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Influence of different nutrient applications on insect populations and damage to cabbage

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ABSTRACT
Objective: Amendments aiming to improve soil fertility have been found to increase pest populations on plants. This study was conducted to evaluate the effects of organic (poultry manure) and synthetic (NPK) fertilizers on insect populations associated with cabbage.
Methodology and results: Two field experiments were conducted at the Theoretical and Applied Biology Department Garden of Kwame Nkrumah University of Science and Technology and CSIR-Crops Research Institute, Kumasi, Ghana from October 2008 to January 2009 and May to August 2009, respectively. Three main treatments, i.e. NPK 15:15:15 fertilizer at 10g/cabbage plant; poultry manure at 50g/cabbage plant and control (no nutrients) were applied. The experimental set up was a Randomized Complete Block design (RCBD) with three replications. Parameters studied included insect pests' numbers and their natural enemies. The percentage leaf damage, fruit damage, plant with multiple head damage and yield were determined. Major insect pest recorded included *Brevicoryne brassicae, Plutella xylostella, Hellula undalis* and *Pieris rapae* which caused damage to the cabbage plant (*Brassica oleracae var. oxyllus*). The natural enemies of pests of cabbage identified were the ladybird beetle, (Cheilomenes sp), *huntsman spider, Heteropoda venotoria* and black carpenter ant *Camponotus pennsylvanicus*. The control plots recorded cabbage plants with the highest yield in terms of head weight. Both poultry manure and inorganic fertilizers (NPK) generally increased insect pest attack on cabbage plants compared to the control.
Conclusions and main findings: It is concluded that when soil amendments such as poultry manure and inorganic fertilizers are applied to restore or increase fertility, pest control measures such as the use of chemical insecticides and other pest management options should be put in place to mitigate the effects of infestation of insect pests on crop productivity.
Key words: Cabbage, NPK, Poultry manure, cabbage pests, natural enemies

INTRODUCTION
Cabbage (Brassica oleracea) is a hardy vegetable that grows especially well in fertile soils all year round (Timbilla, 1998) and is becoming an important source of livelihood for small scale farmers. It is an important and popular vegetable cultivated mainly by backyard and market gardeners (Ninsin, 1997) and consumed by both urban and rural dwellers in Ghana. It has high nutritive value supplying essential vitamins, proteins, carbohydrates and vital minerals (Norman, 1992). Cabbage is a heavy user of nitrogen, phosphorus, and potassium and requires

frequent side dressing (University of Illinois Extension, 2008). It is considered a hard crop on the land, and many growers will rotate with other crops that do not have such high fertility requirements. Application of nitrogenous fertilizers occurs at intervals up to flowering stage (Rice et al., 1986; Schippers, 2000).

Nitrogen in the soil is absorbed by the plant in the form of nitrate and ammonium ions, it is used by plants to synthesize amino acids, proteins and other complex nitrogenous compounds like chlorophyll. Adequate supply of nitrogen is associated with high photosynthetic activity, vigorous vegetative growth and a dark green colour of the leaves (John et al., 2004). Phosphates help in the formation of nucleic acids and high energy phosphate compounds like ATP (Syers et al., 1986).

Poultry manure has historically been used as a source of plant nutrients and a soil amendment to enhance soil productivity, increase the soil organic carbon content, micro-organisms, crumb structure, nutrient status of the soil and crop yield (Beckman, 1973). Poultry manure has nitrogen as its major component but contain many other nutrients such as potassium, phosphorus, magnesium, sodium, and calcium that are essential for plant growth. Chemical fertilizers are compounds given to plants to promote growth, and are usually applied either through the soil for uptake by plants, or by foliar feeding, for uptake through leaves. One of the ways of increasing the nutrient status is by boosting the soil nutrient content either using organic materials such as poultry manure, animal waste, compost or inorganic fertilizers (Dauda et al., 2005).

