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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

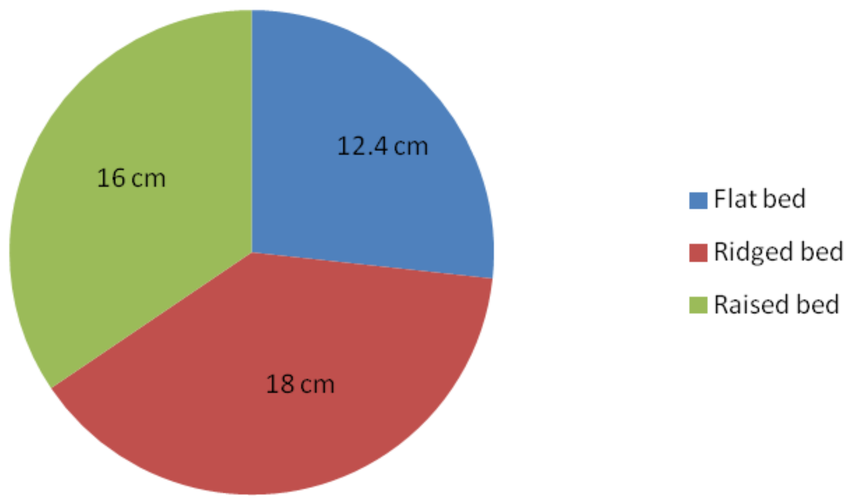

Figure 1a. Leaf width (cm) of cabbage at four weeks after transplanting at Asiwa.

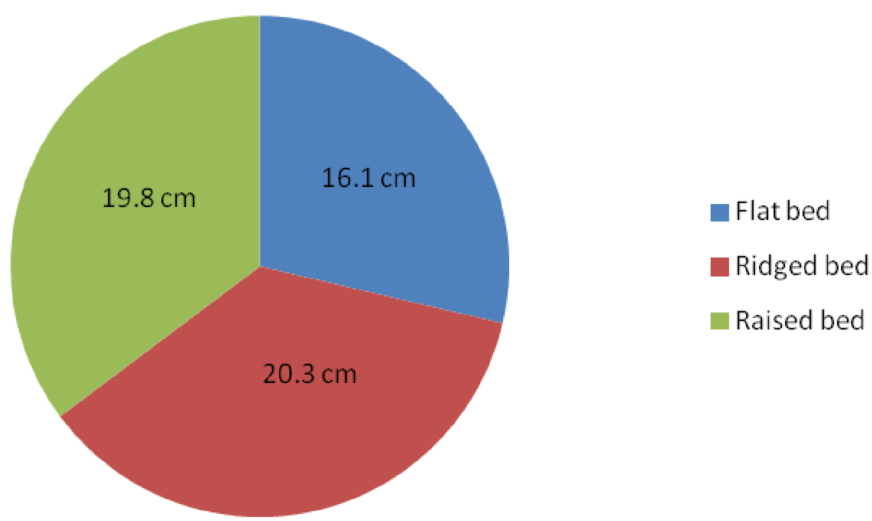

Figure 1b. Leaf width (cm) of cabbage at 4 weeks after transplanting at Dormaa Ahenkro.

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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