p= 0.681) and yield (p= 0.6529). . The coefficient of variances 31.9, 21.0, 23.5, 17.9, 8.1 and 28.1 for petal length, leaf length, leaf width, number of leaves per plant, plant height chlorophyll and yield respectively.

Table 2. Chemical composition (Mean ± Standard Deviation) of kitchen and cow dung raw bio-slurry

Parameter	Raw cow dung bioslurry	Raw kitchen waste bioslurry
Bulk density (g/cm3)	0.52±0.04	0.25±0.02
Dry matter (%)	37.9±3.71	45.2±3.62
Moisture content (%)	62.1±4.21	54.8±3.93
pH (H_20)	6.9±0.51	7.2±0.90.
NH^4 (mg/kg)	125.5±10.91	110.3±10.42
NO_3 (mg/kg)	2.96±0.34	2.43±0.42
HCO_3 (mg/kg)	5560.3±45.72	3968.9±52.40
Electrical Conductivity (mS/cm)	6.99±0.63	5.33±0.32
Exchangeable Phosphorous (mg/kg)	27.6±3.45	20.2±2.85
Exchangeable potassium (cmol/kg)	2.12±0.33	3.13±0.22
Exchangeable Calcium (cmol/kg)	0.29±0.01	0.42±0.02
Exchangeable Magnesium (cmol/kg)	0.42±0.03	0.45±0.02
Exchangeable Iron (mg/kg)	1.36±0.25	1.24±0.19
Exchangeable Zinc(mg/kg)	0.62±0.03	0.72±0.08
Exchangeable Copper (mg/kg)	0.28±0.03	0.35±0.04
Exchangeable sodium (cmol/kg)	1.26±0.21	1.35±0.15
Exchangeable Manganese (cmol/kg)	1.12±0.09	1.21±0.07

Values represent the means ± standard deviations

Table 3. Soil property before cropping season

Parameter	Shade net	Open field
Bulky Density (g/cm^3)	1.90±0.26	1.85±0.21
Porosity (%)	17.35±1.52	15.79±1.57
Moisture Content (%)	18.21±2.37	17.63±2.35
pH (H_20)	7.45±1.34	7.25±1.24
Electric Conductivity (mS/cm)	0.58±0.04	0.47±0.02
Cat ion Exchange Capacity (meq/100g)	4.35±0.90	4.05±0.85
OC (mg/g)	3.10±0.09	3.43±0.02
Exch N (mg/g)	0.34±0.02	0.32±0.01
Exch. P (mg/kg)	16.58±2.42	15.65±1.98
Exch K (cmol/kg)	1.07±0.09	1.05±0.07
Exch Ca (cmol/kg)	1.13±0.15	1.09±0.09
Exch Mg (cmol/kg)	1.22±0.10	1.14±0.07
Exch Fe (mg/kg)	17.60±2.45	15.64±2.31
Exch Zn (mg/kg)	20.14±2.72	20.11±2.41
Exch Cu (mg/kg)	1.67±0.13	1.55±0.09
Exch Na (cmol/kg)	0.10±0.00	0.11±0.00
Exch Mn (cmol/kg)	0.27±0.04	0.22±0.03

Values represent the means ± standard deviations

Table 4. Summary statistics on the effect of bio-slurry on shade net grown swiss chad

Parameters	P values			CV (%)
	Cover	Treatments	Cover × Treatment	
Petiole length (cm)	<.0001	0.0426	0.9997	31.9
Leaf length (cm)	<.0001	0.0464	0.9638	21.0
Leaf width (cm)	0.0436	0.0076	0.8367	23.5
Leaf number (no./plant)	0.0108	0.0008	0.2977	11.7
Plant Height (cm)	0.0393	0.0125	0.9824	17.9
Chlorophyll (concentration index units)	0.0393	<.0001	0.681	8.1
Yield (t/ha)	0.0089	0.0071	0.6529	28.12

Table 5. Effect of cover on growth of shade net grown swiss chad

Cover	Petiole length (cm)	Leaf length (cm)	Leaf width (cm)	Leaf number (no/plant)	Plant height (cm)
Shade	13.3[a]	20.7[a]	10.6[a]	4.2[a]	16.1[a]
Open	8.7[b]	16.9[b]	8.2[b]	3.9[b]	14.4[b]

**Means within a column followed by the same letter are not significantly different (Tukey's test at p = 0.05)*

3.1.4 Effect of interactions between cover and treatment on growth of shade net grown Swiss chard

The results (Table 5) of the experiment revealed the interaction between cover and treatment. Interaction between cover and treatment did not have any significant (p= 0.9997), (p=0.9638), (p= 0.8367), (p= 0.2077), (p= 0.9824), (p= 0.9824)) and (p= 0.0089) effect on petal length, leaf length, leaf width, number of leaves per plant, plant height chlorophyll and yield respectively.

