Journal of Agriculture and Ecology Research International

13(4): 1-12, 2017; Article no.JAERI.38815
ISSN: 2394-1073

Comparative Effects of *Piper guineense* Emulsion and Cabbage-Tomato Intercropping for Controlling Cabbage Pests and Improving Performance

Clovis B. Tanyi[1*], Christopher Ngosong[1] and Nelson N. Ntonifor[1]

[1]Department of Agronomic and Applied Molecular Sciences, Faculty of Agriculture and Veterinary Medicine, University of Buea, P.O.Box 63 Buea, South West Region, Cameroon.

Authors' contributions

This work was carried out in collaboration between all authors. Author CBT designed and established the field trial, prepared organic input and managed the field site, conducted harvest and data collection, data processing and analyses, performed literature searches and wrote the first manuscript draft. Author CN contributed in the experimental design, processed the data and performed statistical analyses, conducted literature searches and coordinated preparation of the first manuscript draft. Author NNN contributed in the experimental design, coordinated the field experimentation and data collection and supervised the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2017/38815
Editor(s):
(1) Maria Panitsa, Department of Environmental and Natural Resource Management, University of Patras, Greece.
Reviewers:
(1) Mohammed Suleiman, Umaru Musa Yar'adua University, Nigeria.
(2) Aanchal Rana, Dr Yashwant Singh Parmar University of Horticulture and Forestry, India.
(3) Isabel Bertolaccini, Universidad Nacional del Litoral, Argentina.
Complete Peer review History: http://www.sciencedomain.org/review-history/22739

Original Research Article

Received 14th December 2017
Accepted 9th January 2018
Published 15th January 2018

ABSTRACT

Aim: To improve cabbage production by controlling cabbage pests using locally produced organic pesticide and cabbage-tomato intercropping.

Methodology: Four treatments (control, cabbage-tomato intercropping, organic and synthetic pesticides) were evaluated for their potential to control cabbage pests and improve performance.

Results: Cabbage pest infestation correlated negatively with treatments (r = −0.95), ranging from 2–23 infested plants across treatments that differed (P = .001) significantly, with highest in control compared to other treatments (P = .05). Diamondback moth ranged from 1–10 per plant and differed (P = .001) significantly across treatments, with highest in control compared to other treatments (P = .05). Looper larvae correlated negatively with treatments (r = −0.62), ranging from

**Corresponding author: E-mail: tanyi.clovis@yahoo.com;*

0–8 per plant and differed (P = .05) significantly across treatments, with highest in control compared to other treatments (P = .05). Snails ranged from 34–91 per treatment and differed (P = .001) significantly across treatments, with highest in control and lowest in organic compared to other treatments (P = .05). The number of sprouted cabbage plants ranged from 0–5 per treatment and differed (P = .001) significantly across treatments, with highest in control compared to other treatments (P = .05). Sprouted cabbage correlated negatively with treatments (r = −0.93) and correlated positively with pest infestation (r = 0.81), diamondback moth (r = 0.71) and looper (r = 0.58). Cabbage yield ranged from 3.2–6.0 t ha^{-1} and differed (P = .05) significantly across treatments with the lowest in control and highest in intercropping (P = .05). Cabbage yield correlated negatively with diamondback moth (r = −0.62), looper (r = −0.63) and sprouted cabbage (r = −0.62).

Conclusion: Piper emulsion and intercropping effectively controlled cabbage pests while intercropping additionally increased cabbage yield.

Keywords: Diamondback moth; looper; piper emulsion; snails; webworm.

1. INTRODUCTION

Cabbage (*Brassica oleracea* Linnaeus) is an exotic nutrient rich leafy vegetable with variable forms of consumption [1,2]. Cabbage cultivation and consumption is an important source of food and nutrient security, income and livelihood, which reduces micronutrient deficiency that cause poor health and high mortality in Africa [3,4]. With about 40% malnutrition in SSA, vegetables 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 reduce the quality and quantity of cabbage by destroying leaves and growing buds or mature heads.

Diamondback moth – DBM (*Plutella xyllostella* Linnaeus) reduced cabbage yield by 90% during severe infestation [7]. Looper (*Trichoplusia ni* Hübner) is an important cabbage pest that feeds on leaves, killed young plants or caused sprouting, while feeding on cabbage heads caused contamination with frass [8]. Webworm (*Helulla undalis* Fabricius) is an important cabbage pest that caused huge loss of yield [8]. Snails facilitate decomposition of plant biomass and serve as biological indicators of soil quality, but they are major pests in tropical and subtropical regions with devastating effects during wet seasons [9,10]. Resistance to conventional pesticides has increased the need for sustainable alternatives such as the use of botanicals to control snails [11].

Continuous use of synthetic pesticides has exacerbated reliance on chemical controls and increased pest resistance, leading to high production cost with negative consequences [12,13]. Synthetic pesticides are commonly used to manage pests and diseases [14-17], but high pesticide cost or pest evolution and resistance coupled with environmental effects often limit their use [13]. Evolution of pest resistance to synthetic pesticides requires more powerful pesticides and high doses that have increased pesticide dependency [18,19]. This has necessitated sustainable alternative management strategies involving the use of botanicals that are effective and affordable without negative consequences [20-22]. However, synthetic pesticides and botanicals demonstrated idiosyncratic responses to pest infestation [18,23,24].

PAMS model (prevention, avoidance, monitoring and suppression) was used to evaluate pest management practices [25]. Prevention includes treatments, crop rotation and use of pest-resistant cultivars while avoidance includes alternate planting dates and efficient irrigation management [25]. Avoidance includes intercropping with a repellent crop like tomato (*Solanum lycopersicum* Linnaeus), and cabbage-tomato intercropping reduced diamondback moth [3,26]. The odour from tomato plants repelled diamondback moth and caused oviposition deterrent effect [3,27], which is consistent with the repellent effect on diamondback moth by onion (*Allium cepa* Linnaeus) and garlic (*Allium sativum* Linnaeus) [26,28].

