

Original Research Article

Comparative Effects of *Piper guineense* Emulsion and Cabbage-Tomato Intercropping for Mitigating Cabbage Pest Infestation and Improving Performance

ABSTRACT

AIMS: This study aims to improve cabbage production by mitigating cabbage pests via locally produced organic pesticide and cabbage-tomato intercropping.

METHODOLOGY: Four treatments (control, cabbage-tomato intercropping, organic and synthetic pesticides) were evaluated on cabbage pests and yield.

RESULTS: Pest infestation correlated negatively with treatment ($r = -0.95$), ranging from 2 – 23 larvae per plant (what is unit?) and varied across treatments ($P = .001$), with the highest in control compared to the others ($P = .05$). DBM larvae ranged from 1 – 10 and varied across

treatments ($P = .001$), with highest in control compared to the others ($P = .05$).

Looper correlated negatively with treatment ($r = -0.62$), ranging from 0 – 8 ???and varied across treatments ($P = .05$), with the highest in control compared to the others

($P = .05$). Snail population ranged from 34 – 91 ???and varied across treatments ($P = .001$), with the highest in control and the lowest in organic treatment compared to the

others ($P = .05$). Number of sprouted plants ranged from 0 – 5 and varied across treatments ($P = .001$) with the highest in control compared to the others ($P = .05$).

Number of sprouted cabbage correlated negatively with treatments ($r = -0.93$), but positively correlated with pest infestation ($r = 0.81$), DMB ($r = 0.71$) and Looper ($r =$

0.58). Cabbage yield ranged from 3.2 to 6.0 (unit? Kg/ plant or tones/ ha) and varied across treatments with the

lowest in control and the highest in intercropping ($P = .05$). A negative correlation

occurred between cabbage yield and DBM ($r = -0.62$), Looper ($r = -0.63$) or sprouting ($r = -0.62$).

CONCLUSION: The organic emulsion pesticide effectively mitigated cabbage pest populations below economic injury threshold.

Keywords: *Diamondback Moth, Looper, Piper emulsion, Snails, Webworm*

1. INTRODUCTION

Cabbage (*Brassica oleracea* L.) is an exotic nutrient rich leafy vegetable with variable forms of consumption [1,2]. Cabbage cultivation is an important source of food and nutrient security, income and livelihood in Cameroon [3]. Cabbage consumption limits micronutrient deficiency that is a major cause of poor health and high mortality in Africa [4]. With 40% malnutrition in SSA, vegetable diets represent the most affordable and accessible source of micronutrients, vitamins and health-promoting secondary metabolites [5,6]. However, cabbage is a nutritious succulent leafy vegetable that attracts many insect pests that bore leaves and destroy growing buds and mature heads. Hence, cabbage production is affected by field pests, which are mitigated by various farm management practices including intercropping, synthetic pesticides and botanicals.

Cabbage yield loss caused by diamondback moth – DBM (*Plutella xylostella*) can reach up to 90% during severe field infestation [7]. Looper (*Trichoplusia ni*) is a major pest of cabbage that feeds on leaves and kills young plants or cause sprouting, while feeding on cabbage heads causes contamination with frass [8]. Webworm (*Helulla undalis*) is an important cabbage pest that accounts for huge field losses [8]. Snails facilitate decomposition of plant material and serve as biological indicators of soil quality, but they represent major pests of tropical and subtropical

51 regions and most damaging during wet seasons [9,10]. Meanwhile, resistance to
52 conventional molluscicides has increased the need for alternative sustainable control
53 measures for Snails that include the use of plant products [11].

54 Globally, the use of commercial synthetic pesticide has exacerbated reliance on
55 chemical controls and increased pest resistance, leading to higher production cost
56 with negative externalities [12,13]. Commercial synthetic chemicals are commonly
57 used to manage field pests and diseases [14-17]. However, pest evolution and
58 resistance, environmental effects and high cost of synthetic chemicals often limit
59 their use in smallholder farming systems [13]. Moreover, the evolution of pest
60 resistance to synthetic pesticides requires the use of more powerful pesticides at
61 higher doses, which increases insecticide dependency [18,19]. Hence, this has
62 necessitated alternative sustainable management strategies involving the use of
63 botanicals that are effective and affordable without negative externalities [20-22].
64 However, both synthetic pesticides and botanicals have demonstrated variable
65 responses to field pests and diseases [18,23,24].

