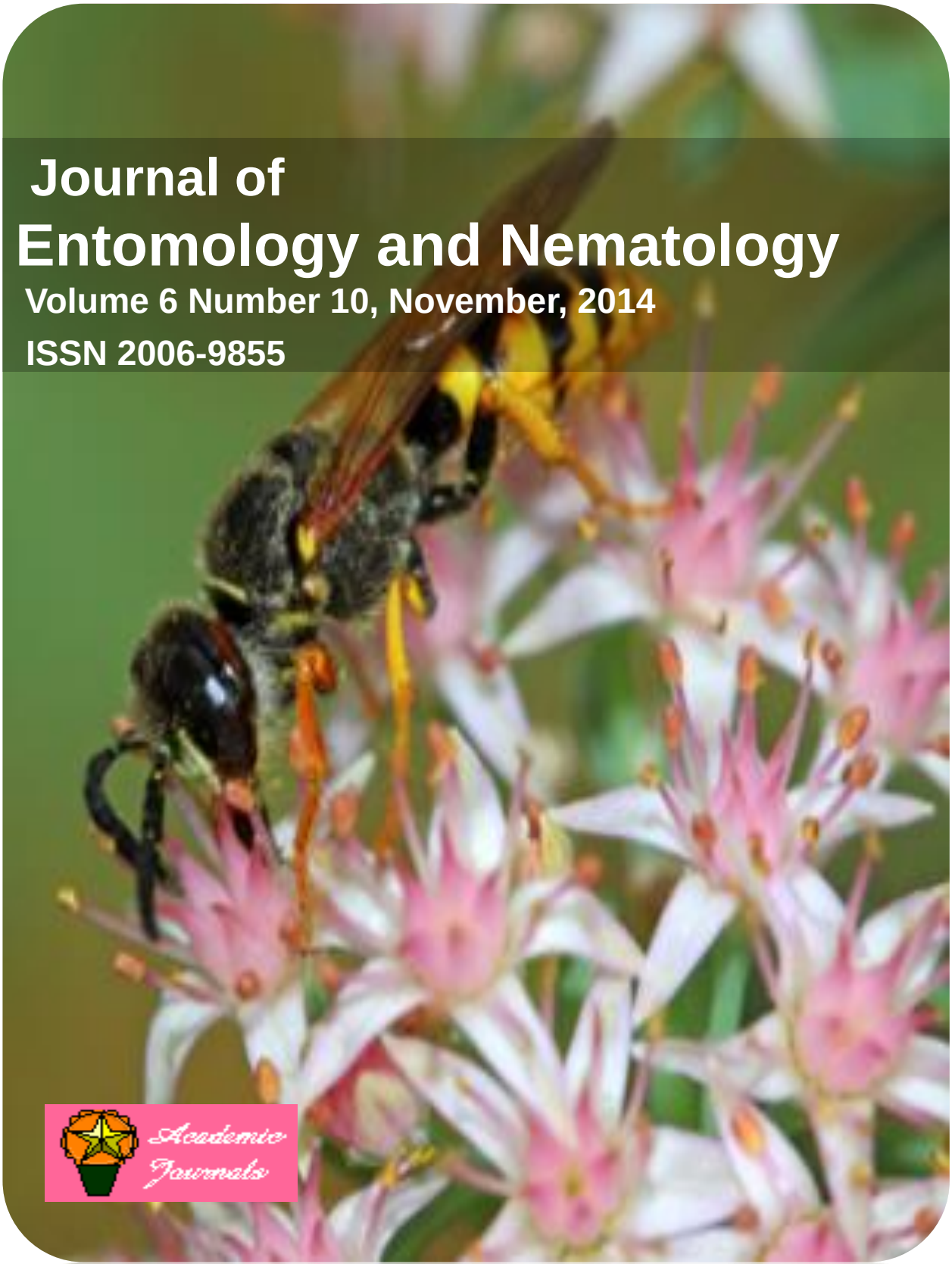

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Table of Contents: Volume 6 Number 10, November, 2014

ARTICLES

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Full Length Research Paper

Response of chips from different varieties of yam to larger grain borer (LGB) (*Prostephanus truncatus* (Horn) (Coleoptera: bostrichidae) infestation