This study intends to improve cabbage production by incorporating the concepts of integrated pest management and integrated soil fertility management via intercropping or organic and synthetic pesticides [29]. It was hypothesized that (i) the locally produced organic pesticide will effectively control cabbage pests, (ii) cabbage-tomato intercropping will reduce cabbage pest infestation, and (iii) cabbage-tomato intercropping will improve cabbage performance.

2. MATERIALS AND METHODS

2.1 Experimental Site and Setup

This study was conducted at the teaching and research farm of the Faculty of Agriculture and Veterinary Medicine, University of Buea. The site is located at the foot of mount Cameroon, Southwest Region Cameroon, situated between latitudes 4º3'N and 4º12'N of the equator and longitudes 9º12'E and 9º20'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 85–90% relative humidity. The dry season starts from November to May and rainfall ranges from 2085−9086 mm between March and November [32]. The mean monthly air temperature ranges from 19−30°C and soil temperature at 10 cm depth decreases from 25°C to 15°C with increasing elevation from 200 m to 2200 m, respectively, above sea level [31,33,34].

The experimental setup is a randomized complete block design with four replicates per treatment. The experimental field was cleared manually using a cutlass and partitioned into 16 plots measuring 3x4 m each. Each experimental plot was tilled using a hoe to produce raised beds (about 30 cm high). The experimental setup comprised four treatments including a control (control – sole cabbage and sole tomato), tomato intercrop, organic piper emulsion and synthetic pesticide. Each cabbage plot contained 8 rows and 6 columns of cabbage with 50×50 cm inter and intra row spacing, leading to 48 plants per plot. The cabbage-tomato intercrop plots contained 4 rows and 3 columns of cabbage (24 plants) and tomato (24 plants) planted at 50×50 cm inter and intra row spacing on one alternate row between cabbage and tomato plants. The experimental plots were separated from each other by a non-tilled 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 in the Southwest Region of Cameroon. 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) purchased from the local market. The mixture was thoroughly stirred and 10 g detergent (SABA®, Douala-Cameroon) was added to produce a sticky emulsion, which was stored in a plastic container at room temperature.

Prior to field application of piper emulsion, a laboratory trial was conducted to determine the effective dose for best field results. For the laboratory trial, ten diamondback moth larvae were randomly collected in the morning from the field and placed in five petri dishes with two larvae each. Cabbage leaves were harvested from neighbouring fields and added in petri dishes as food substrate for larvae. Five concentrations were prepared from the organic piper 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 a syringe was used to apply the different doses into the five petri dishes containing insect larvae. Based on performance evaluations, the 0.003 concentration (50:15 ml:L) was adopted for field applications.

Field application of organic piper emulsion was performed during cold dry early morning periods with minimal drift. For field applications, 50 ml piper emulsion was filtered using a double 169-folded muslin cloth to remove sediments and diluted in 15 L water. This was stirred vigorously to achieve homogeneity and the homogenized mixture was poured into a knapsack sprayer and uniformly sprayed (i.e. both sides of cabbage leaves including folded leaves) on all 192 plants in the respective four experimental plots every two weeks.

2.3 Plant Cultivation

2.3.1 Cabbage

Hybrid cabbage seeds (*Brassica oleraceae* L.; F1 Green Coronet; STARKE AYRES®, France) were purchased from an agro-shop in Buea Cameroon. The seeds were pre-germinated at 15×15 cm inter-row spacing on nearby 2.5×1 m nursery bed that was cleared using a cutlass and tilled manually using a hoe. Vigorous seedlings were transplanted from the nursery to experimental plots on 10th March 2016, which is the common planting date in the study area.

Cabbage seedlings were field-planted at 50×50 cm inter and intra row spacing on 3×4 m (12 m^2) experimental plots of manually raised soil beds (about 30 cm high). One plant was planted per stand, giving 48 plants in the sole cabbage plots and 24 plants in the intercrop plots.

2.3.2 Tomato

Hybrid tomato seeds (*Solanum lycopersicum* L.; F1 Cobra 26; TECHNISEM®, France) were purchased from an agro-shop in Buea Cameroon. The seeds were pre-germinated at 15x15 cm inter-row spacing on nearby 2×1 m nursery bed that was cleared using a cutlass and tilled using a hoe. The nursery was amended with 0.5 kg NPK fertilizer (20:10:10) and sprayed with a mixture of pesticides and fungicides. 35 ml synthetic pesticide (K-Optimal; SCPA SIVEX International® France; comprising 15 g/l Lambda – cyhalothrine + 20 g/L Acetamipride as active ingredients) and 100 g fungicide (Mancozan super; SCPA SIVEX International® France; comprising 640 g/kg Mancozebe + 80 g/kg Metalaxyl as active ingredients) were dissolved in 15 L water and applied using a knapsack sprayer. After three weeks of nursery establishment, vigorous seedlings were transferred to 3×4 m (12 m^2) experimental plots (about 30 cm raised soil beds) and planted at 50×50 cm inter and intra row spacing. One plant was planted per stand, giving 48 plants in the sole tomato plots and 24 plants in the intercrop plots.

2.4 Field Management

2.4.1 Fertilizer amendment

All the experimental plots were amended with the same type and amount of soil fertilizer inputs seven days before transplanting and 30 days after transplanting. Poultry droppings and urea fertilizers were applied on all experimental plots at 5 g per plant by ringing at about 5 cm from plants.