66 The PAMS model (prevention, avoidance, monitoring, and suppression) was
67 used to evaluate various pest management practices [25]. The preventive tactics
68 included treatments or crop rotation and planting of pest-resistant cultivars, while the
69 avoidance tactics included altering planting dates and managing irrigation schedules
70 [25]. Further avoidance tactics involves intercropping cabbage with a repellent crop
71 like tomato (*Lycopersicon esculentum* L.), and cabbage-tomato intercropping
72 reportedly reduced DBM infestation in cabbage fields [3,26]. The odour from the
73 tomato intercrop repels DBM [3] or has an oviposition deterrent effect on DBM [27].
74 This similar to onion (*Allium cepa*) and garlic (*Allium sativum*) that also demonstrated
75 repellent effects on DBM [26,28].

This study was intended to improve cabbage production by incorporating the concepts of integrated pest management and integrated soil fertility management via a combination of planting time, intercropping, and organic or inorganic inputs [29]. It was hypothesized that (i) locally produced organic pesticide effectively mitigates field pests, (ii) Cabbage-tomato intercropping reduces pest infestation, and (iii) Cabbage-tomato intercropping enhances cabbage performance.

2. MATERIALS AND METHODS

2.1 Experimental Site and Setup

The study was conducted at the teaching and research farm of the Faculty of Agriculture and Veterinary Medicine of the University of Buea, located at the foot of mount Cameroon, Southwest Region. It is situated between latitudes 4°3'N and 4°12'N of the equator and longitudes 9°12'E and 9°20'E. The soil is derived from weathered volcanic rocks dominated by silt, clay and sand [30,31]. Buea has a mono-modal rainfall regime with less pronounced dry season and 85% to 90% relative humidity. Heavy rainfall occurs between June and October while the dry season starts from November to May, with mean annual rainfall of 2085 mm to 9086 mm between March and November [32]. Mean monthly air temperature ranges from 19°C to 30°C, while soil temperature at 10 cm depth decreases from 25°C to 15°C with increasing elevation from 200 m to 2200 m above sea level [31,33,34].

The experiment was randomized complete block design with four replicates per treatment. The field was cleared manually with a cutlass and tilled with a hoe and partitioned into 16 plots measuring 3x4 m each. The experimental setup comprised four treatments including a control (control – sole cabbage and sole tomato, synthetic pesticides, organic pesticide, tomato intercrop). Each plot contained 8 rows and 6 columns of cabbage with 50×50 cm planting distance, leading to 48 plants.

The intercropped plots had 24 cabbage plants and 24 tomato plants, planted at 50×50 cm, in one alternating row crop. Meanwhile, the experimental plots were separated from each other by a 50 cm buffer zone.

2.2 Locally Produced Organic Pesticide

The locally produced organic amendment comprised West African black pepper *Piper guineense* Schum. and Thonn, harvested from a primary forest at Inokun-Eyumojock, Southwest Cameroon. The fresh Piper seeds were sun-dried for one week and blended into fine powder using a kitchen blender. 250 g Piper powder was dissolved in 1 L vegetable oil (KING'S®, Lagos-Nigeria) commonly sold in the local market. The mixture was thoroughly stirred and 10 g of commercial detergent (SABA®, Douala-Cameroon) added to produce a slightly sticky emulsion for easy absorption by plants. The organic emulsion pesticide was stored at room temperature in a plastic container. Prior to field application of the organic pesticide, a laboratory evaluation trial was conducted to determine the effective application dose for best field results. For this, ten DBM larvae were randomly collected in the morning from the field and placed in five petri dishes with two larvae each. A piece of cabbage leaf was introduced into the petri dish as food substrate for the larvae. Five concentrations were prepared from the stock organic emulsion; 0.007 (100:15), 0.005 (80:15), 0.004 (60:15), 0.003 (50:15) and 0.013 (20:15) product:water (ml:L) ratio and applied in five respective petri dishes containing insects using a syringe. Based on performance evaluations, the 0.003 concentration (50:15 ml:L) was chosen for field applications. The field application of organic amendment was performed during cold dry periods, often in early mornings with minimal drift. For field

applications, 50 ml of organic product was filtered using a double 169-folded muslin cloth to remove the sediments, diluted in 15 L water and stirred vigorously to achieve homogeneity. The homogenized mixture was poured into a knapsack sprayer and used to uniformly spray both sides of the cabbage leaves, including folded leaves for all 192 plants in the respective four experimental plots, at two weeks intervals.

