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Population Dynamics of the Diamondback Moth and Control of Lepidopteran Insects on Cabbage in the Rainy Season

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Cabbage production is seldom undertaken in southern Nigeria due to difficult climatic conditions and stress from pests and diseases. To increase producer confidence in cabbage production, appropriate insecticides to minimize insect pest damage and increase yield were tested. The trials were carried out during the 2004 and 2006 rainy seasons. The synthetic insecticides chlorpyrifos (Termex®), cypermethrin+acetamiprid (Conquest®), and the natural insecticide neem (*Azadirachta indica* A. Juss) seed oil extract were used. The insecticides significantly reduced the populations of diamondback moth, *Plutella xylostella* L., and the cabbage head caterpillar, *Crocidolomia binotalis* Zeller. There was an increase in male adult diamondback moth populations during cabbage head formation and a decrease after harvest. Thereafter, a slight population increase was observed in the regrowth. The percentage of plants with unmarketable heads was lower for plots treated with chlorpyrifos in 2004 than in the control only. In 2006, the treated plots had significantly lower percentages of plants with damaged heads. Plots treated with chlorpyrifos, cypermethrin+acetamiprid, or neem seed oil extract had higher yields than the untreated plots, although these were not significantly different.

Keywords *Azadirachta indica*, *Brassica oleracea*, *Crocidolomia binotalis*, Nigeria, Plant extract, *Plutella xylostella*.

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INTRODUCTION

Cabbage, *Brassica oleracea* L. var. *capitata*, is a temperate climate vegetable that has become very popular in tropical Africa (Anon., 2002a). It is widely cultivated in northern Nigeria and predominantly in the plateau areas where climatic conditions are suitable for its production (Van Epenhuijsen, 1978). Adequate yields in the tropics can be obtained if temperature is favorable (16–24°C, maximum temperature of 28°C in some varieties) and humidity is low (Rice et al., 1990; Tindal, 1993). Mean annual rainfall in the location is about 1278 mm and temperatures can vary between 25 and 39°C, making cabbage production unfavorable or difficult. High humidity levels during cabbage production influence an increase in the incidence of lepidopteran pests and diseases such as damping-off and bacterial rot. Consequently, in the rainforest area of southern Nigeria, cabbage is under significant stress. The number of insect taxa associated with damage of cabbage is large throughout Nigeria (Umeh and Kefas, 2006), requiring increasing cost of inputs for control.

In Nigeria, cabbage is attacked by the diamondback moth *Plutella xylostella* L. (DBM) (Lepidoptera: Yponomeutidae), the cabbage webworm *Hellula undalis* Fabricius, the cabbage head caterpillars *Crocidolomia binotalis* Zeller (CHC) (Lepidopotera: Pyralidae), the cabbage looper *Trichoplusia ni* Hübner (Lepidoptera: Geometridae), and many species of aphids, mainly the mealy cabbage aphid *Brevicoryne brassicae* (L.) (Homptera: Aphididae; Umeh and Kefas, 2006). However, DBM is the most serious pest of Brassicaceae in the world (Guilloux et al., 2003). In absence of control measures, yields are often completely lost due to damage of cabbage heads during larval feeding (Anon., 2003a). DBM is resistant to many insecticides and several organophosphate, carbamate, and pyrethroid materials are no longer effective (Ivey and Johnson, 1997). This has led to a search for alternative methods of control, principally as components of integrated pest management. The use of environmentally safe microbial agents such as *Bacillus thuringiensis* (Berliner) has proved to be effective against DBM (Ivey and Johnson, 1997). However, reliability on *B. thuringiensis* for DBM control is already questionable due to field resistance detected in many countries (Alam, 1992; Kirsch and Schumutterer, 1988; Shelton et al., 1993). The use of semiochemicals as attracticides is increasingly being applied in crop protection (Maxwell et al., 2006). The sex pheromone of DBM has been characterized for mating disruption (Tamaki et al., 1977). Unfortunately, Schroeder et al. (2000) reported that synthetic pheromones for mating disruption did not effectively suppress density of DBM on cabbage. Further development of insecticides is necessary to control DBM. Insecticides that are to be recommended to low-income farmers, which constitute the majority of Nigerian cabbage farmers, must be affordable and readily available.

Insecticides of plant origin have been used extensively in control of pests of various crops worldwide. Pesticides from the neem tree, *Azadirachta indica* A. Juss., are used in different formulations for control of pests in agriculture (Schmutterer, 1990; Umeh and Ivbijaro, 1999). The present study was undertaken to (1) to monitor the population dynamics of diamondback moth on cabbage and (2) evaluate the efficacy of synthetic insecticides and a natural insecticide in control of major cabbage insect pests.