2.4.2 Pesticides and fungicides

The organic plots were sprayed with locally produced piper emulsion while the synthetic plots were sprayed with commercial pesticide (K-Optimal; SCPA SIVEX International® France) and fungicide (Mancozan super; SCPA SIVEX International® France). The cabbage-tomato intercrop plots were not sprayed with piper emulsion or synthetic pesticide and the tomato plants were expected act as repellent or attractant of cabbage pests. Meanwhile, piper emulsion and synthetic pesticide were not applied in the sole cabbage or sole tomato control plots.

2.4.3 Tillage

Before transplanting cabbage and tomato seedlings from the nursery, the experimental field was cleared using a cutlass and tilled manually using a hoe to produce raised soil beds (about 30 cm high). The experimental plots were separated by 50 cm non-tilled buffer zone.

2.4.4 Irrigation and weeds

All the experimental plots were manually irrigated to improve soil moisture before seedlings were transplanted. After transplanting seedlings, the experimental plots were manually irrigated every two days to maintain optimum soil moisture for plant growth and performance. Weed emergence on experimental plots was monitored regularly and weeded manually using a hoe.

2.5 Cabbage Yield and Sprouted Plants

At physiological maturity, cabbage was harvested manually and marketable yield data was presented in t ha^{-1} (Mean ± SD). During harvesting, ten cabbage plants were incised above the soil on each experimental plot and weighed using a top loading balance (Brand MK-01, China). A cutter was used to remove all damaged leaves before harvested cabbage was weighed. Sprouted cabbage was assessed as the total number of plants with multiple shoots (sprouts) per experimental plot and presented as number (Mean ± SD) of sprouted cabbage per treatment.

2.6 Pest Infestation

Cabbage plants were assessed for pest infestation before and after heading while wrapper leaves were monitored regularly for symptoms of pest damage. Data on pest infestation was presented as total number (Mean ± SD) of infested cabbage plants per treatment based on occurrence of major pests (i.e. diamondback moth, looper and webworm larvae). Cabbage plants were identified as infested based on the observation of pest larvae or their damage.

2.6.1 Diamondback moth

Diamondback moth – DBM (*Plutella xyllostella* L.) was identified as small round holes, scratches or skeleton damage of cabbage leaves with partially damaged epidermis, which gives cabbage leaves a windowpane appearance. Five plants with visible signs of damage were randomly selected from each plot and assessed for occurrence and damage of diamondback moth larvae on wrapper leaves. Data were presented as number (Mean ± SD) of diamondback moth larvae per plant.

2.6.2 Looper

Cabbage looper (*Trichoplusia ni* H.) was assessed and presented as the number (Mean ± SD) of looper larvae per plant. The assessment of looper larvae was performed on five randomly selected plants per experimental plot.

2.6.3 Webworm

Plant damage (i.e. leaves held together with silk) and the occurrence of webworm (*Helulla undalis* F.) larvae was assessed on five randomly selected cabbage plants from each experimental plot. Data were presented as the number (Mean ± SD) of webworm larvae per plant.

2.6.4 Snails

Snails were assessed on each experimental plot and presented as total number (Mean ± SD) of snails per treatment. Snails were considered as minor pests in this study because their damage was concentrated on the lower leaves that were not harvested alongside cabbage heads. Hence, snails did not account for the calculation of pest infestation, although high snail infestation can cause significant damage by feeding on tender wrapper leaves and disrupting head formation.

2.7 Statistical Analyses

All data sets were subjected to statistical analyses using STATISTICA 9.1 for Windows [35]. The dependent variables like pests (i.e. DBM, looper, webworm and snail) and cabbage performance (i.e. infestation, sprouting and yield) were subjected to univariate analysis of variance (ANOVA, *P* = .05) to test effect of treatments (*n*=4) as categorical predictors. Significant data 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 dependent variables (i.e. pests and cabbage performance) and treatments as categorical predictors.

3. RESULTS

3.1 Effect of Treatment on Cabbage Pests

Four main pests were identified during this investigation with diamondback moth was most dominant and webworm was the least. The number of infested cabbage plants ranged from 2−23 plants per treatment and differed (ANOVA: $F_{3,11}$ = 71.8, *P* = .001; Fig. 1) significantly across treatments. The highest infestation was recorded in control that differed (Tukey's HSD, *P* = .05; Fig. 1) significantly from the other treatments. However, there was no significant difference between the synthetic pesticide and intercropping or organic piper emulsion. Overall, the number of infested cabbage plants decreased across treatments as corroborated by the negative correlation between treatments and infested cabbage plants (*r* = −0.95, *P* = .05). Correspondingly, the different treatments demonstrated a similar effect on the individual cabbage pests (i.e. DBM, looper, webworm and snails).

3.1.1 Diamondback moth

The number of diamondback moth larvae on cabbage plants ranged from 1−10 larvae per plant that differed (ANOVA: $F_{3,11}$ = 20.7, *P* = .001; Table 1) significantly across treatments. The highest diamondback moth was recorded in control that differed (Tukey's HSD, *P* = .05; Table 1) significantly from the other treatments. However, there was no significant difference between the synthetic pesticide and intercropping or organic piper emulsion (Table 1) and DBM demonstrated a strong tendency to correlate with treatments (*r* = −0.54, *P* = .05).

3.1.2 Looper

The number of looper on cabbage plants ranged from 0−8 larvae per plant that differed (ANOVA: $F_{3,11}$ = 140.2, *P* = .05; Table 1) significantly across treatments. The highest looper larvae occurred in control that differed (Tukey's HSD, *P* = .05; Table 1) significantly from the other treatments. There was no significant difference between the synthetic pesticide and intercropping or organic piper emulsion (Table 1). The number of looper larvae on cabbage plants decreased with treatments as corroborated by the negative correlation with treatments (*r* = −0.62, *P* = .05).