3.1.5 Effect of cover on growth of shade net grown Swiss chard

The results recorded, regarding to the effect of cover on the growth of shade net grown Swiss chard is shown in (Table 5). The results reveal that cover significantly (p<.0001), (p<.0001), (p= 0.0436), (p= 0.0436) and (p= 0.0108) influenced petal length, leaf length, leaf width, number of leaves per plant and plant height respectively. Petals and leaves were longer, leaves were wider, the number of leaves per plant was more and plants were taller under the shade net by 149.4%, 22.5%, 53.6%, 7.7% and 11.6% respectively compared to those under open field.

3.1.6 Effect of cover on chlorophyll content and yield of shade net grown Swiss chard

The results regarding to the effect of cover on chlorophyll content and yield of shade net grown Swiss chard is presented on (Fig. 6). Chlorophyll and yield were significantly (p= 0.0393, p= 0.0089) influenced by cover (shade net). Chlorophyll content was higher under open field by 8.7% compared to under shade net while yields were higher by 12.5% under shade net compared to open

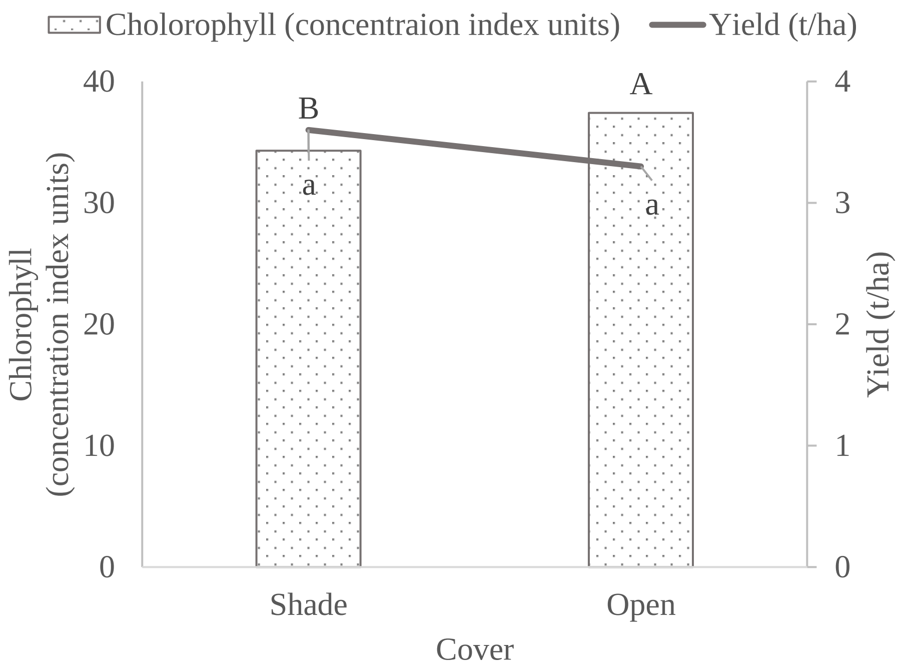

Fig. 6. Effect of cover on chlorophyll content and yield of shade grown swiss chad. Means followed by the same letter are not significantly different (Tukey's test at p = 0.05

3.1.7 Effect of bioslurry treatment on the growth of shade net grown swiss chad

The results regarding to the effect of bio-slurry treatment on the growth of shade net grown Swiss chad are shown in (Table 6). The results reveal that bio-slurry treatment significantly (p= 0.0426), (p= 0.0464), (p=0.0076), (p= 00.0008) and (p= 0.0125)) influenced petal length, leaf length, leaf width, number of leaves per plant and plant height respectively.

Petiole length: Bio-slurry treatment significantly (p= 0.0426) influenced the petiole length of shade net grown Swiss chard. From the results, the performance followed the following trend T3>T2>T1 (Control). Petioles on plants treated with 100% kitchen feedstock bio-slurry was longer by 23.6% and 114.8% compared to plants treated with 100% synthetics and control respectively. Additionally, the petioles of plants that received 100% synthetics (T2) was 73.8% longer compared to the control. Treatment T3 was comparable with T4, T5, T6 and T7 but had the highest (114.8%) increase compared to control.