2.3 Plant Cultivation

2.3.1 Cabbage

Hybrid cabbage seeds (*Brassica oleraceae* L. var. *capitata* F1 Green Coronet; STARKE AYRES®, France) were purchased from an agro-shop in Buea Cameroon and pre-germinated on a 2.5×1 m nursery bed beside the experimental plots. The nursery bed was prepared by clearing the site with a cutlass and the soil tilled manually using hoes. Cabbage seeds were sown at an inter-row spacing of 15×15 cm. Vigorous seedlings were transplanted from the nursery to the experimental plots on the 10th of March 2016 following the usual planting season in this region. The cabbage seedlings were field-planted at 50×50 cm spacing on 3×4 m (12 m²) experimental plots of manually raised soil beds of approximately 30 cm height, with one plant per stand and 48 plants per plot.

2.3.2 Tomato

Hybrid tomato seeds (*Lycopersicon esculentum* L.; F1 Cobra 26; TECHNISEM® France) were purchased from an agro-shop in Buea Cameroon and pre-germinated on nearby 2×1 m nursery bed at 15×15 cm inter-row spacing. The nursery seedlings were amended with 0.5 kg of NPK fertilizers (20:10:10) and treated with 35 ml synthetic insecticide (K-Optimal; SCPA SIVEX International® France; comprising

active components Lambda – cyhalothrine 15 g/l + Acetamipride 20 g/L) and 100 g fungicide (Mancozan super; SCPA SIVEX International® France; comprising active components 640 g/kg Mancozebe + 80 g/kg Metalaxyl) in 15 L of water, and applied with knapsack sprayer. After 3 weeks, vigorous seedlings were transferred from nursery to experimental plots. The tomato seedlings were field-planted on the raised beds at 50×50 cm spacing on 3×4 m plots (12 m²), with one plant per stand and 24 plants per plot.

2.4 Field Management

2.4.1 Fertilizers

All treatment plots received the same type and amount of fertilizer inputs as soil amendments. Poultry droppings and urea fertilizer were applied to experimental plots at the rate of 5 g per plant, 7 days before transplanting and 30 days after transplanting.

2.4.2 Pesticides

Organic plots were only treated with the locally produced organic emulsion while inorganic plots received a combination of synthetic pesticide (K-Optimal; SCPA SIVEX International® France) and fungicide (Mancozan super; SCPA SIVEX International® France). The intercropped plots only had tomato plants that served as pest repellent or attractant. Meanwhile, there were no organic or conventional inputs in the sole cabbage or sole tomato control plots.

2.4.3 Tillage

Before transplanting, the experimental field was tilled manually to produce raised soil

beds of approximately 30 cm height, with a non-raised bed of 50 cm buffer zone between the experimental plots.

2.4.4 Irrigation and Weeds

The experimental site was irrigated manually to improve soil moisture before seedlings were transplanted. After transplanting, the experimental plots were supplemented every two days by manual irrigation to maintain soil moisture for optimal plant growth. Meanwhile, weed emergence was monitored regularly after transplanting and weeded manually using hoes.

2.5 Harvests and Yield

Harvest was conducted manually and data for cabbage yield was obtained as the crop attained physical maturity. At harvesting stage, 10 cabbage plants were incised above the soil level per experimental unit and weighed individually using a top loading balance (Brand MK-01, China). Before weighing, all damaged leaves were removed using a cutter. The mean weight of harvested cabbage heads per treatment was recorded as a yield and considered as marketable yield.

2.6 Pest Infestation

Plants were observed for pest infestation before and after heading, with regular monitoring of the wrapper leaves for observable signs of pest damage. Data on pest infestation was collected as the total number of infested cabbage plants per plot based on the major field pests such as DMB, Looper and Webworm larvae. Plants were identified as infested based on the observation of larvae or their damage.

2.6.1 Diamondback Moth

DBM was observed as small round holes or scratching off the leaf tissue leaving the epidermis on one side untouched giving a window appearance. Five plants with DBM damage were randomly selected per plot and assessed for the number of larvae on the wrapper leaves per plant.