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Laboratory studies were conducted at the University of Port Harcourt to evaluate the response of dried yam chips as a host for *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). The test was conducted using four improved yam varieties namely; Adaka, Ame, Nwokpoko and Obiaturugo. Ten grams of each substrate of the dried yam chips were placed in plastic containers of 300 ml and each container was infested with three pairs of one to three days old *P. truncatus*. Data on insect developmental periods in the various dried chips, as well as the susceptibility of the substrates, weight gain on the chips and the weight of frass produced were recorded. The beetles exhibited differential levels of preference for the yam chips from different varieties. They developed better on Obiaturugo and Nwokpoko than on Adaka and Ame. The mean developmental period of *P. truncatus* on yam dried chips were 96.33 and 65.33 days for Obiaturugo and Nwokpoko, respectively but failed to develop on Adaka and Ame. There was significant difference (P<0.05) in weight between the amount of frass produced on Obiaturugo and that produced on the other substrates. Also, there was significant difference (P<0.05) in weight gained between Nwokpoko and the other substrates. The study has shown that of the dried chips from the four varieties of yam, only Nwokpoko and Obiaturugo were found to be possible hosts of *P. truncatus* and thus need protection against the pest during storage.

Key words: *Prostephanus truncatus*, infestation, yam, chips.

INTRODUCTION

Yam belongs to the genus *Dioscorea* (Family: Dioscoreaceae), a perennial herbaceous vine cultivated for the consumption of their starchy tubers. Of the estimated 300-600 species that are available, there are just over half-dozen principal species that are grown for consumption, while others are grown for medicinal

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purposes (FAO, 2003). Yams originated in the Far East and spread westwards. They have since evolved independently in the Eastern and Western Hemispheres, and today yams are grown widely throughout the tropics. In the West African yam zone, which is the principal producer on a global basis, *Dioscorea rotundata*, *Dioscorea alata*, and *Dioscorea esculenta* are the most common species (FAO, 2003). Yam has a rough skin that is difficult to peel, but which softens after heating. The tuber is composed of a much softer substance known as the 'meat' which varies in colour from white or yellow to purple or pink in mature yam (Ensminger et al., 1983; IITA, 2009). They are grown in many tropical regions throughout the world, but the main production centre is the savannah region of West Africa, where more than 90% of the crop is grown (FAO, 2011). Yam is an important food crop in the yam zones of West Africa, comprising Cameroon, Nigeria, Benin, Togo, Ghana and Cote d' Ivoire, which together produce over 90% of the total world production estimated at about 20-25 metric tonnes (MT) per annum (p.a.) (Sanusi and Salimonu, 2006; Izekor and Olumese,2010). Nigeria with about 15.9 MT p.a. is the leading producer of yam in the world with about 71% of the world output followed by Côte d'Ivoire (2.7 MT p.a.), Benin (1.1 MT p.a.) and Ghana (1.0 MT p.a.) (FAO, 2010).

Yam contributes over 200 dietary proteins per capita daily for more than 150 million people in West Africa, while serving as a source of income and contributing immensely to food security of the people (Babaleye, 2003). It is rich in carbohydrate especially starch and consequently has a multiplicity of end uses and its availability throughout the year has made it preferable compared to other seasonal crops (FAO, 1987). However, the high perishability and losses during storage (up to 50%) are major constraints in yam production systems (FAO, 2010). Storage of fresh yam tubers has proven difficult over the years; with post harvest losses of between 30-85% being recorded (Coursey, 1982; Baco et al., 2004; FAO, 2011; Obadofin et al., 2013).

In order to minimize losses or damage, the yam tubers that normally will not store well as fresh tubers for example tubers of poor quality and badly damaged yams during harvesting or handling are processed into dried yam chips (Adeyusi, 1978; Vernier et al., 2005). The conversion of yam into chips and their storage for long periods exposes them to attack by some stored product insect pests, which threaten food security in sub-Saharan Africa (Isah et al., 2012). Yam and cassava chips and flour constitute important sources of carbohydrate for many people in West Africa (Obadofin et al., 2013).

One of the major insect pests that severely attacks yam chips, thereby reducing both its qualitative and quantitative value is the Lager Grain Borer (LGB), *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) (Vernier et al., 2005; Onolemhenhen, 2009). It is a native of Mexico and Central America was accidentally introduced into Africa in the early 1980s (Dustan and Magazini, 1981). The beetle has since spread to at least 17 countries on the continent (Farrell, 2000). In Africa, *P truncatus* is an outbreak pest of economic importance which has assumed a serious pest of stored maize and dry cassava chips (Dick, 1988; Chijindu, 2002; Chijindu et al., 2008; Danjuma et al; 2008; Isah et al., 2012). Losses of 61.5% on maize, 66% on cassava chips, 24% on cocoyam chips, 73% on plantain chips, 80% on maize, have been recorded in Mozambique, Benin, Ghana, Tanzania and Togo respectively (Cugala et al., 2007; Gnonlonfin et al., 2008; Isah et al., 2012; Boxall, 2002; Wright et al., 1993). This study assessed the susceptibility and post-harvest losses of chips of four yam varieties attributable to *P. truncatus* in the laboratory in the humid Niger Delta region of Nigeria.