Leaf length: Bio-slurry treatment significantly (p= 00.0464) influenced the leaf length of shade net grown Swiss chard. From the results, the performance followed the following trend T2=T3=T4=T5=T6=T7> T1 (Control). Leaves under T2, T3, T4, T5, T6 and T7 were longer compared to control by 37.9%, 63.6%, and 49.2%, 41.7%, 34.8% and 55.3% respectively. T3 had the highest (63.6%) increase in length although statistically was the same as T2, T3, T4, T5 and T6

Leaf width: Bio-slurry treatment significantly (p= 0.0076) influenced leaf width of shade net grown Swiss chard. From the results, the performance followed the following trend T2=T3=T4=T5=T6=T7> T1 (Control). Leaves under T2, T3, T4, T5, T6 and T7 were wider compared to control by 92.5%, 113.2%, and 86.8%, 75.5%, 73.5% and 96.2% respectively. T3 had highest (113.2%) width increase although statistically was the same as T2, T4, T5, T6 and T7.

Number of leaves per plant: Bio-slurry treatment significantly (p=0.0008) the number of leaves per plant of shade net grown Swiss chard. From the results, the performance followed the following trend T2= T3= T4= T5= T6= T7> T1 (Control). The number of leaves per plant under T2, T3, T4, T5, T6 and T7 were more compared to control by 44.8 %, 120.7%, 41.4%, 48.3%, 37.9% and 51,7% respectively. T3 had the highest (120.7%) increase on the number of leaves although statistically was the same as T2, T4, T5, T6 and T7.

Plant height: Bio-slurry treatment significantly (p=0.0125) influenced plant height of shade net grown Swiss chard. From the results, T7 recorded the tallest plant height though there was no significant difference with T3, T4, T5 and T6. It was comparable with T2 the performance follows the following trend T1 (Control). Leaves under T3, T4, T5, T6 and T7 were longer compared to control by 57%, 55.1%, and 43.9%, 43% and 58.9% respectively. T7 had the highest (58.9%) plant height increase although statistically there was no significant difference compared to T3, T4, T5 and T6. T7 as well was comparable with T2.

3.1.8 Effect of bioslurry treatment on chlorophyll of shade net grown swiss chad

The results regarding to the effect of bio-slurry treatment on chlorophyll of shade net grown swiss chad is shown on (Fig. 7). Bio-slurry treatment significantly (p <.0001) influenced chlorophyll content of shade net grown Swiss chard. From the results, the chlorophyll content followed the following trend T2= T3= T4= T5= T6= T7> T1 (Control). The chlorophyll content under T2, T3, T4, T5, T6 and T7 was higher compared to control by 44.7 %, 39.8%, and 38.3%, 43.9%, 43.9% and 40.9% respectively. T2 had the highest (44.7%) increase on chlorophyll content although statistically there was no significant difference compared to T3, T4, T5, T6 and T7.

3.1.9 Effect of bio-slurry treatment on yield of shade net grown swiss chad

The results regarding the effect of bio-slurry treatment on the yield of shade net grown swiss chad are shown in (Fig. 8). Bio-slurry treatment significantly (p= 0.0071) influenced yield of shade net grown Swiss chard. From the results, the yield followed the following trend T3= T6= T7> T1 (Control). In addition, T3 was comparable to T2, T4 and T5. The yield under T3, T6 and T7 was higher compared to control by 104.8 %, 93.9%, and 140.4% respectively.T7 had the highest (140.4%) increase on the yield although statistically was the same on the number of leaves as T6 and T3 and comparable to T2, T4and T5.