2.6.2 Looper

Looper was assessed as the total number of plants with Looper larvae in five randomly selected plants per experimental plot.

2.6.3 Webworm

Plant damage (i.e. leaves held together with silk) was assessed via five randomly selected plants for the occurrence of Webworm larvae.

2.6.4 Snails

These were assessed as the total number of Snails per experimental plot. Snails were considered as minor pests because their damage was concentrated on the lower leaves that are often not harvested alongside cabbage heads for marketing, and therefore they did not account for the calculation of pest infestation. But at high Snail infestation, damages can be significant to producers as they could feed on the tender wrapper leaves and disrupt head formation.

2.7. Statistical Analyses

All data sets were subjected to statistical analyses using STATISTICA 9.1 for Windows [35]. The response design variables such as insect pests (i.e. DBM,

Looper, Webworm and Snail) and cabbage performance (i.e. yield and sprouting) were subjected to univariate analysis of variance (ANOVA, $P = .05$) to test effect of treatments ($n=4$) as categorical predictors. Significant means were compared by posthoc Tukey's HSD test ($P = .05$). Where applicable, Spearman Rank Correlation ($P = .05$) was performed to determine the degree of association between pests or cabbage performance and the categorical predictors.

3. RESULTS

3.1 Effect of Treatment on Cabbage Pests

Four major pests were identified during the different growth stages of cabbage with Diamondback Moth being the most and Webworm the least. The number of infested cabbage plants ranged from 2 to 23 per plot and differed significantly across treatments (ANOVA: $F_{3,11} = 71.8$, $P = .001$; Fig. 1). The highest pest infestation was recorded in the control plots that differed significantly from all the other treatments (Tukey's HSD, $P = .05$; Fig. 1). However, the synthetic pesticide was neither significantly different from intercropping nor from the organic treatment. Overall, the number of infested cabbage plants decreased with treatments as corroborated by the negative correlation between treatments and number of infested cabbage plants ($r = -0.95$, $P = .05$). Meanwhile, the different treatments demonstrated a similar effect and correlation for the individual pests (i.e. DBM, Looper, Webworm and Snails).

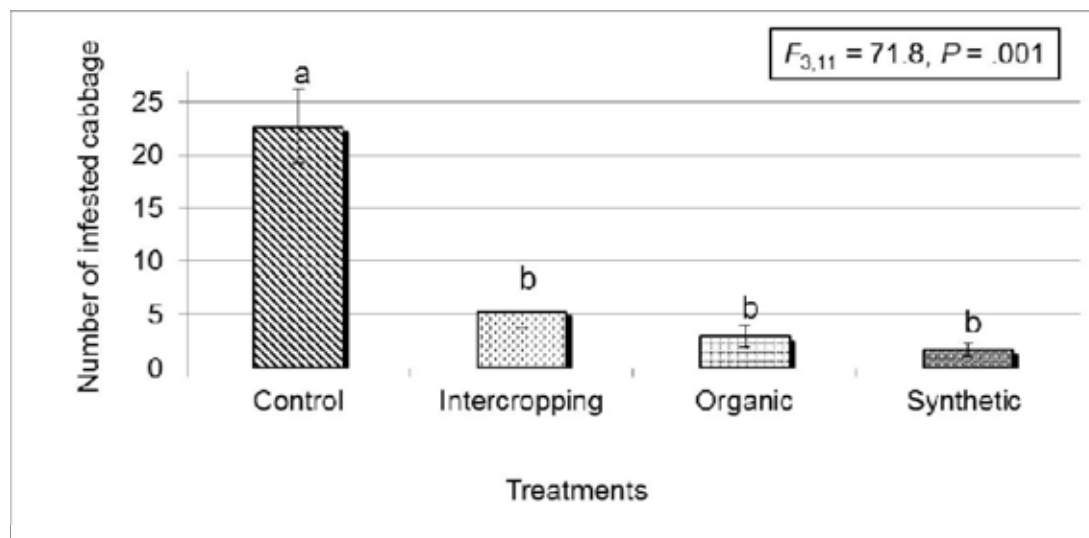


Fig. 1. Effect of treatments (i.e. control, intercropping, organic or synthetic pesticides) on the number of infested plants due to Diamondback moth, Looper and Webworm (Mean $\pm$ SD); Values with different letters are significantly different according to Tukey's HSD, $P = .05$.