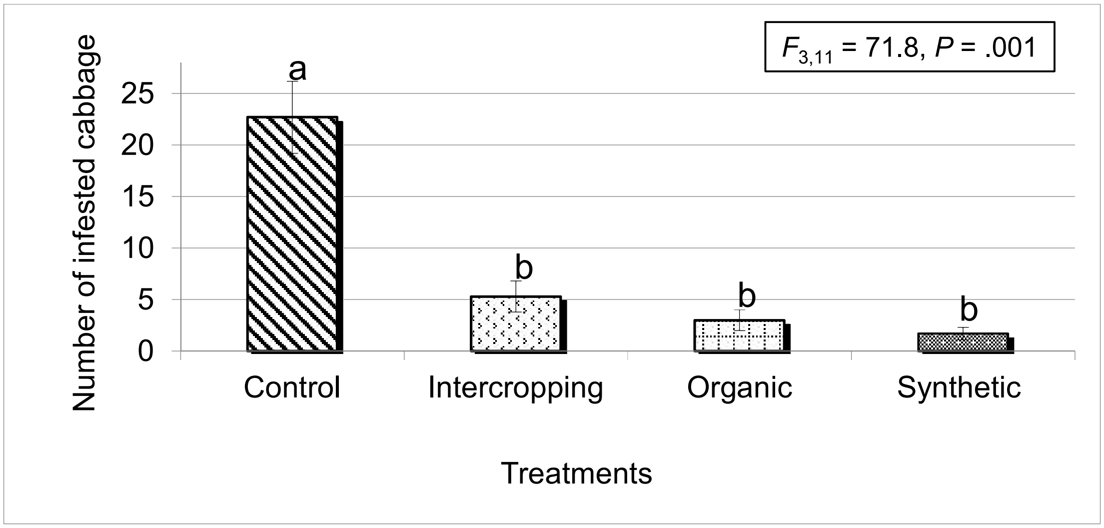

Fig. 1. Effect of treatments (control, intercropping, organic piper emulsion and synthetic pesticide) on the number (Mean ± SD) of infested cabbage plants per treatment due to diamondback moth, looper and webworm; Values with different letters are significantly different according to Tukey's HSD, *P* = .05

Table 1. Effect of treatments (control, intercropping, organic piper emulsion and synthetic pesticide) on the number (Mean ± SD) of pests (diamondback moth, looper, webworm) per plant; Values with different letters are significantly different according to Tukey's HSD, *P* = .05

Treatments	Diamondback moth	Looper	Webworm
Control	10.3 ± 2.1a	8.3 ± 0.6a	4.0 ± 1.0a
Intercropping	1.3 ± 2.3b	0.3 ± 0.6b	3.7 ± 3.5a
Organic piper emulsion	1.0 ± 1.0b	0.7 ± 0.6b	1.3 ± 1.2a
Synthetic pesticide	1.3 ± 1.2b	0.3 ± 0.6b	0.0 ± 0.0a

3.1.3 Webworm

The number of webworm on cabbage plants ranged from 0−4 larvae per plant but there was no significant difference across treatments (ANOVA: $F_{3,11}$ = 2.9, P = .09; Table 1). Similarly, there was no significant difference between the synthetic pesticide and intercropping or organic piper emulsion (Table 1). The number of webworm larvae on cabbage plants was negatively correlated with treatments (r = −0.75, P = .05).

3.1.4 Snails

Snails were not identified to species level but various snail species were observed in the field (i.e. *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. The number of snails ranged from 34−91 snails across treatments and differed (ANOVA: $F_{3,11}$ = 18.5 P = .001; Fig. 2) significantly. The highest snail population occurred in control that differed (Tukey's HSD, P = .05; Fig. 2) significantly from the other treatments. The lowest snail population occurred in organic piper emulsion that differed (Tukey's HSD, P = .05; Fig. 2) significantly from synthetic pesticide, intercropping and control. The highest snail population occurred in control that differed (Tukey's HSD, P = .05; Fig. 2) significantly from the other treatments. However, there was no significant difference between synthetic pesticide and intercropping (Tukey's HSD, P = .05; Fig. 2). Snails demonstrated strong tendency to correlate with treatments (r = −0.51, P = .05).

3.2 Impact of Treatment on Cabbage Performance

Crop data are presented for cabbage as the main crop because tomato served as comparable treatment to synthetic pesticide and organic piper

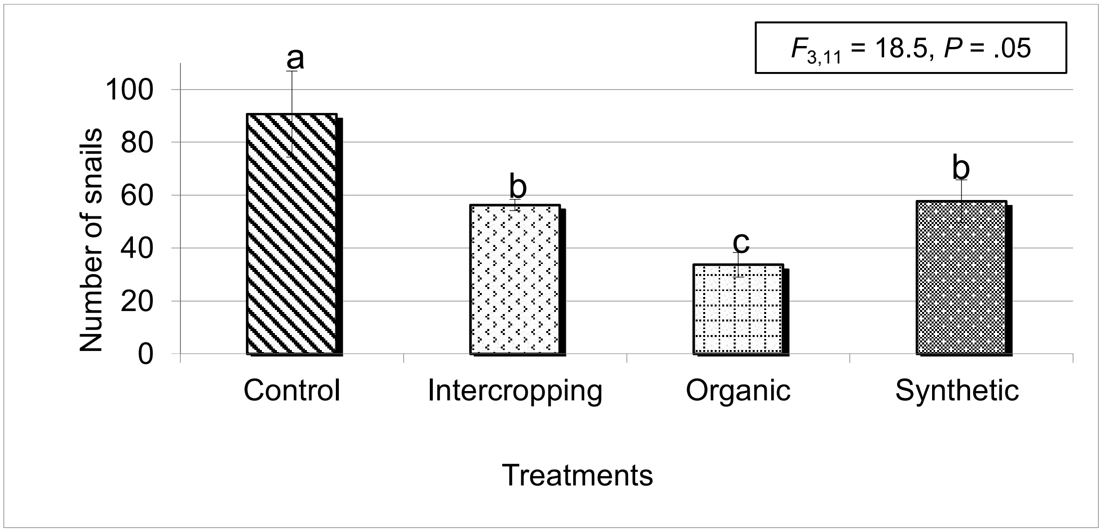

Fig. 2. Effect of treatments (control, intercropping, organic piper emulsion and synthetic pesticide) on the number (Mean ± SD) of snails per treatment; Values with different letters are significantly different according to Tukey's HSD, *P* = .05

emulsion. However, tomato plants in the sole tomato control and cabbage-tomato intercrop plots were completely damaged by pests before physiological maturity. This demonstrates the pest deterrent ability of tomato plants in cabbage fields by acting as repellent or attractant.