Table 6. Effect of bioslurry treatment on growth of shade net grown swiss chad

Treatment	Petal length (cm)	Leaf length (cm)	Leaf width (cm)	Leaf number (no./plant)	Plant height (cm)
T1	6.1[c*]	13.2[b]	5.3[b]	2.9[b]	10.7[b]
T2	10.6[b]	18.2[a]	10.2[a]	4.2[a]	14.8[ab]
T3	13.1[a]	21.6[a]	11.3[a]	4.4[a]	16.8[a]
T4	12.0[ab]	19.7[a]	9.9[a]	4.1[a]	16.6[a]
T5	11.6[ab]	18.7[a]	9.3[a]	4.3[a]	15.4[a]
T6	11.3[ab]	17.8[a]	9.2[a]	4.0[a]	15.3[a]
T7	12.1[ab]	20.5[a]	10.4[a]	4.4[a]	17.0[a]

**Means within a column followed by the same letter are not significantly different (Tukey's test at p = 0.05)*

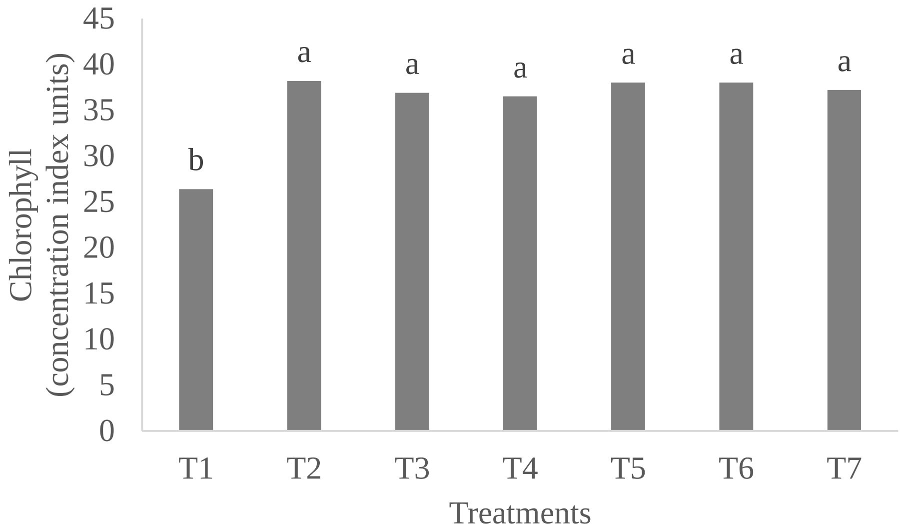

Fig. 7. Effect of bio-slurry treatment on chlorophyll content of shade grown swiss chad. Means followed by the same letter are not significantly different (Tukey's test at p = 0.05)

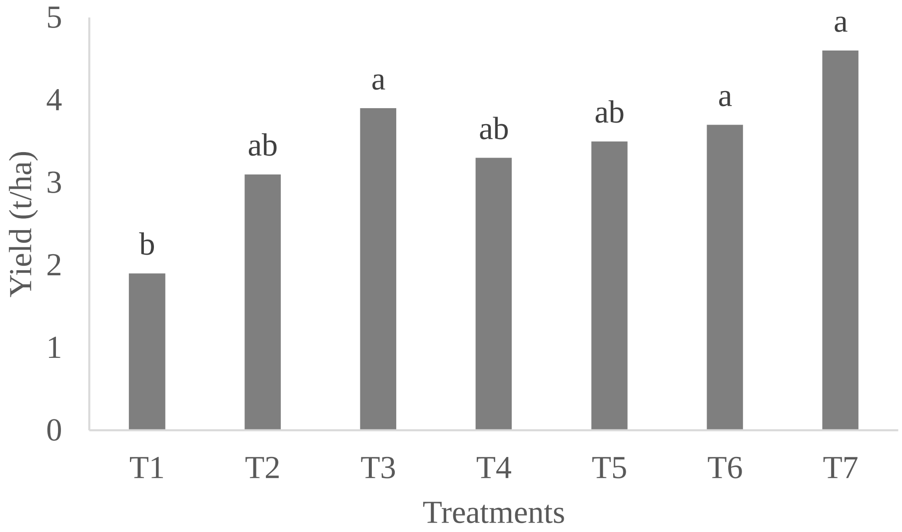

Fig. 8. Effect of bio-slurry treatment on yield of shade grown swiss chad. Means followed by the same letter are not significantly different (Tukey's test at p = 0.05)

Plate 1. Swiss chard under shade net

Plate 2. Swiss chard under shade net

3.2 Discussion

The bulky density of cow dung bio-slurry was 51.9% higher compared to that from the kitchen. The lower bulk density of the kitchen feedstock might be due to high organic matter available. Moisture content for cow dung bio-slurry was 7.3% higher compared to the kitchen waste. This result aligns with a study conducted by Zhang et al. (2007), which analyzed food waste and recorded that the optimal moisture content ranged between 74% and 90%.