MATERIALS AND METHODS

Study site

This laboratory study was carried out in the Department of Crop and Soil Science, University of Port Harcourt, Nigeria. The experiment was conducted under the prevailing conditions of 25-30°C and 70-90% relative humidity.

Yam varieties

Chips from four improved varieties of yam: Adaka, Ame, Nwokpoko and Obiaturugo were obtained from the National Root Crop Research Institute, Umudike, Abia State, Nigeria. The chips were sterilized in a hot air oven at 100°C for 2 h to disinfest them from mites and insect pests. The plastic containers were sterilized in hypochloride diluted in water. Ten grams of each chip were weighed on a digital scale (Model MP2001) into 50 ml plastic containers.

Mass rearing of *P. truncatus*

Adults of *P. truncatus* were obtained from the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria. Maize cobs and dried cassava chips were heat-sterilized in an oven (GNP-9082) at 60°C for 90 min. The adults were first cultured on the maize cobs and subsequently maintained on the sterilized cassava chips in 1-L Kilner jars in the laboratory under 25-30°C and 70-90% R.H. After one week, the adults were sieved out and eggs laid were allowed to develop to F_1 progeny of uniform age (1-3 days) (Zakka et al., 2010) and then used for the experiments.

Functional and physico-chemical analysis

The yam chips were analysed for chemical composition using the official methods of analysis described by the Association of Official Analytical Chemists (AOAC, 1990).

Progeny production

Three replicates of 10 g each of chips from the different yam varieties (Adaka, Ame, Nwopoko and Obiaturugo) were weighed

using a digital balance (Model J2003) and placed in 50 ml transparent containers with lids. Three pairs of the newly emerged adults of *P. truncatus* were introduced on each 10 g lot of yam chips. They were allowed to oviposit for one week after which they were removed. The set-up was left undisturbed until emergence of F_1 generation. The experiment was carried out in a completely randomized design (CRD). The number of adults, pupae, larvae, total progeny and developmental period (days) of *P. truncatus* were recorded after 96 days.

Frass weight

Frass was obtained by sieving off chips remaining and insects that remained at the end of the experiment and then weighed.

Determination of weight loss percentage

The final weight of chips was determined after 3 months of storage, by sieving off the insects and frass, the remaining chips were weighed and the observed changes in weight were used to correct the changes of corresponding trail samples (Hurlock, 1967). Percentage weight loss was calculated using the formula (Hurlock, 1967);

$$\text{Weight loss} = \frac{\text{Weight of sample} - \text{Final weight}}{\text{Weight of control sample}} \times 100$$

Susceptibility index

The susceptibility index was calculated using the formula developed by Dobie (1977);

$$\text{Susceptibility index (SI)} = \frac{\log_e F}{D} \times 100$$

Where, F = total number of F_1 adults and D = median development period (from the middle of oviposition period to 50% of emerged adults)

Data analysis

Data recorded on number of larvae, pupae, adults and total progeny were recorded and log (Log_{10} (x+1) transformed (Zar, 1999), while data on percentage weight loss of chips was arcsine transformed. The data on weight of the adults, weight of frass produced by the insects and developmental period (days) were also recorded.

All data obtained were subjected to Analysis of Variance (ANOVA) where significant differences were observed ($P<0.05$) means were separated using Least Significant Difference (LSD).

RESULTS

Functional and physico-chemical analysis

The result on the physico-chemical and mineral composition of the chips from the four varieties showed the highest fat content in Ame (0.55) with Adaka (0.37) showing the least. Water absorption capacity was highest in Adaka (1.70). Oil absorption capacity was relatively higher in Adaka (1.75) and the least in Nwopkoko (0.95), although it was higher in moisture content (15.32%) than any other substrate. The ash content was highest in Ame (1.05%), but least in Obiaturugo (0.55%). Sodium percent was highest in Adaka (0.58%) and least in Nwokpoko (0.23%). Nwokpoko was higher in Phosphorus (0.88%), Potassium (0.33%) and Nitrogen (0.77%) but, was least in Obiaturugo (0.83%), Ame (0.18%) and Adaka (0.28%) respectively (Table 1).

Mean number of adults

Table 2 shows the mean numbers of adults, pupae, larvae and total progeny that developed on the four substrates of yam chips. There were no significant differences between the substrates ($P>0.05$). No adult, pupal or larval progeny developed on chips of Ame and Adaka.