3.2.1 Sprouted plants

The number of sprouted cabbage ranged from 0−5 plants per treatment and differed (ANOVA: $F_{3,11}$ = 30.6, P = .001; Fig. 3) significantly. The highest number of sprouted cabbage occurred in control that differed (Tukey's HSD, P = .05; Fig. 3) significantly from the other treatments. However, there was no significant difference between synthetic pesticide and intercropping or organic piper emulsion. Positive correlations occurred between sprouted cabbage plants and pest infestation (r = 0.81, P = .05) or looper (r = 0.58, P = .05), while negative correlations occurred between sprouted cabbage plants and treatments (r = −0.93, P = .05) or diamondback moth (r = −0.71, P = .05).

3.2.2 Cabbage yield

Cabbage yield ranged from 3.2−6.0 t ha^{-1} across treatments and differed (ANOVA: $F_{3,11}$ = 46.3 P = .05; Fig. 4) significantly. The lowest cabbage yield was recorded in control that differed (Tukey's HSD, P = .05; Fig. 4) significantly from the other treatments. Intercropping differed (Tukey's HSD, P = .05; Fig. 4) significantly different from the organic piper emulsion and synthetic pesticide, but there was no significant difference between synthetic pesticide and organic piper emulsion. Negative correlations occurred between cabbage yield and diamondback moth (r = −0.62, P = .05), looper (r = −0.63, P = .05) and sprouted cabbage plants (r = −0.62, P = .05). Cabbage yield decreased with increasing pest infestation but no significant correlation occurred between them (r = −0.37, P = .05).

4. DISCUSSION

4.1 Effect of Treatments on Cabbage Pests

The significantly high pest infestation in control (i.e. untreated cabbage plants) compared to other treatments (i.e. intercropping, organic piper emulsion and synthetic pesticide) indicates effectiveness of the management practices [3]. The significantly low pest infestation in cabbage-tomato intercrop is likely due to confusing olfactory and visual cues received from tomato that reduced pest larvae [3,36]. Hence, the repellent and attractant ability of tomato was comparable with the insecticidal properties of synthetic pesticide and organic piper emulsion [3]. However, other studies on cabbage intercropping demonstrated idiosyncratic responses to pest infestation without reliably controlling diamondback moth [3]. This may be due to various factors including the type of associated crop, plant spacing, planting time, etc.

Higher plant density and row spacing used in other studies likely limited the effect of tomato intercrop on pest infestation as compared to this study where tomato intercrop effectively reduced diamondback moth [3].

The low snail infestation in organic piper emulsion treatment is likely due to isobutyl amide plant secondary metabolites (i.e. natural lipophilic amides, piperine and piperiline), which are active ingredients in *Piper guineense* that act as neurotoxins in insects [37,38]. Piper-derived extracts demonstrated strong potential for controlling pests [39]. Correspondingly, the efficacy of mixed powders of *Piper guineense* and *Zingiber officinale* was reported against *Callosobruchus maculatus* [40,41]. The comparable pest mitigation performance observed for intercropping, synthetic pesticide and organic piper emulsion is consistent with the first and second hypotheses of this study. Therefore, farmers can use tomato intercropping or organic piper emulsion as sustainable alternatives for synthetic pesticide to manage cabbage pests without jeopardizing crop performance.

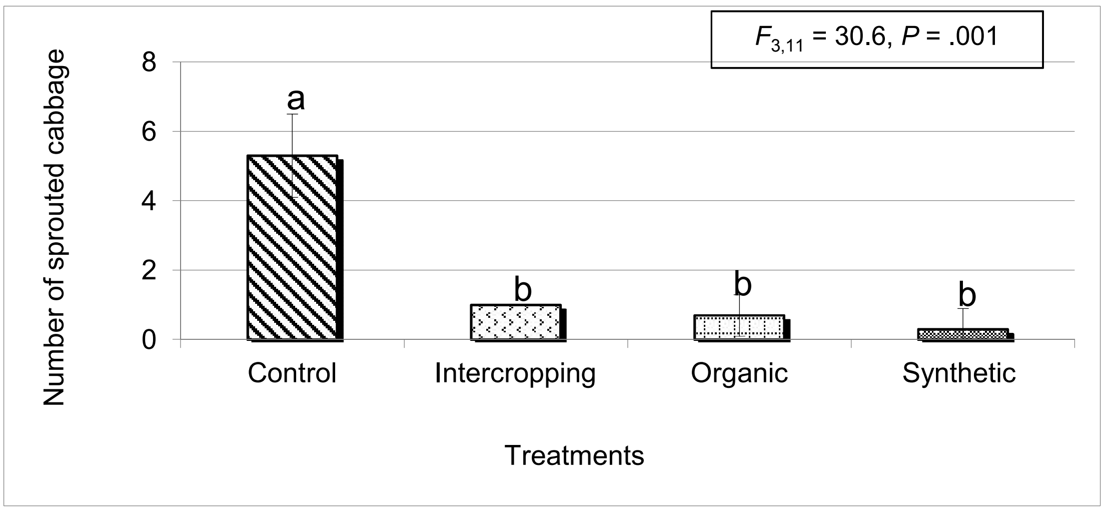

Fig. 3. Impact of treatments (control, intercropping, organic piper emulsion and synthetic pesticide) on the number (Mean ± SD) of sprouted cabbage plants per treatment; Values with different letters are significantly different according to Tukey's HSD, *P* = .05.