Dry matter for bio-slurry from kitchen source feedstock was higher by 7.3% compared to that of cow dung. This may be due to the mixture of different food waste components, which had high dry matter content. The results by [5] recorded the highest moisture content (80.4%) and lowest dry matter (19.6%) in fruit and vegetable food waste. Bread waste had 77.2 % dry matter, mixed food waste and potato peel had a similar quantity of dry matter with a standard deviation (± 2). Meat had around 43 % dry matter, whereas for beans, rice, leafy vegetables, cow dung and fish waste in order from highest to the least were between 30 to 40 % dry matter. The high dry matter content in kitchen waste may also be attributed to the high fiber content in the food waste components. A study conducted by [5] on techno-economic valuation of methane gas production from kitchen waste through anaerobic digestion; found that dates with high fiber content had the highest dry matter content. Although bio-slurry from kitchen source feedstock was higher by 7.3%, in terms of dry matter, both bio-slurry dry matter was high as rated by [2].

Kitchen bio-slurry had higher exchangeable potassium, calcium, magnesium, sodium, and manganese by 32.3%, 13%, 6.7%, 6.7%, and 7.4%, respectively, compared to cow dung bio-slurry. Similarly, zinc and copper were higher by 13.9% and 20%, respectively, compared to cow dung bio-slurry. This might be due the different components of food waste with different mineral composition levels.

The pH (H_2O) level of bio-slurry was all neutral as rated by [39], this might be due to the fact that when organic manure is digested anaerobically, organic solids are converted to fatty acids which are volatile. These organic acids build up and pH initially reduced. However, due to the buffering capacity of the organic manure, these acids are prevented from lowering the pH excessively [61]. Methanogenic microbes in the following step converts the volatile fatty acids to methane, as these fatty acids were changed, the pH of the bio-slurry increased due to the utilization of protons during the methanogenesis phase [6]. Eventually, this leads to pH level of bio-slurry greater than 7. This is in agreement with reports of farmers in United States using bio-slurry on their farms who recorded a rise in soil pH [53]. The increase of the pH level of the bio-slurry could also be due to the influence of the base cations concentration like Calcium and potassium, which buffer the pH due to hydrogen ions in the liquid phase. The effective hydrogen ion concentration was reduce and pH level increased. At the same time, precipitation of carbonates (CaCO3) buffered pH level between 7 and 8 [6]. NH_4, was high for the both the kitchen source feedstock (3968.9± 52.40) and cow dung source feedstock (5560.3± 45.72) which was high [24]. HCO_3, NH_4 and NO_3, was higher in the bio-slurry from cow dung source feedstock by 28.6%,12.1% and 17.9% respectively compared to that from kitchen source feedstock. NH_4 was high for both the bio-slurry as recorded by [4]and [7]. The electrical conductivity of bioslurry from kitchen source feedstock was 23.7% much less compared to bio-slurry from cow dung source feedstock but all were considered as slightly saline as rated by [45]. The electrical conductivity of bio-slurry is directly related to the polarity and presence of ions concentration. Increased conductivity values indicate the availability of more soluble ions like potassium or sodium and more polar solution [12]

Exchangeable phosphorus and exchangeable iron were higher for the cow dung compared to kitchen waste bio-slurry by 26.6% and 8.8% respectively. Generally, the exchangeable phosphorus for bio-slurry for both bio-slurry was high as established by [22]. The exchangeable (Ca^{2+}, Mg^{2+}, K^+, and Na^+) in the two analyzed bio-slurry exhibited the following pattern (K^+ > Na+ > Mg^{2+} > Ca^{2+}. For K^+ was high as recorded, Mg^{2+} and Na^+ were at optimal levels as recorded by [23] and [30]. The exchangeable (phosphorus, Iron, zinc and copper) also exhibited the following trend P_2O_3> Exchangeable Iron > Exchangeable sodium> Exchangeable Zinc> Exchangeable Copper [36]

The soil pH under the shade net and under the open field was neutral [39] though pH value under shade net was higher by 26.8% compared to that of the open field. The electrical conductivity of the soils is all within the range of non-saline soil [26].

The soil organic carbon for all the soils was high and the phosphorus level was considered as high as established by [51]. The exchangeable Nitrogen was considered as high as recorded by [51]. The exchangeable (Ca2+, Mg2+, K+, and Na+) in the two soil samples exhibited the following pattern (Ca^{2+} > K^+ > Mg^{2+}>Na+). The exchangeable Potassium, Sodium, Magnesium and Calcium were very low according to the ratings recorded by [23]**.**

Cation exchange capacity for the soil varied from (4.05± 0.85) and (4.35± 0.9) indicating low cation exchange capacity for the two samples [26] and [30].