Fertilizers in general are one of the major inputs for increased agricultural productivity. The form of these inputs can influence pest populations in various agroecosystems, depending on the kind of fertilizers used, the crops grown, and the insect pests present. However, excessive nutrient application can also lead to pest problems by increasing the reproduction, longevity and overall fitness of certain pests (Jahn, 2004). Extensive use of inorganic fertilizer has a depressing effect on yield, reducing number of fruits, and also delaying and reducing fruit setting which subsequently delays ripening and leads to heavy vegetative growth (Aliju et al., 1992).

Farmers spend much money in applying fertilizer, aiming to obtain a good yield at harvest but many of them achieve a yield below their expectation. Again, advocates of organic agriculture often assert that plants supplied exclusively with nutrient from biological materials are more resistant to insects than those grown using chemical fertilizer.

The current study evaluated the influence of different soil amendments such as NPK fertilizer and poultry manure on insect pest populations, crop damage as well as yield.

MATERIALS AND METHODS

Study sites: The minor season study was conducted on experimental farm at the Department of Theoretical and Applied Biology of the Faculty of Biosciences KNUST, Kumasi between October 2008 and January 2009. The site is near a tributary of Wiwi River. The major season study was conducted at the Crops Research Institute at Kwadaso, Kumasi between May and August 2009. The two sites have a comparable soil type of intermediate between sand and clay. Generally, the top soils are about 0.3m deep and contain less gravel.

Land preparation and transplanting: The land was cleaned and root stumps removed after weeding prior to sowing of seeds. Ploughing and raking activities were performed on the land before beds were made. The cabbage variety sown was Oxyllus with seeds treated with carbendazim or Thiram (from Holland, distributed in Burkina Faso by "KING AGRO"). Healthy cabbage seedlings from the nursery were transplanted to the main experimental fields/plots on 12th November, 2008 and 23rd May 2009 in the minor and major seasons respectively. Seedlings of length from 0.1m to 0.15m with between 5-8 leaves were transplanted. The row was five meters long and the plants were spaced 50cm x 50cm. Watering was done twice a day (morning and evening) especially in the minor growing season. A plant based insecticide, Emamectin Benzoate (Attack), 1.9 % (W/V) E.C. distributed in Ghana by AGRO-MAT LTD was applied to each plot one week after transplanting at the

manufacturer's recommended rate of 1 ml /1 litre of water to kill pests present at the time of transplanting.

Experiment design: The design was a Randomized Complete Block (RCBD) consisting of three treatments replicated three times. The treatments were NPK 15:15:15 fertilizer, Poultry manure and Control (no nutrient application).

Application of nutrients: The different nutrients were applied twice before harvesting for the two growing seasons. In each season, the first application was done ten days after transplanting and the second application was five weeks after transplanting using 10g of NPK 15:15:15 fertilizer and 50g of poultry manure applied per plant in ring form (Ogunjobi et al., 2005).

Data recording: Data collection started two weeks after transplanting. Data on insect pest population, plant damage and yield were recorded from the two middle rows which had an average of twenty (20) cabbage plants per plot/bed. The assessment of the numbers of various insect pest species was done by carefully examining the selected cabbage plants; leaf by leaf and turning of leaves as well to collect any insects from the under-surface of the leaves. The insect pests collected from each plot were identified, counted and recorded. Percentage leaf damage was based on the total number of leaves damaged in sample divided by the total number of leaves in the sample. Data were collected weekly until harvest between 06:30 and 09:00 hrs. Yield assessment was based on the heads per bed which were weighed at harvest.

Statistical analysis: Data obtained were subjected to analysis of variance and means of numbers of insects counts, percentage leaf damage and weight of heads were compared using PROC GLM; SAS Institute, 2004/2005 (Version 9). When significant differences were obtained ($P<0.05$), means were separated with Student-Newman Keul's (SNK) test. Insect counts were transformed to the logarithm base 10 while percent leaf damages were arcsine square root transformed prior to analysis (Sokal & Rohlf, 1981).