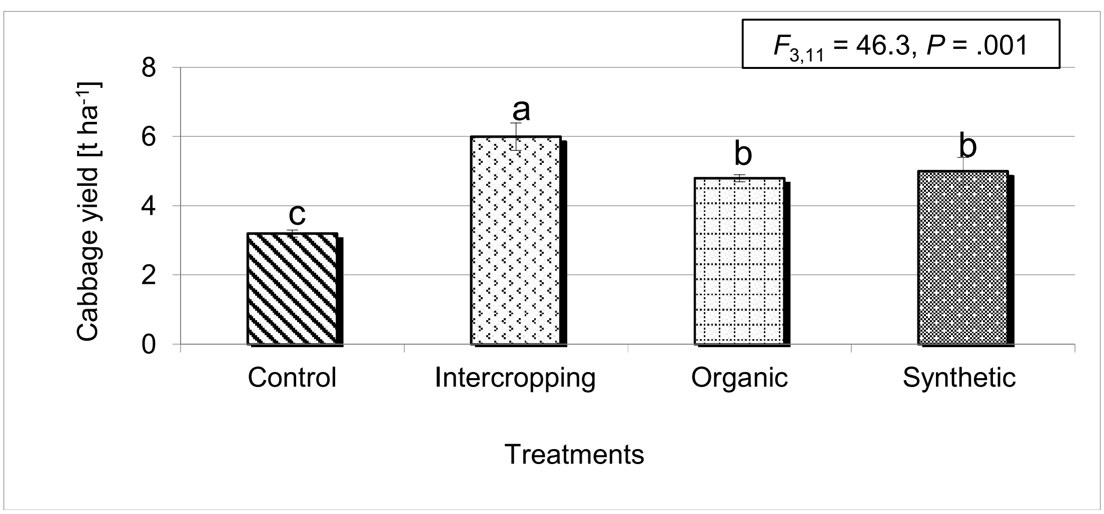

Fig. 4. Impact of treatments (control, intercropping, organic piper emulsion and synthetic pesticide) on cabbage yield (t ha^{-1} ± SD); Values with different letters are significantly different according to Tukey's HSD, *P* = .05

4.2 Impact of Treatment on Cabbage Performance

Cabbage performance is consistent with the rate of pest infestation with increased cabbage performance as pest infestation decreases and vice versa. Cabbage performance is consistent with the third hypothesis of this study that advocates greater cabbage yield due to tomato intercropping. The high cabbage sprouting in control compared to the other treatments (Fig. 2) is consistent with the rate of pest infestation [3]. Likely, pests were able to feed on the growing point of cabbage plants, which caused growth disturbances resulting in multiple shoot formation from buds (sprouted plants). By controlling cabbage pest infestation, the different treatments were able to reduce the effect of pests on cabbage sprouting (i.e. multiple heads). Diamondback moth and looper are known to cause sprouting of cabbage plants but looper was more damaging [42]. However, the stronger correlation of sprouted cabbage with diamondback moth compared to looper is likely due to higher infestation of diamondback moth in this study that increased cabbage sprouting [43].

The low cabbage yield in control is consistent with the pest infestation and the corresponding higher leaf and head damage that likely reduced photosynthetic carbon fixation and consequently plant growth [44]. This is consistent with report of DBM as the most serious pest of cabbage that is responsible for low yield [3]. Additionally, looper and webworm demonstrated significant cabbage damage that is comparable to DBM damage and considered as major yield reducing cabbage pests [8]. The high cabbage yield in cabbage-tomato intercropping compared to synthetic pesticide and organic piper emulsion treatments is not consistent with the trend of pest infestation in this study. This strongly indicates additional factors that improved cabbage yield. The complete pest damage of tomato plants in sole tomato control and cabbage-tomato intercrop treatments might have improved soil fertility and nutrition of cabbage plants in the intercropped treatment. Additional fertilizer in the cabbage-tomato intercropping treatment coupled with decomposing biomass of dead tomato plants likely enhanced soil nutrients and biological dynamics, which favoured the growth and yield of cabbage plants [45]. Crop residue compost reportedly produced highly mummified organic matter that conditioned the soil and plant responses [46,47]. Meanwhile, improved soil fertility and plant nutrition resulting from changes in soil biological parameters were linked to substrate availability for microbial growth [46,48,49]. The improved cabbage performance may have also resulted from compost humic fraction that enhanced proliferation of cabbage roots and nutrient acquisition [50,51]. The higher cabbage yield in cabbage-tomato intercrop treatment highlights the need for alternative farm management strategies that integrate the below and aboveground including soil fertility and pest management.

5. CONCLUSION

Besides poor soil fertility and plant nutrition, pest damage causes significant cabbage yield loss. 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 efficacy of synthetic pesticides and organic piper emulsion or cabbage-tomato intercropping for controlling cabbage pests below economic injury threshold. Thereby, enabling cabbage yield increase with potentially higher income for farmers considering the relatively low cost of producing the organic piper emulsion. Hence, the locally produced organic piper emulsion and cabbage-tomato intercropping treatments are the best-bet options to manage cabbage pests and stimulate cabbage performance without negative consequences. They can be used preferably as sustainable alternatives for synthetic pesticides in cabbage production systems.