Exchangeable Nitrogen and Exchangeable phosphorus were higher under the shade net by 5.9% and 5.6% respectively compared to the soil under the open field. Exchangeable potassium, exchangeable calcium, exchangeable magnesium, and exchangeable manganese were higher under the shade net by 1.9%, 3.5%, 10.7% and 22% respectively compared to open field. While exchangeable sodium was higher under the open field by 9% compared to that under the shade net. Exchangeable zinc, Exchangeable copper and Exchangeable iron were higher under the shade net by 0.03%, 7.2% and 11.1% respectively compared to the soil under the open field.

The soil bulky density under the shade net was 2.6% higher compared to that from the open field. Since the soil type where the study was conducted is sandy loam, soil bulky density for the two different soil samples was above 1.5gm /cm^3 as the rating given by [26] and 1.41.5gm /cm^3 given by [57] as bulky density for sandy loam soils

Moisture content under shade net was 0.58 % higher compared to open field. Although the soil under the shade net was more porous by 1.6% compared to the soil under the open field, all the soils were considered highly porous [50].

The increased plant growth parameters (plant height, leaf length, leaf width stem, petiole length number of leaves) under the shade net might have resulted due to reduced light, low temperature and increased humidity under the shade net thereby creating a favorable microclimate for high cell division in the plant apical meristem leading to plant height increase. In addition, it might be because of enhanced auxin transportation in plants under a shading environment as earlier recorded by [41]. It may also be due to the conducive environment created by the shade net, which improved the process of photosynthetic in Swiss chard [48]. In addition, it might also be due to multiplication in cell number and cell elongation that led to increased growth parameters due to the low light environment in the shade net. These findings agree with [35] who recorded that petiole length in Arabidopsis thaliana increased in low light environments. The finding also supports [49] who recorded greater leaf length and leaf width of Anthurium under a deeply shaded environment.

The open field had higher chlorophyll content compared to shade net. This difference could have resulted due to radiant energy and the intensity that are responsible for the formation of carboxydismutase enzyme, which induces the formation of chlorophyll. Therefore, a reduction in light would lead to a decrease in the formation of carboxydismutase enzyme and therefore result in a lower amount of chlorophyll. These results are similar to the results reported by [15] who recorded that, chlorophyll levels tend to diminish with an increase in shading in baby spinach. Similar results were found by [43] who recorded that open field environments tend to have higher SPAD values.

Swiss chard grown under shade net had higher yield fresh weight than those under the open field. This improvement might be due to the low light intensity under the shade net, which created a more conducive environment for vegetative growth. This resulted in the regeneration of additional new leaves during the growing season as compared to the open field [15]. It might also be due to the higher number of leaves, taller plants and broader leaves under the shade net, which developed carbohydrates through the photosynthesis process and eventually increased yield. Similarly, it might also be due to the reduced heat and improved soil moisture that favoured growth, which led to higher yields. Another study conducted by [52] demonstrated that growing tomatoes under shade net increased the yields. This is contrary to the results by [11] who recorded lower yields undercover as compared to open field, which was the control experiment.

The current study recorded the highest increase on petiole length, leaf length, leaf width and number of leaves per plant where plants were treated with kitchen bio-slurry.

The high increase of the growth parameters compared to control might due to the application of kitchen bio-slurry, which released the nutrients faster. While that of cow dung bioslurry mineralized slowly and therefore supplied less nutrients during the growth period [18]. Research conducted by [18] reported that kitchen garbage is enriched with ammonium nitrogen which is over 99% of the total nitrogen while 20% of the nitrogen in cow dung bio-slurry was in organic which needed to be mineralized to be accessible to plants. This is also contrary to the research that has been conducted with livestock waste bio-slurry from biogas plants. A pasture mixture of timothy (Phleum pratense L.) and leguminous, sugar beet (*Beta vulgaris* L. subsp. vulgaris), Irish potato (Solanum tuberosum L.), and wheat (Triticum aestivum L.) were planted with cow dung bio-slurry combined with phosphate fertilizers [31]. The yield of the mixed pasture, sugar beet, potato, and wheat grown with cow dung was the same as those planted with inorganic fertilizers. A study conducted by [55] established that cow dung bio-slurry could substitute for inorganic fertilizer nitrogen top dressing of paddy rice production.