Mean developmental period of *P. truncatus*

The developmental period was 96.33 days in Obiturugo and 65.33 days in Nwokpoko, although the difference was not significant ($P>0.05$). However, there were significant differences ($P\leq0.05$) in % weight gain between Nwokpoko and the other three chips. There were also significant differences in the weight of frass produced in Obiaturugo and the other three chip substrate. The higher susceptibility index of 1.30 was recorded on Nwokpoko, while the least of 0 was recorded on Ame and Adaka (Table 3).

DISCUSSION

The study shows that *P. truncatus* can survive and breed on Nwokpoko and Obiaturugo as shown by the number of adults, pupae and larvae that developed in them. This could be attributed to its low bulk density (Hodges et al., 1985; Dick, 1988; Chijindu, 2002; Chijindu et al., 2008; Danjuma et al., 2008; Isah et al., 2012), high moisture content (Obeng-Ofori and Boateng, 2008) and low dry matter and high phosphorous content. Isah et al. (2012) reported that *P. truncatus* can survive on yam chips, but contradicts the work of Hill (2002) who reported that *P. truncatus* can only breed on maize and dried cassava chips. The study also showed that it took *P. truncatus* two months to develop on Nwokpoko and three months on Obiaturugo, but failed to develop on Adaka and Ame. This may be attributed to the differences in their physico-chemical properties and mineral content. The development period of 96 days recorded in this study was more than the 36-37 days found by Chijundu et al. (2008) on cassava chips and also longer than the 40.5-41 days

Table 1. Physico-chemical and mineral composition of chips from four yam varieties.

Physico-chemical/ mineral composition	Ame	Adaka	Nwokpoko	Obiaturugo
WAC	1.30	1.70	1.30	1.60
Swelling index	1.20	1.20	1.20	1.10
GT (°C)	67.00	65.00	65.00	66.00
Bulk density	0.89	0.85	0.82	0.88
MC (%)	12.87	12.45	15.32	12.07
Dry matter (%)	87.70	87.80	84.70	87.10
OAC	1.15	1.75	0.95	1.25
Fat (%)	0.55	0.37	0.39	0.42
Crude fibre (%)	0.16	0.24	0.26	0.27
Ash (%)	1.05	0.75	0.85	0.55
Na (%)	0.40	0.58	0.23	0.40
K (%)	0.18	0.23	0.33	0.28
P (%)	1.10	0.88	1.55	0.83
N (%)	0.63	0.28	0.77	0.43

GT-Gelation temperature, WAC, water absorption capacity; OAC, oil absorption capacity; MC, moisture content.

Table 2. Mean number of adults and immature stages of *P. truncatus* on four yam chips substrate.

Substrate	Number of adults	Number of pupae	Number of larvae	Total progeny
Ame	0 (1.00)[a]	0 (1.00)[a]	0 (1.00)[a]	0 (1.00)[a]
Adaka	0 (1.00)[a]	0 (1.00)[a]	0 (1.00)[a]	0 (1.00)[a]
Obiaturugo	0.33 (1.14)[a]	0.33 (1.14)[a]	0.33 (1.14)[a]	1 (1.14)[a]
Nwokpoko	0.67 (1.24)[a]	0.33 (1.14)[a]	0.33 (1.14)[a]	1.33 (1.47)[a]

Means in the same column with the same letters are not significantly different (P≥0.05).

Table 3. Mean developmental period of *P. truncatus*, weight loss and frass produced on the different yam chips.

Substrate	% Weight (g)		Developmental period (days)	Weight of frass (g)	Susceptibility indices
	Loss	Gain			
Ame	-	10.43 (4.33)[b]	0.00 (1.00)[b]	0.20 (0.02)[b]	0.00
Adaka	-	10.37 (3.67)[b]	0.00 (1.00)[b]	0.17 (0.20)[b]	0.00
Obiaturugo	-	10.43 (4.33)[b]	96.33 (9.86)[a]	0.80 (0.80)[a]	0.61
Nwokpoko	-	10.73 (7.33)[a]	65.33 (6.97)[a]	0.30 (0.03)[b]	1.30

Means in the same column with the same letters are not significantly different (P≥0.05)

on cocoyam chips found by Isah et al. (2012). The implication may be that dried yam chips especially those of Ame and Adaka may not be at risk of infestation by *P. truncatus*.

There was an overall weight gain in the chips substrate at the end of the study; this can be attributed to their moisture content, swelling index and the high humidity during the study. It could also be as a result of the hygroscopic nature of the yam, thereby absorbing from the atmosphere. This is in agreement with the work of Zakka et al. (2013) who attributed it to the functional properties of the yam chips. There was little frass produced on the substrate implying that these yam varieties are not particularly suitable hosts.