3.1.1 Diamondback Moth

The number of DBM larvae on cabbage plants ranged from 1 in botanicals to 10 in the control, which differed significantly across treatments (ANOVA: $F_{3,11} = 20.7, P = .001$; Table 1). The highest DBM infestation was recorded in the control plots, which differed significantly from all the other treatments (Tukey's HSD, $P = .05$; Table 1). However, the synthetic pesticide was neither significantly different from intercropping nor from the organic treatment. Overall, the number of DBM larvae decreased with treatments but there was no correlation between treatments and number of larvae ($r = -0.54, P = .05$).

Table 1. Impact of treatments (i.e. control, intercropping, organic or synthetic pesticides) on the population density of field pests (i.e. Mean $\pm$ SD number of DBM, Looper, Webworm and Snails); Values with different letters are significantly different according to Tukey's HSD, $P = .05$.

Treatments	Diamondback Moth	Looper	Webworm
Control	10.3 $\pm$ 2.1a	8.3 $\pm$ 0.6a	4.0 $\pm$ 1.0a
Intercropping	1.3 $\pm$ 2.3b	0.3 $\pm$ 0.6b	3.7 $\pm$ 3.5a
Organic pesticides	1.0 $\pm$ 1.0 b	0.7 $\pm$ 0.6 b	1.3 $\pm$ 1.2a
Synthetic pesticides	1.3 $\pm$ 1.2b	0.3 $\pm$ 0.6b	0.0 $\pm$ 0.0a

3.1.2 Looper

The average number of Looper larvae on cabbage plants ranged from 0 to 8 **per plot** and

differed significantly across treatments (ANOVA: $F_{3,11} = 140.2$, $P = .05$; Table 1). The highest Looper infestation was recorded in the control plots, which differed significantly from all the other treatments (Tukey's HSD, $P = .05$; Table 1). Meanwhile, the synthetic pesticide was neither significantly different from intercropping nor from the organic treatment. Meanwhile, the number of Looper larvae on cabbage plants decreased with treatments as corroborated by the negative correlation between treatments and number of Looper larvae on cabbage plants ($r = -0.62$, $P = .05$).

3.1.3 Webworm

The number of Webworm larvae on cabbage plants ranged from 0 to 4 **per plot**, with no significant difference across treatments (ANOVA: $F_{3,11} = 2.9$, $P = .09$; Table 1).

Similarly, synthetic pesticide was neither significantly different from intercropping nor from the organic treatment. Meanwhile, the number of Webworm larvae on cabbage plants was negatively correlated with treatments ($r = -0.75$, $P = .05$).

3.1.4 Snails

Although Snails were not identified to species level, various Snail species were observed in the field (*Limicolaria numidica*, *Limicolaria aurora*, *Limicolaria flammea*, *Limicolaria martensiana* and *Limicolaria zebra*). Amongst them, *Limicolaria aurora* and *Limicolaria zebra* were often found feeding towards cabbage wrapper leaves with potential for significant damage crops at higher densities. The number of Snails ranged from 34 in botanicals to 91 in the control, and differed significantly across treatments (ANOVA: $F_{3,11} = 18.5$ $P = .001$; Fig. 2). The highest Snails infestation was recorded in the control plots that differed significantly with all the other treatments (Tukey's HSD, $P = .05$; Fig. 2). The organic treatment was significantly different from the synthetic and intercropping, but there was no significant difference between the synthetic and intercropping treatments. Overall, the number of Snails decreased with treatments but there was no correlation between treatments and number of Snails ($r = -0.51$, $P = .05$).