RESULTS

Insect pest populations: The cabbage plants attracted a number of insect pests at different stages of the plant growth due to their nutritive and luxuriant nature. Major insect pests that attacked the plant included cabbage aphids (*Brevicoryne brassicae* (L.)), imported cabbage worm (Pieris rapae), diamond-back moth (*Plutella xylostella* (L.)) and cabbage webworm (*Helulla undalis* (F.)). Cabbage aphids fed on plant sap and caused leaf cupping outward and inward. Attacked leaves appeared weak and wrinkled at the under surface. P. rapae larvae fed on the first formed outer leaves of the cabbage plants, which resulted in large holes in leaves. They also attacked the head at maturity. The damage they caused was similar to that of diamond-back moth. The larvae of *P. xylostella* larvae fed on the leaf tissues except the veins. Some of the insects fed on the under surface of the leaves. During head formation, larger larvae were found burrowing into heads and feeding on it as well. The caterpillar of *H. undalis* fed on the growing points (apical meristem) and the developing leaves. Larger larvae were found feeding on cabbage plants and some even cut the stem of less established plants. Small larvae tunneled into the main stem which resulted in stunting and deformed plants.

Generally, insect pest populations were lower in the major growing season of 2009 compared to the minor growing season of 2008 (Tables 1a and 1b). There were no significant differences among plots treated with poultry manure, NPK (inorganic fertilizer) as well as the control plots for both *B. brassicae* and *P. xylostella* populations for the two growing seasons (Tables 1a and 1b). However, significant differences were recorded for populations of *P. rapae* from both plots treated with both the poultry manure and NPK compared to the control. Populations of *H. undalis* showed significant differences among the treated plots. Plots treated with the inorganic fertilizer recorded the highest mean population (40.33) of *H. undalis* with the least recorded (10.33) on the control plots for the two growing seasons (Tables 1a and 1b). A particular snail (mollusc) (Plate 1) was observed feeding on the cabbage, however, populations were too low to be considered as a parameter but their defoliation activity could not go unreported.

Plate 1: Snail on cabbage head

Table 1a: Mean populations of insect pests on cabbage (*Brassica oleracea var. oxyllus*) grown with different nutrient applications, minor season, 2008-09

Treatment	*Plutella xylostella*	*Brevicoryne brassicae*	*Hellula undalis*	*Pieris rapae*
Control	8.67 + 2.33a	19.67 + 0.33a	10.33 + 1.20c	7.07 + 0.58b
Poultry Manure	12.00 + 1.53a	19.33 + 1.45a	26.33 + 1.23b	12.33 + 1.45a
NPK (15:15:15)	13.67 + 2.19a	22.67 + 1.76a	40.33 + 6.06a	12.67 + 1.45a
F-value	1.55	2.77	17.04	6.66
P	0.2869	0.1405	0.0034	0.0300

Means with the same letters in the same column are not significantly different at P=0.05

Table 1b: Mean populations of insect pests on cabbage (*Brassica oleracea var. oxyllus*) grown with different nutrient applications, major season, 2009

Treatment	*Plutella xylostella*	*Brevicoryne brassicae*	*Hellula undalis*	*Pieris rapae*
Control	7.66 + 2.33a	17.68 + 0.33a	8.33 + 1.20c	5.07 + 0.58b
Poultry Manure	11.01 + 1.53a	18.35 + 1.45a	24.33 + 1.23b	10.67 + 1.45a
NPK (15:15:15)	12.57 + 2.19a	20.68 + 1.76a	35.33 + 5.06a	11.33 + 1.35a
F-value	1.65	2.97	19.04	7.66
P	0.3869	0.2405	0.0024	0.0310

Means with the same letters in the same column are not significantly different at P=0.05.

Natural enemies of cabbage pests: The natural enemies of pests of cabbage identified were the ladybird beetle, (Cheilomenes sp). (Coleoptera: *Coccinellidae*) (Plate 2), huntsman spider, *Heteropoda venotoria* (*Araneae: Lnyphiinae*) and black carpenter ant *Camponotus pennsylvanicus* (Hymenoptera: Formicidae) (Plate 3). The mean numbers of the various natural enemies are presented in Table 2a and b. Generally for the two seasons, ladybird beetle populations were least on NPK-treated plots and largest on the control plots, even though the differences were not significant. *H. venotoria* numbers were larger on NPK-treated plots and least on the control plots. The differences were not significant. Similarly, the numbers of *C. pennsylvanicus* on all the plots did not differ significantly (Tables 2a and 2b).