This study also shows that Nwokpoko and Obiaturugo are both slightly susceptible to *P. truncatus*. All the yam chips also absorbed moisture from the atmosphere. The implication of this is that *P. truncatus* can also infest dried

yam chips in addition to dried maize and cassava and that when stored they should be stored in air-tight containers to avoid spoilage. This has grave implication for yam stored as chips and thus food security in the country, since yam is a major staple food. Therefore, urgent steps should be taken in developing novel techniques to protect yam chips during storage from infestation by *P. truncatus*.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Effect of plant bed type on nematode density and yield of cabbage in two regions of Ghana

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Cole crop production in general and cabbage in particular is constrained by pest infestation, reducing the farmer's profit margin considerably. In this study, the effects of three plant bed types: flat, ridges and raised beds were investigated in 2012 and 2013 at Asiwa and Dormaa Ahenkro in Ghana, respectively to study their effects on plant parasitic nematodes and the yield of cabbage. Treatment effects on nematode density/200 cm^3 soil, nematode density/5 cm^3 cabbage root, root galling, cabbage heads, yield and leaf width were investigated. Flat bed treatment resulted in significant ($P < 0.05$) nematode reduction (84 and 67%) of *Meloidogyne* spp. and *Helicotylenchus multicintus*, respectively, at Asiwa compared to ridged bed treatment. At Dormaa Ahenkro, however, flat bed treatment resulted in significant reduction (81, 62, 97 and 98%) of *Meloidogyne* spp., *Pratylenchus penetrans*, *H. multicintus* and *Rotylenchulus reniformis,* respectively. Also, flat bed treatment resulted in 24 and 16% more cabbage heads compared to ridged and raised bed treatments at Asiwa and 44 and 17% more than ridged and raised bed treatments at Dormaa Ahenkro, respectively. Yield differences among treatments were however found to be not significant. The weakness in the experiment was that instead of using yield /unit area in determining the potential yield of the respective treatments, the weight of 10 heads of cabbage/treatment was used. Ridged bed treatment cabbage leaves were 0.5 and 0.2 times broader than flat bed treatment cabbage at Asiwa and Dormaa Ahenkro, respectively. The adoption of Oxylus variety, a poor host of root-knot nematode and flat method of planting, could sustain very well the cabbage industry in Ghana.

Key words: *Brassica oleracea,* cole crops, Ghana, plant parasitic nematodes, plant bed.

INTRODUCTION

Cabbage (*Brassica oleracea* L.) is an important vegetable crop and its production is a major economic sideline in Ghana. It is cultivated mostly on the outskirts of urban cities. Cabbage is a rich source of vitamins and minerals with significant medicinal values (Fahey et al., 2001). In the culinary industry in Ghana, cabbage is exclusively used in the preparation of salads. Production of cole crops in general, and cabbage in particular, is beset with serious pest problems. Insect pests such as the diamondback moth, *Plutella xylostella*, the cabbage maggot, *Delia brassicae*, and the armyworm, *Spodoptera exigua,* usually cause wilting, stunting and death of infested plants. In severe infestations, 100% of the crop may be lost (Grafius, 1993; Zandstra and

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Stephens, 1988). Plant parasitic nematodes (PPN) remain a major challenge in crop production, especially in developing countries (Rubino et al., 2008). They cause annual losses estimated at USD125 billion worldwide (Chitwood, 2003). Plant parasitic nematodes have been shown to parasitize cabbage (Potter and Olthof, 1993; Waceke, 2007). The spiral nematode, *Helicotylenchus multicintus* has been reported in Kenya, Uganda and other parts of the world as been associated with cabbage (Bafokuzara, 1996). The root lesion nematode, *Pratylenchus penetrans*, has the potential to reduce market yield of cabbage by 19-33% (Olthof and Potter, 1973). However, cabbage has been recommended as a rotational crop in nematode management because it is regarded as a poor host to root knot nematodes, *Meloidogyne* spp. (RKN) (Bello et al., 2004; Pattison et al., 2006). The type of farming system employed might influence the diversity and density of agricultural pests. For instance, an intercropping system involving crops highly susceptible to RKN such as tomato (*Solanum lycopersicum* L.) increases the damage to the associated crops by *Meloidogyne* sp. (Atu and Ogbuji, 1986). The objective of the present study was to evaluate the effect of different plant beds on nematode density and yield of cabbage in two regions of Ghana.