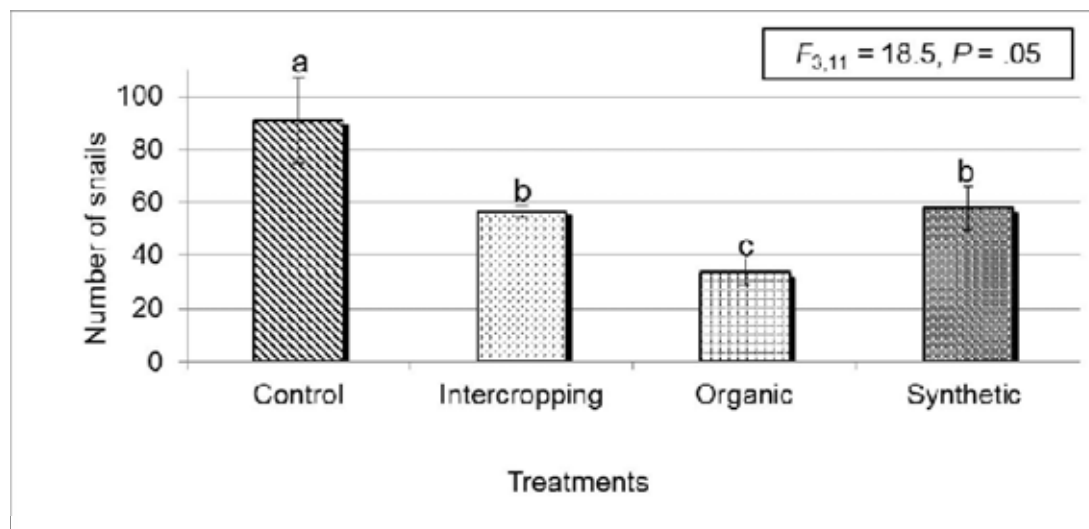


Fig. 2. Effect of treatments (i.e. control, intercropping, organic or synthetic pesticides) on the number of Snails (Mean $\pm$ SD); Values with different letters are significantly different according to Tukey's HSD, $P = .05$

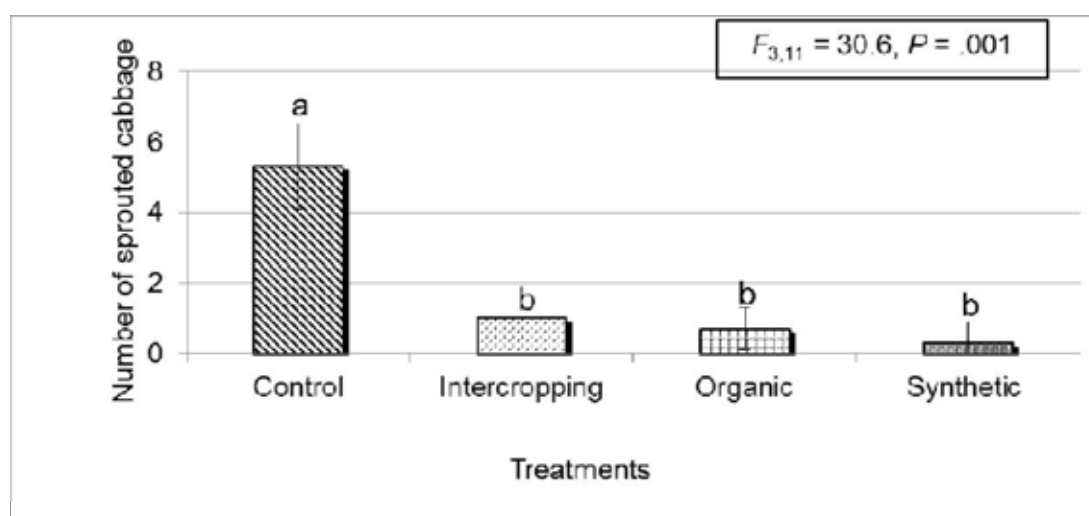
3.2 Impact of Treatment on Cabbage Performance

Crop data are only presented for cabbage as the main crop since tomato was mainly introduced as a comparable treatment to the synthetic and organic pesticides. Interestingly, tomato plants in the sole tomato control and cabbage-tomato intercrop treatments were completely damaged by pest infestation, which indicates a strong ability of tomato to attract the cabbage pests.

3.2.1 Sprouted Plants

The number of sprouted cabbage plants ranged from 0 to 5 and differed significantly across treatments (ANOVA: $F_{3,11} = 30.6$, $P = .001$; Fig. 3). The highest number of sprouted cabbage plants was recorded in the control plots, which differed significantly from all the other treatments (Tukey's HSD, $P = .05$; Fig. 3). Meanwhile, the synthetic pesticide was neither significantly different from the intercropping nor