ACKNOWLEDGEMENTS

We gratefully acknowledge support from the Faculty of Agriculture and Veterinary Medicine of the University of Buea Cameroon and Ministry of Higher Education of Cameroon.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Van der Vossen HAM, Seif AA. *Brassica oleracea* L. (headed cabbage) In: Grubben GJH, Denton OA, eds. PROTA 2: Vegetables/Légumes. [CD-Rom]. PROTA, Wageningen, Netherlands; 2004.

2. Norman JC. Tropical vegetable crops in Elms Court Ilfracombe, Stockwell. Devon Publishers; 1992.
3. Asare-Bediako E, Addo-Quaye AA, Mohammed A. Control of diamondback Moth (*Plutella xylostella*) on cabbage (*Brassica oleracea* var capitata) using Intercropping with non-Host crops. American Journal of Food Technology. 2010;5:269-274.
4. Biesalski HK. Hidden Hunger. Springer-Verlag. 2013;245.
5. Grubben G, Klaver W, Nono-Womdim R, Everaarts A, Fondio L, Nugteren JA, Corrado M. Vegetables to combat the hidden hunger in Africa. Chronica Horticulture. 2014;54:24-32.
6. Thomson B, Amoroso L. CAB International and FAO. Combating micronutrient deficiencies: Food-based approaches (eds.). 2011;397.
7. Mohammad FD, Fauziah I, Mohd RZ, Fairuz K, Abu ZU, Syed A, Rahman SAR, Ismail RM, Hanysyam MN, Norazliza R. Asymmetry effect of intercropping non host crops between cabbage and climatic factor on the population of the diamondback moth (*Plutella xyllostella* L.) and yield. Journal of Agriculture, Forestry and Fisheries. 2014;3:171-177.
8. Mochiah MB, Banful B, Fening KO, Amoabeng BW, Offei K, Bonsu E, Braimah H, Owusu-Akyaw M. Botanicals for the management of insect pests in organic vegetable production. Journal of Entomology and Nematology. 2011;3:85-97.
9. Barker GM. The biology of terrestrial Molluscs. CABI publishing, New Yourk, USA. 2001;558.
10. Burch JB, Timothy AP. Terrestrial gastropoda. Soil Biology Guide. John Wiley and Sons Inc D. L. Dindal, ed, New York, NY. 1990;201-299.
11. Prakash A, Rao J. Botanical pesticides in agriculture. CRC press, Inc. Lewis publishers. 1997;345-54.
12. Susila W, Sumiartha K, Nemoto H, Kawai S. The effect of insecticides on populations of diamondback moth, *Plutella xylostella* (Lepidoptera: Yponomeutidae) and its parasitoid, *Diadegma semiclausum* (Hymenoptera: Ichneumonidae) in cabbage. Journal of International Society for Southeast Asian agricultural Sciences. 2003;9:132-138.
13. Xu QC, Xu HL, Qin FF, Tan JY, Liu G, Fujiyama S. Relay-intercropping into tomato decreases cabbage pest incidence. Journal of Food, Agriculture and Environment. 2010;8:1037-1041.
14. Sarfraz M, Keddie BA. Conserving the efficacy of insecticides against *Plutella xylostella* (L.) (Lepidoptera, Plutellidae). Journal of Applied Entomology. 2005;129:149-57.
15. Syed TS, Lu YY, Liang GW. Effect of crude extracts from plants on the oviposition behavior of diamondback moth. Journal of South China. 2003;24:87-88.
16. Shelton AM, Sances FV, Hawley J, Tang JD, Boune M, Jungers D, Collins HL, Farias J. Assessment of insecticide resistance after the outbreak of diamondback moth (Lepidoptera: Plutellidae) in California. Journal of Economic Entomology. 2000;93:931-936.
17. Shelton AM, Wyman JA, Cushing NL, Apfelbeck K, Dennehy TJ, Mahr SER, Eigenbrode SD. Insecticide resistance of diamondback moth (Lepidoptera: Plutellidae) in North America. Journal of Economic Entomology. 1993;86:11-19.
18. Perez CJ, Alvarado P, Narvaez C, Miranda F, Hernandez L, Vanegas H, Hrusk A, Shelton AM. Assessment of insecticide resistance in five insect pests attacking field and vegetable crops in Nicaragua. Journal of Economic Entomology. 2000;93:1779-1787.
19. Roush RT, Tabashnik BE. Pesticide resistance in arthropods. NewYork: Chapman and Hall; 1990.
20. Li M, Gao X, Gao Z, Zhao W, Su Z. Insecticidal activity of extracts from forty-eight plants including *Xanthium sibiricum* Patrin. Huanjing Xuebao Jinan. 2008;17:33-37.
21. Sayyed AH, Saeed S, Noor-Ul-Ane M, Crickmore N. Genetic, biochemical, and physiological characterization of spinosad resistance in *Plutella xylostella* (Lepidoptera: Plutellidae). Journal of Economic Entomology. 2008;101:1658-1666.
22. Liu S, Ji M, Zhao L, Wei S, Wang G, Li X, Li L. Preliminary study on bioactivity of two plant extracts against three kinds of pests. Xiandai Nongyao, Shenyang. 2007;6:27-29.
23. Rani M, Suhag P, Kumar R, Singh R, Kalidhar SB. Chemical components and biological efficacy of *Melia azedarach*