From the results, plants treated with the combination of 50% kitchen bio-slurry and 50% cow dung bio-slurry recorded the highest increase in plant height compared to control. This might be due to the combined effect of bio-slurry at the ratio of 50% kitchen and 50%cow dung (T7) at planting and at topdressing, which provided plant nutrient that enhanced plants growth. Nitrogen is a basic part of chlorophyll and plays an important role in plant growth and development. Due to the ability of the bio-slurry to stay longer in soil, holding and providing plant nutrients more efficiently, the bio-slurry mixture and the increased pH could have improved the assimilation of some of the plant nutrients. The optimum uptake of nitrogen in the form of ammonium and nitrate was reported to be influenced by pH [14]. The higher increase in the growth parameter could be because of the bio-slurry, which is enriched with organic and inorganic plant nutrients like; nitrogen, phosphorus and potassium, amino acids, proteins, nucleic acids and sugars, which play an important role in improving crop yield [10]. Although its nutrient status is lower compared to synthetic fertilizer, after anaerobic digestion, nitrogen, phosphorus, potassium and other plant nutrients become readily available for crops to absorb more conductively to promote plant growth [28]. In addition, a study conducted by [17] recorded the tallest ford hook giant where 200% of bio-slurry was used, while those applied with inorganic fertilizers had the shortest plants. In contrast [18], found that kitchen garbage bioslurry could not be equivalent to nitrogen-source inorganic fertilizers for oat (Avena sativa L.) and barley (Hordeum vulgare L.).

The current study revealed that the chlorophyll content was highest where plants received 100 DAP at planting and 100% (T2) of the recommended application rate. This is due to higher concentration of nitrogen and faster mineralization in the synthetic fertilizer. Nitrogen is a fundamental part of chlorophyll and plays an essential role in plant growth by increasing meristematic growth therefore promoting cell division and elongation.

The results did not have any significant difference compared to T3, T4, T3, T6 and T7.This clearly demonstrated that bio-slurry might be a good alternative to inorganic fertilizer. The level of chlorophyll content in leaves can show the photosynthetic ability of the plants [64], influencing crop production [58]. As bio-slurry is rich in N, P, S, Mg and other elements that institute chlorophyll, protein as well as lamella film [56], the use of bio-slurry can effectively increase chlorophyll levels in leaves [63]. The improvement of electron transport and stomata opening is useful to the enhancement of sunlight energy capture, conversion efficiency and the rate of carbon dioxide fixation [47], thus increasing the photosynthetic ability of leaves [54]. Another study on the use of bio-slurry on bitter melon could increase photosynthetic indexes; lower stomata limit value, lengthen the harvesting duration and increase production [64]. Study conducted on tomato by [59] also revealed that bio- slurry might significantly improve leaf nitrogen and chlorophyll levels hence increase the rate photosynthetic, transpiration and stomata conductance. Chlorophyll levels and carboxylase activity influence the rate of photosynthesis. Nitrogen is the main constituent of chlorophyll and carboxylase [60]. Inadequate or too much nitrogen application can lead to a decrease in chlorophyll content and induce leaf senescence [42].

Many researchers have conducted a number of studies on the influence of the use of bio-slurry on crop yield [62]. Therefore, on the current study it was noted that yield increase was higher when a combination of 50% cow dung bioslurry and 50% kitchen waste bio-slurry was applied compared to the control (T1). The high yield increase might be due to the prolonged harvest period, which could be due to the slow-release organic matter as well as humic acid in the bio-slurry, which lengthens the fertilizer effectiveness and the harvesting period. Also bio-slurry improved the soil properties The longer the harvest duration the more the pepper could be produced within one crop cycle, hence achieving extra cost-effective benefits [33].

4. CONCLUSION

The result clearly revealed that, the use of bio-slurry improved the growth parameters and yield of shade net grown Swiss chard. Application of bio-slurry therefore could boost crop production by increasing crop yields by farmers thus contributing towards Kilifi County and Kenya as whole on food security. Transforming kitchen waste resources into bio-slurry by use of biodigster can provide a sustainable best way to manage kitchen waste thus creating a sustainable environment as defined by the National Vision 2030 while creating an added benefit through enhancing soil fertility and long-term carbon sequestration thus reducing greenhouse gas emissions

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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