Plate 2: Lady beetle

Plate 3: Black ant

Table 2a: Mean numbers of natural enemies of pests of cabbage (*Brassica oleracea var. oxyllus*) grown with different nutrient applications, minor season, 2008-2009.

Treatment	Mean no. of ladybird beetles	Mean no. of spider	Mean no. of ants
Control	3.33±1.45a	7.33±0.88a	26.67±3.84a
Poultry manure	2.00±0.58a	5.33±1.45a	20.33±4.26a
NPK (15:15:15)	1.67±0.33a	9.33±1.45a	29.67±5.0a
F-value	1.67	2.47	1.86
P	0.3738	0.2169	0.3245

Means with the same letters in the same column are not significantly different at P=0.05.

Table 2b: Mean numbers of natural enemies of pests of cabbage (Brassica oleracea var. oxyllus) grown with different nutrient applications, major season, 2009.

Treatment	Mean no. of ladybird beetles	Mean no. of spider	Mean no. of ants
Control	2.67±0.33a	5.67±1.45a	23.67±8.09a
Poultry manure	1.00±0.58a	3.33±1.45a	18.33±4.26a
NPK (15:15:15)	0.57±0.33a	7.33±1.45a	27.67±8.09a
F-value	1.27	2.17	1.36
P	0.4938	0.3179	0.4347

Means with the same letters in the same column are not significantly different at P=0.05.

Damage and yield assessment: For the two growing seasons, there were significant differences in percentage leaf damage among the three treatments (P<0.05). NPK (inorganic fertilizer) treated plots recorded the largest mean percentage leaf damage, whilst the control plots recorded the least percentage leaf damage (Tables 3a and 3b) (Plates 4a, b, c and d). There was no significant difference among plots treated with the poultry manure, NPK as well as the control plots for plants with multiple heads formation (Plate 5). There were significant differences in the weight per head recorded for the three treatments (P=0.05). The highest yield per (355g and 555g) head of cabbage (weight) was recorded by the control plots whilst NPK (inorganic fertilizer) recorded the least yield for the two growing seasons (Tables 3a and 3b).

(a) (b)

(c) (d)

Plate 4a-d: Different levels of Cabbage damage by defoliators

Plate 5: Early terminal bud damaged leading to multiple heads

Table 3a: Leaf damage, multiple head formation and yield data of cabbage (Brassica oleracea var. oxyllus) under different nutrient applications, minor season, 2008-09.

Treatment	% Leaf damage	Plants with multiple heads	Yield (g)
Control	11.70+ 0.74c	2.33+ 0.88a	355.20+ 23.28a
Poultry Manure	22.93+ 0.18b	3.67+ 0.33a	286.03+ 9.38b
NPK (15:15:15)	31.47+ 1.60a	3.33+ 0.33a	137.83+ 16.97c
F-value	93.54	1.44	40.30
P	0.0001	0.3075	0.0003

Means with the same letters in the same column are not significantly different at P=0.05.

Table 3b: Leaf damage, multiple head formation and yield data of cabbage (*Brassica oleracea var. oxyllus*) under different nutrient applications, major season, 2009.

Treatment	% Leaf damage	Plants with multiple heads	Yield (g)
Control	9.60+ 0.54c	1.23+ 0.78a	555.20+ 23.28a
Poultry Manure	19.43+ 0.12b	2.57+ 0.23a	486.03+ 9.38b
NPK (15:15:15)	28.33+ 1.20a	2.23+ 0.23a	337.83+ 16.97c
F-value	63.34	1.44	41.20
P	0.0001	0.2076	0.0004

Means with the same letters in the same column are not significantly different at P=0.05.