stems. Journal of Medicine Aromat Plant Science. 1999;21:1043-1047.
24. Ganeshan G, Chethana BS. Bioefficacy of pyraclostrobin 25% EC against early blight of tomato. Journal of World Applied Science. 2009;7:227-229.
25. Dudley TS, Marvin KH, Liu T.X. Adoption of pest management practices by vegetable growers. Journal of American Entomologist. 2002;48:197–199.
26. Facknath S. Application of neem extract and intercropping for the control of some cabbage pests in Mauritius. Proceedings of the international Neem Conference, Queensland; 2000.
27. Endersby NM, Morgan WC. Alternatives to synthetic chemical insecticides for use in crucifer crops. Journal of Biol. Agriculture and Horticulture. 1991;8:33-52.
28. Said M, Itulya FM. Intercropping and nitrogen management effects of diamondback moth and yield of collards in the highlands of Kenya. Journal of African Crop Science. 2003;2:35-42.
29. Vanlauwe B, Bationo A, Giller KE, Merckx R, Mokwunye U, Ohiokpehai O, Pypers P, Tabo R, Shepherd KD, Smaling EMA, Woomer PL, Sanginga N. Operational definition and consequences for implementation and dissemination. Outlook on Agriculture. Integrated Soil Fertility Management. 2010;39:17-24.
30. Manga VE, Agyingi CM, Suh CE. Trace element soil quality status of Mt. Cameroon soils. Advances in Geology. 2014;8:894103.
31. John Proctor, Ian DE, Robert WP, Laszlo N. Zonation of forest vegetation and soils of Mount Cameroon, West Africa. Plant Ecology. 2007;192:251-269.
32. Fraser PB, Brodie HM, Cheek MD, Healey SJ, Marsden JN, Nning NJ, McRobb A. Plant succession on the 1922 lava flow of Mt. Cameroon. In: Timberlake J, Kativu S, Eds. African Plants: Biodiversity, Taxonomy and Uses, Royal Botanic Garden, Kew. 1999;253-262.
33. Payton RW. Ecology, altitudinal zonation and conservation of tropical rainforest of Mount Cameroon. Final Project-Report R4600, ODA, London; 1993.
34. Fraser PJ, Hall JB, Healing JR. Climate of the Mount Cameroon region, long and medium term rainfall, temperature and sunshine data, SAFS, University of Wales Bangor, MCP–LBG. Limbe. 1998;56.
35. StatSoft. Statistica 9. 1 for Windows. StatSoft Inc., Tusla, USA; 2010.
36. Krishna MPK, Srinivasan K. Indian mustard as a trap crop of major lepidopterous pests of cabbage. Tropical Pest Management. 1991;37:26-32.
37. de Paula VF, de A Barbosa LC, A. Demuner AJ, Pilo-Valeso D, Picanço MC, Synthesis and insecticidal activity of new amide derivatives of piperine. Journal of Pest Management Science. 2000;56:168-174.
38. Scott IM. Efficacy of Piper (Piperaceae) Extracts for Control of Common Home and Garden Insect Pests. Journal of Economic Entomology. 2004;97:1390-1403.
39. Okonkwo CO, Ohaeri OC. Insecticidal potentials of some selected plants. Journal of Chemical and Pharmaceutical Research. 2013;5:370-376.
40. Akunne CE, Afonta CN, Mogbo TC, Ononye BU, Ngenegbo UC. Evaluation of the efficacy of mixed powders of *Piper guineense* and *Zingiber officinale* against *Callosobruchus maculatus (F.)* (Coleoptera: Bruchidae). American Journal of Biology and Life Sciences. 2014;2:63-67.
41. Arong GA, Oku EE, Obhiokhenan AA, Adetunji BA, Mowang DA. Protectant ability of *Xylopia aethiopica* and *Piper guineense* leaves against the cowpea bruchid *Callosobruchus maculatus* (fab.) (Coleoptera: Bruchidae). World Journal of Science and Technology. 2011;1:14-19.
42. Shelton AM, Andaloro JT, Barnard J. Effects of Cabbage Looper, Imported Cabbageworm, and Diamondback Moth on Fresh Market and Processing Cabbage. Journal of Economic Entomology. 1982;75:742-745.
43. Baidoo PK, Mochiah MB, Apusiga K. Onion as a pest control intercrop in organic cabbage (*Brassica oleracea*) production system in Ghana. Journal of Sustainable Agriculture Research. 2012;1:1927-1933.
44. Pavel IK, Brian F, Christine HF, Robert DH. Plant responses to insect herbivory: interactions between photosynthesis, reactive oxygen species and hormonal signaling pathways. Journal of Plant, Cell and Environment. 2012;35:441-453.
45. Pane C, Celano G, Piccolo A, Villecco D, Spaccini R, Palese AM, Zaccardelli M. Effects of on-farm composted tomato residues on soil biological activity and yields in a tomato cropping system.

Journal of Chemical and Biological Technologies in Agriculture. 2015;2:4. DOI: 10.1186/s40538-014-0026-9.
46. Pane C, Villecco D, Zaccardelli M. Short-time response of microbial communities to waste compost amendment of an intensive cultivated soil in Southern Italy. Journal of communication in soil science and plant analysis. 2013;44:2344-2352.
47. Bernal-Vicente A, Ros M, Tittarelli F, Intrigliolo F, Pascual JA. Citrus compost and its water extract for cultivation of melon plants in greenhouse nurseries. Evaluation of nutriactive and biocontrol effects. Journal of Bioresource Technology. 2008;99:8722-8728.
48. Komilis D, Kontou I, Ntougias S. A modified static respiration assay and its relationship with an enzymatic test to assess compost stability and maturity. Journal of Bioresource Technology. 2011;102:5863-5872.
49. Iannotti DA, Pang T, Toth BL, Elwell DL, Keener HM, Hoitink HAJ. A quantitative respirometric method for monitoring compost stability. Journal of Compost Science and Utilization. 1993;1:52-65.
50. Arancon NQ, Lee S, Edwards CA, Atiyeh RM. Effects of humic acids derived from cattle, food and paper-waste vermicomposts on growth of greenhouse plants. Pedobiologia. 2003;47:741-744.
51. Atyeh RM, Lee S, Edwards CA, Arancon NQ, Metzger JD. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. Journal of Bioresource Technology. 2002;84:7-14.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/22739