MATERIALS AND METHODS

Study sites

Field trials were conducted in 2012 and in 2013 at Asiwa and Dormaa Ahenkro, respectively. Asiwa in the Bosome Freho district of the Ashanti region is located at 6° 00′ N and 6° 26′ N and 1° 00′ W and 1° 30′ W, in a deciduous forest agro-ecological zone with Juaso-Manso soil series. Dormaa Ahenkro in the Dormaa Central district of the Brong Ahafo region of Ghana is located at 7° 00′ N and 7° 30′ and 3° 00′ and 3° 30′, in the forest belt with Bekwai-Nzema compound association. Cabbage is cultivated intensively in these districts. The cabbage cultivar Oxylus, commonly cultivated at both locations, was used in the study. Seeds purchased from an accredited agro input dealer had been treated with Metalaxyl-M and Iprodione before planting.

Nursery practices

A nursery was established at Asiwa on 26 June and seedlings transplanted on 25 July 2012, while the same operations were completed on 11 April and 22 May 2013 at Dormaa Ahenkro. The nursery bed was heat-treated by burning dried wood chips (50 kg/10 m^2) for 6 h on the surface to control plant parasitic nematode pests, soil arthropods and weed seeds. Nursing of seed was done a day after heat treating of the nursery bed. The nursery bed was covered with protective netting (Agribon) after seed germination to prevent insect damage. One and two week(s) after nursing, seedlings were sprayed with a botanical insecticide (Attack (IPROCHEM Co. Ltd); active ingredient emamectin benzoate 1.9%) at 250 ml/ha to prevent insect damage.

Treatments

Treatments consisted of flat, ridged and raised bed plots and were arranged in a randomized complete block design with three replications for a total of nine 6 x 5 m plots. Seedlings were transplanted 100 and 50 cm between and within rows, respectively. Basal fertilizer (NPK 15:15:15) and insecticide (Golan) were applied at rates of 250 kg/ha and 30 ml/16 L of water, respectively, two weeks after transplanting. Golan (Amiran Kenya Ltd; active ingredient acetamiprid 20%SP) was applied four weeks later at 30 ml/100 L of water. Four weeks after transplanting, the width (cm) of the 6^{th} leaf from the basal leaf from three randomly selected plants/plot and cabbage heads per plot were measured.

Sampling, extraction of nematodes and data analysis

Soil samples (200 cm^3/plot) were randomly collected from three points per plot before transplanting cabbage seedlings and also at harvest from the rhizosphere of cabbage plants, with a 5 cm diameter soil auger to a depth of 20 cm. The three soil samples collected from each plot were thoroughly mixed to constitute a composite sample. Each soil sample was kept in a black polythene bag, sealed and labeled. Samples were kept in an ice chest during transit. In the laboratory, nematodes were extracted from the soil samples using the modified Baermann funnel method as described by Hooper et al. (2005). Five cabbage plants per plot were randomly sampled at harvest and the root system rated for gall index according to the Zeck's 0-10 scale (Sikora and Fernandez, 2005).

Yield was calculated based on the weight of 10 heads of cabbage/treatment. Cabbage root samples were assessed for nematode infestation (motile stages) using the Baermann funnel extraction method from 5 cm^3 of the five cabbage root samples/treatment used for gall indexing. Roots were taken from cabbage plants from which rhizosphere soil was sampled. After 24 h of extraction, nematodes were relaxed in warm water in 60ºC for 3 min and fixed with 40: 1: 89 (formalin: glacial acetic acid: distilled water) solution. Second, third and fourth stage nematodes were mounted on aluminium double-coverglass slides and specimens were identified using morphological characteristics such as the spear, head skeleton, lumen of the oesophagus, excretory pore and spicules. Nematode count data were normalized using logarithmic (ln (x+1)) transformation prior to analysis of variance (ANOVA) using GenStat 8.1. (Lawes Agricultural Trust, VSN International). Means were compared using the Standard Error Difference (SED) test at ($p < 0.05$).

RESULTS

Four PPN belonging to the order Tylenchida were identified from pre-plant soil samples at both locations. The PPN in order of abundance were *R. reniformis* > *H. multicintus* > *P. penetrans* > *Meloidogyne* spp. (juveniles). At harvest, total nematode counts resulted in lower densities of *Meloidogyne* spp. in the rhizosphere of cabbage plants produced in flat bed plots than in ridged or raised bed plots in both years and locations. Twenty three nematodes were recovered from flat bed plots compared with 140 and 94 in ridged and raised beds respectively at Asiwa in 2012 and 108 compared with 258 and 567 in ridged and raised beds respectively at Dormaa Ahenkro in 2013 (Table 1). Rhizosphere densities of *Meloidogyne* spp. were significantly ($P < 0.05$) highest on raised beds in Dormaa Ahenkro but similar for plants grown on ridged and raised bed plots in

Table 1. Soil nematode densities/200 cm^3 soil at Asiwa (2012) and Dormaa Ahenkro (2013) at harvest of cabbage produced on three types of plant bed.