320 organic treatments. Overall, there was a positive correlation between pest infestation
 321 and sprouted cabbage plants ($r = 0.81$, $P = .05$). However, a strong negative
 322 correlation occurred between the number of sprouted cabbage plants and treatments
 323 ($r = -0.93$, $P = .05$), while positive correlations occurred between the number of
 324 sprouted cabbage plants and DBM ($r = -0.71$, $P = .05$) or Looper ($r = 0.58$, $P = .05$).
 325



326
 327 Fig. 3. Impact of treatments (i.e. control, intercropping, organic or synthetic
 328 pesticides) number of sprouted cabbage (Mean $\pm$ SD); Values with different letters
 329 are significantly different according to Tukey's HSD, $P = .05$.
 330

331 **3.2.2 Cabbage Yield**

332 The cabbage yield ranged from 3.2 to 6.0 **unit???** and differed significantly across
 treatments

333 (ANOVA: $F_{3,11} = 46.3$ $P = .05$; Fig. 4). The lowest cabbage yield was recorded in the
 334 control plots, which differed significantly from all the other treatments (Tukey's HSD,
 335 $P = .05$; Fig. 4). The intercropping treatment was significantly different from the
 336 organic and synthetic treatments, but there was no significant difference between
 337 synthetic and organic.

Overall, cabbage yield decreased with increasing pest infestation but no significant correlation occurred between them ($r = -0.37$, $P = .05$). However, a negative correlation occurred between cabbage yield and DBM ($r = -0.62$, $P = .05$) and Looper ($r = -0.63$, $P = .05$). Meanwhile, a negative correlation occurred between cabbage yield and the number of sprouted cabbage plants ($r = -0.62$, $P = .05$).

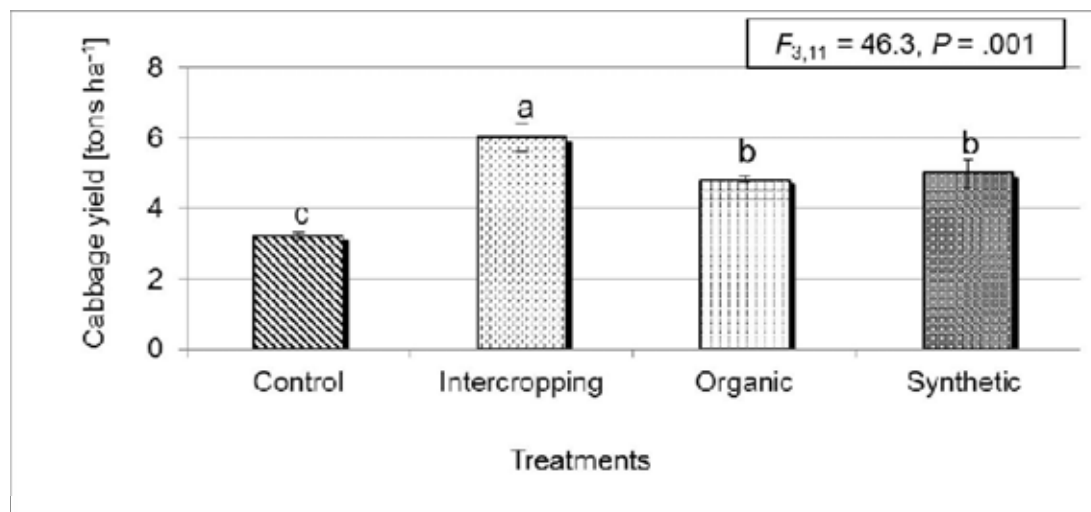


Fig. 4. Impact of treatments (i.e. control, intercropping, organic or synthetic pesticides) on cabbage yield (tons ha⁻¹ ± SD); Values with different letters are significantly different according to Tukey's HSD, $P = .05$

4. DISCUSSION

4.1 Effect of Treatments on Cabbage Pests

The significantly higher pest population recorded for the untreated cabbage plants compared to the treated plants indicates effectiveness of the various pest management practices that were used to protect the cabbage plants, which is consistent with other findings [3]. The significantly lower pest infestation in the cabbage-tomato intercropping is likely due to the confusing olfactory and visual cues

received from tomato, which results in reduction of larvae numbers [3,36]. Hence, the repellent and attractant ability of tomato was as effective as the insecticidal properties of both the synthetic and organic pesticides [3]. However, cabbage intercropping has demonstrated idiosyncratic responses to pest infestations, as Asare-Bediako et al. [3] reported unreliability in controlling DBM. However, this may be due to varying factors (including the type of associated crop, plant spacing, planting time, etc.). Incidentally Asare-Bediako et al. [3] used higher plant density and row spacing, which likely had less effect on the pest dynamics compared to the present study where tomato as a companion crop exhibited deleterious effect on DBM.