DISCUSSION

This study's data suggested that the application of either organic or synthetic fertilizers could increase pest populations on cabbage. In this study, there were lower populations of aphids on cabbage grown with the organic fertilizer than on those grown with the synthetic fertilizers in both the minor and major seasons of the experiments. Reduction in aphid population due to the application of organic manure in brinjal crop has been reported in India (Godase & Patel, 2001). Similarly, Sureka & Rao (2001) indicated that application of vermicompost at 7.5t/ha was more effective in bringing down aphid population on okra. Similar observations were made by Yardim and Edwards (2003) when they evaluated the effects of organic and synthetic fertilizer sources on pest and predatory insects associated with tomatoes. Miguel and Clara (2003) observed that crops grown with organic matter generally exhibit less insect herbivores, reductions that may be attributed to a lower nitrogen content in organically farmed crops. Findings from this study indicate that poultry manure (organic fertilizer) may have the potential to reduce pest attacks in the long term. The application of nutrients to the soil aids plants to produce more broad, succulent and fresh leaves (Jahn, 2004) which could serve as suitable surfaces for egg-laying by the various pests. Again, nitrogen has been found to affect the reproduction, longevity and overall fitness of certain pests (Jahn, 2004).

In general, the poultry manure and NPK treatments recorded low yield (<500g) in both the minor and major seasons. This could be due to high infestation of pest species which caused damage to the cabbage. However, the whole plant yield i.e. the flapper leaves together with the heads (marketable yields) from the poultry manure and NPK treatments were higher than the control. Van den Boogaard & Thorup-Kristensen, 1997 reported that large amounts of nitrogen increased whole plant yields of broccoli but not its marketable yield. The control plots recorded the highest yield which might be explained by the low insect pest infestation and low percentage leaf damage. Low percentage leaf damage logically means the plant will comparatively present larger or increased leaf area that would result in more radiation intercepted for photosynthesis. In related studies, Abusahela & Shanmugavelu (1988) and Yadav et al. (2004) working on Okra plants grown with poultry manure observed increased plant height with relatively fewer pest attacks. The increased plant height as a result of poultry manure was due to the presence of high phosphorus content which increased the availability of native soil phosphorus and increased biological activity (Adilakshmi et al., 2008). Plants uptake phosphorus from soil as dissolved orthophosphate. However, native soil phosphorus levels are often low enough to limit crop production organic phosphorus sources (animal manures) is adept at supplying the orthophosphate ion and correcting phosphorus deficiencies in soil. Although it varies, typically 30 to 50 percent of the phosphorus in animal manure is in an organic form, which must be converted to plant-available inorganic forms via soil biological activity, a process known as mineralization. The net effect of this mineralization is that phosphorus derived from animal manure can act more like a slow-release fertilizer than commercial inorganic fertilizers, in which the phosphorus is formulated to be more soluble and readily available to plants. Ukwungwu (1985) and Setamou et al. (1993; 1995) have demonstrated that damage to crops by insect pests increased with the application of fertilizers. Application of poultry manure and NPK fertilizer to the soil increased the pest populations and consequently decreased the head weights of the cabbage in both growing seasons' experiments. Most likely this could be attributed to the increased availability of nitrogen from the poultry manure and NPK. The lower yield from the poultry manure and PNK treated plots could be accounted for by the prolonged vegetative growth which conforms to the findings of Aliju et al. (1992) and John et al. (2004). These authors contended that intensive use of inorganic fertilizer has a depressing effect on yield in that it causes reduction in head formation due to prolonged vegetative growth. The current study evidence is limited on how much nitrogen can be tolerated for all fields in all situations. However, growers with manure should consider maximum allowable manure application rate for individual fields. Again, growers should be encouraged to make commercial fertilizer applications formulated with nitrogen (N), to meet the crop needs of the fields

More studies comparing pest populations on plants treated with synthetic versus organic fertilizers are needed. Understanding how organic fertilization improves plant health may lead to new and better integrated pest management and integrated soil fertility management designs.

In this study, the application of nutrients to boost the growth and yield of cabbage negatively impacted on the plants by increasing the insect pest populations. In conclusion, it must be noted that though soil amendments such as poultry manure and inorganic fertilizers (NPK) are essential for plant growth and must be applied at certain times, pest control measures such as the use of chemical insecticides and other pest management options should be put in place to mitigate the impact of insect infestation on crop productivity.

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