Treatment	*Meloidogyne* spp.	*Pratylenchus penetrans*	*Helicotylenchus multicintus*	*Rotylenchulus reniformis*
ASIWA				
Flat bed	23 (1.3)‡	163 (2.2)	139 (2.0)	401(2.6)
Ridged bed	140 (2.0)	69 (1.8)	418 (2.5)	707(2.8)
Raised bed	94 (1.9)	93 (1.9)	140 (2.1)	400(2.6)
Mean	(1.7)	(1.9)	(2.2)	(2.7)
SE	(0.2)**	(0.1)**	(0.2)**	(0.5)NS
Dormaa Ahenkro				
Flat bed	108 (1.8)	85 (1.6)	11(1.2)	2 (1.0)
Ridged bed	258 (2.2)	50 (1.4)	14(1.3)	30 (1.4)
Raised bed	567 (2.7)	226 (2.1)	435 (2.5)	114 (1.7)
Mean	(2.2)	(1.7)	(1.7)	(1.4)
SE	(0.3)**	(0.3)**	(0.1)*	(0.2)**

Data are means of three replications; ‡Log transformed (ln (x+1)) data used in analysis in parenthesis**; ****Significant at P < 0.05; *****significant at P < 0.01.

Table 2. Plant population/30 m^2 at Asiwa (2012) and Dormaa Ahenkro (2013).

ASIWA	Plant population	DORMAA AHENKRO	Plant population
Flat bed	170	Flat bed	189
Ridged bed	129	Ridged bed	106
Raised bed	143	Raised bed	156
Mean	148	Mean	150
SE	9.06*	SE	5.68**

******Significant at P < 0.05; *****Significant at P < 0.01.

Asiwa. Nematode densities of *H. multicinctus* were highest in rhizosphere of plants grown on ridges in Asiwa, but highest on raised beds in Dormaa Ahenkro. *P. penetrans* densities were highest on flat beds in Asiwa but highest on raised beds in Dormaa Ahenkro. There were no significant differences between treatments in densities of *R. reniformis* in Asiwa, but rhizosphere densities of this PPN were significantly lowest on flat beds and highest on raised beds in Dormaa Ahenkro. No galls were observed on cabbage roots, neither were nematodes extracted from roots at either location.

Planting on flat beds consistently resulted in significant (P < 0.05 and 0.01) increase in cabbage heads at the two locations compared with planting on ridged or raised beds. There were (24 and 16) % and (44 and 17) % more cabbage heads on flat beds than on ridged and raised beds at Asiwa and Dormaa Ahenkro respectively (Table 2). However, there were no significant differences in yield among treatments at either location (Table 3). Cabbage leaves from plants grown on ridged beds were significantly (P < 0.05) wider than leaves from plants grown on flat and raised beds. There were no differences in leaf width between plants grown on ridges and those grown on raised beds (Figure 1a and b).

DISCUSSION

Two of the nematode taxa, *H. multicintus* and *P. penetrans*, encountered at both locations have been reported to be associated with cabbage (Bafokuzara, 1996; Olthof and Potter, 1973). In the current study, *R. reniformis* was also identified to be a major PPN on cabbage. Flat bed treatment compared with ridged bed treatment suppressed nematode density particularly of *Meloidogyne* spp. and *H. multicintus* at Asiwa and compared with raised bed treatment in all four nematode taxa encountered at Dormaa Ahenkro. Compared with the ridged bed treatment, flat bed treatment resulted in reduction of 84 and 67% of *Meloidogyne* spp. and *H. multicintus*, densities at Asiwa. In comparison with the raised bed treatment, flat bed treatment showed significant reduction of nematode densities at Dormaa Ahenkro. Plant parasitic nematodes are obligate parasites and food resource mediates population dynamics (Kerry, 2000). Therefore, flat bed treatment plants which did not develop deeper root system because of minimal preparation of plant bed resulted in comparatively lower densities of PPN. Also, flat bed treatment resulted in highest number of cabbage heads compared

Table 3. Yield [(kg)/ 10] cabbage heads at Asiwa (2012) and Dormaa Ahenkro (2013).