The lower snail infestation recorded in organic pesticide plots compared to other treatments is likely due to the presence of isobutyl amides (natural lipophilic amides piperine and piperiline) plant secondary metabolite, which is an active ingredient in Piper that acts as neurotoxins in insects [37,38]. Meanwhile, the comparable pest mitigation performance observed for intercropping, synthetic and organic pesticides are consistent with the first and second hypotheses of this study.

4.2 Impact of Treatment on Cabbage Performance

Cabbage performance was generally consistent with the observed rate of pest infestations, as cabbage performance increased with decreasing pest population and vice versa. Correspondingly, cabbage performance is consistent with the third hypothesis of this study that advocates greater cabbage yield in the cabbage-tomato intercropping treatment. The highest number of sprouted cabbage plants recorded in the control plots that differed with all the other treatments is consistent with the level of pest infestations recorded in the respective treatments. This could be attributed to

the rate of pest damage to cabbage plants in relation to the level of protection by the respective treatments [3]. Likely, the observed pests were able to feed on the growing point of cabbage plants, causing growth disturbances that resulted in multiple shoot formation from the buds (sprouted plants). Hence, by mitigating pest infestations, the different treatments were able to reduce the potential effects of pests on cabbage sprouting (i.e. multiple heads). Although both DBM and Looper are known to cause sprouting of cabbage plants, Looper was reportedly more damaging [39]. However, the stronger correlation of DBM with sprouted cabbage compared to Looper in this study is likely due to the higher pest population of DBM, which increased cabbage sprouting as compared to Looper [40].

The low cabbage yield recorded in the control treatments is consistent with the level of pest infestation, with the corresponding higher leaf and head damage that likely reduced photosynthetic carbon fixation and consequently plant growth [41]. This is consistent with report of DBM as the most serious pest of cabbage that is responsible for low yield [3]. In addition, Looper and Webworm demonstrated significant cabbage damage that is comparable to DBM damage, and therefore considered as major yield reducing cabbage pests [8]. The higher cabbage yield recorded in the cabbage-tomato intercropping as compared to the inorganic and organic pesticide treatments is not consistent with the observed trend of pest infestation in this study. This strongly indicates additional factors that contributed in improving cabbage performance. Meanwhile, the complete pest damage of tomato plants in the sole tomato control and cabbage-tomato intercropping treatments might have contributed in improving soil fertility and nutrition of the cabbage plants in the intercropped treatment. Moreover, the additional fertilizer input supplied to the cabbage-tomato intercropping treatment together with the decomposing biomass of

the dead tomato plants likely enhanced soil nutrients and biological dynamics, which favoured the cabbage plants [42]. Crop residue compost produces highly mummified organic matter that condition soil and plant responses [43,44]. Meanwhile, improved plant nutrition resulting from changes in soil biological parameters have been reasonably linked to substrate availability for microbial growth [43,45,46]. In addition, improved cabbage performance may have also resulted from the compost humic fraction that enhanced the proliferation of cabbage roots [47,48].

5. CONCLUSION

Besides poor soil fertility and plant nutrition, pest damage causes significant yield loss to cabbage farmers, particularly smallholder farmers in Sub-Saharan Africa with inadequate finances to purchase synthetic pesticides. Moreover, pest evolution and resistance to synthetic pesticides coupled with the associated health and environmental risks have necessitated a change of course to more sustainable alternative management strategies. This study demonstrated comparable pest mitigation effect of synthetic pesticides and Piper emulsion on cabbage-tomato intercropping. Hence, the locally produced organic Piper emulsion pesticide effectively reduced cabbage pest population below the economic injury threshold. Thereby, enabling cabbage yield increase with potentially higher income for farmers considering the relatively low cost of producing the Piper emulsion. Hence, the locally produced Piper emulsion and cabbage-tomato intercropping treatments are the best-bet options to manage cabbage pests and stimulate cabbage growth and performance without negative externalities. Therefore, these treatments can be used preferably over synthetic pesticides in smallholder cabbage production systems in Sub-Saharan Africa.

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