ASIWA	Yield	Dormaa Ahenkro	Yield
Flat bed	11.2	Flat bed	8.9
Ridged bed	11.9	Ridged bed	12.7
Raised bed	11.9	Raised bed	9.3
Mean	11.6	Mean	10.3
SE	2.2 NS	SE	1.6 NS

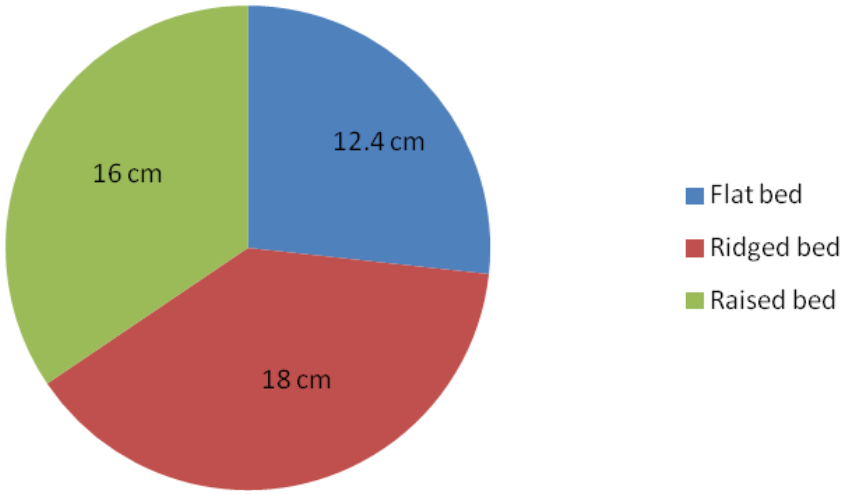

Figure 1a. Leaf width (cm) of cabbage at four weeks after transplanting at Asiwa.

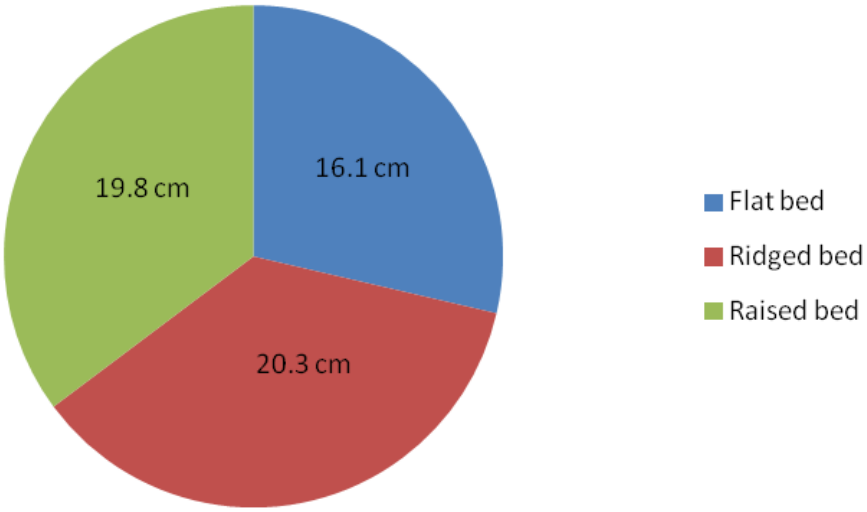

Figure 1b. Leaf width (cm) of cabbage at 4 weeks after transplanting at Dormaa Ahenkro.

to ridged and raised bed treatments. Ridged method of planting resulted in comparatively lower number of cabbage heads because area in between the ridges was lost for planting.

The effect of plant bed preparation on crop yield has been documented (Mohamed et al., 2009). In a similar study, Yousif and Sallah (2013) concluded that good plant bed preparation is necessary for improving sunflower production. Flat bed treatment consistently resulted in significantly more cabbage heads than ridged and raised bed treatments. In all cases, over 10% more cabbage heads were recorded from flat bed treatments. Ridged bed involved much improved method of tillage compared with flat bed with observed production of heavy heads of cabbage from the former treatment. Nematode suppression and high number of cabbage heads potential of flat beds, make it the preferred plant bed option for the cultivation of cabbage. Ridged treatment cabbage leaves were approximately 0.5 and 0.2 times broader than flat treatment cabbage at Asiwa and Dormaa Ahenkro respectively.

The fact that sufficient densities of root-knot nematode, *Meloidogyne* spp., were recovered from the rhizosphere of cabbage plants in all treatments but that the root samples did not gall and also *Meloidogyne* spp. were not extracted from the samples suggest that the variety used in the study, Oxylus, might possess some levels of resistance to *Meloidogyne* spp.

Conclusion

Farmers should be encouraged to cultivate Oxylus variety of cabbage since it has sufficiently demonstrated to be a poor host of RKN, *Meloidogyne* spp. The cultivation of Oxylus variety using flat bed method of planting could sustain very well the cabbage industry in Ghana.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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