MATERIALS AND METHODS

The trials were established in the NIHORT vegetable field at Ibadan in May during the rainy seasons of 2004 and 2006. Seed of cabbage, cv. Copenhagen Market, were planted in sterilized soils in planting trays arranged under a shade canopy. The seedlings were watered manually on a daily basis using a watering can. No insecticides or fertilizers were applied prior to transplanting. Fields were plowed in mid-April and disked 2 weeks later. Five- and four-week-old seedlings with soil around roots were manually transplanted to plots in 2004 and 2006, respectively. About 20 kg $\cdot ha^{-1}$ of cured poultry manure (exposed to the sun after a period of 6 months for detoxification) was applied to the plots at planting. Each plot measured 4 × 4 m. Plant spacing was 50 × 50 cm within and between rows. A distance of 2 m was maintained between plots to minimize effects due to insecticide drift. Plots were arranged in a randomized complete block design with four replications. Treatments included application of chlorpyrifos (Termex® 48 EC) 480 $g{\cdot}L^{-1}$ a.i., cypermethrin 144 $g{\cdot}L^{-1}$ a.i.+acetamiprid 32 $g{\cdot}L^{-1}$ a.i. (Conquest® EC), and neem seed oil extract (250 $g{\cdot}L^{-1}$ a.i.) at the rates of 5 mL/10 L of water. Treatments were made as a soil drench + foliar application using a backpack CP15 sprayer of 15 L capacity with adjustable plastic nozzle of 1.3 mm and 5 bar pressure. Omo® soap solution (067 $mL{\cdot}L^{-1}$) was used as an emulsifier to ensure mixing of neem oil with water. Neem oil extraction from seed was done with hexane solvent using the method of Ivbijaro and Bolaji (1990). Control plots without any insecticide application were also maintained. Insecticides were applied three times at 2-week intervals starting from 3 weeks after transplanting. Fertilizers (NPK 15:15:15) were applied to plants as ring application in two splits of 150 $kg{\cdot}ha^{-1}$ per application at 4 and 8 weeks after transplanting. Plots received water by hand. Manual weeding was carried out as needed.

Insect populations were monitored weekly by sampling 10 randomly selected cabbage plants. Plants were tagged for all assignments. A mating disruption sex pheromone was used in a wing trap tied to a 50-cm peg placed in the middle of each untreated (control) plot to monitor DBM adult population dynamics. The DBM sex pheromone consists of three components: (Z)-11-hexadecenal, (Z)-11-hexadecen-1-ol acetate, and (Z)-11-hexadecanol (Tamaki et al., 1977).

Adult population dynamics of CHC were not monitored due to unavailable sex pheromone. Ten mature cabbage plants were sampled to assess lepidopteran larval damage. This method was based on the level of damage that can be marketable in Nigeria. After wrapper leaves were removed, head leaves with >15% leaf area consumed (≈18 holes or more) were regarded as unmarketable and the percentage of marketable heads calculated. Yields of fresh heads were evaluated at plant maturity.

Data were transformed using square root transformation $(x+1)^{0.5}$ and percentages of unmarketable cabbage heads were arcsine transformed. All data were subjected to analysis of variance (ANOVA.). Means were separated using the Student-Newman-Keuls test.

RESULTS AND DISCUSSION

Population Dynamics of the Diamondback Moth on Cabbage

Two economically important insect pests, DBM and CHC, were found on cabbage at the site. Low presence of adults and larvae of DBM was observed in the untreated plots in 2004 and 2006 during first 4 weeks after transplanting (WAT; Figure 1). In both study years, increases in population of DBM were observed from the 5th to the 10th week after transplanting during cabbage head formation. In 2004, the peak adult population was observed in the 7th week after transplanting (16 adult moths/trap). In 2006, the peak population was observed at the 10th week after transplanting (45 adult moths/trap). During the study periods of May–October 2004 and 2006 respectively, environmental temperatures varied between 25–27.4°C and 25.1–28.4°C, and relative humidity was between 81%–87% and 80%–90%. Adult DBM populations decreased drastically after harvest, at the 10th and 12th WAT in 2004 and 2006, respectively. The DBM larval populations increased during the period of high adult flight (trap catches) and decreased after harvest in 2004 and 2006 (Figure 1). Smaller DBM population increases were observed between 11–13 and 13–14 WAT in 2004 and 2006, respectively, during postharvest regrowth. The regrowth increase was most prominent in 2004. The DBM population followed the head development, harvest, and postharvest regrowth. Regrowths of new foliage or small heads (often not marketable because of size) supported a new population increase. In the present study, several overlapping generations (≈5) of DBM were observed (Figure 1). It has been reported that high temperatures coupled with low wind velocities and availability of food are conditions most favorable to flight and oviposition of DBM. These conditions often govern the number of generations that can occur. DBM is multivoltine with 4 to 20 generations a year in temperate and tropical regions, respectively (Harcourt, 1986; Vickers et al., 2004).

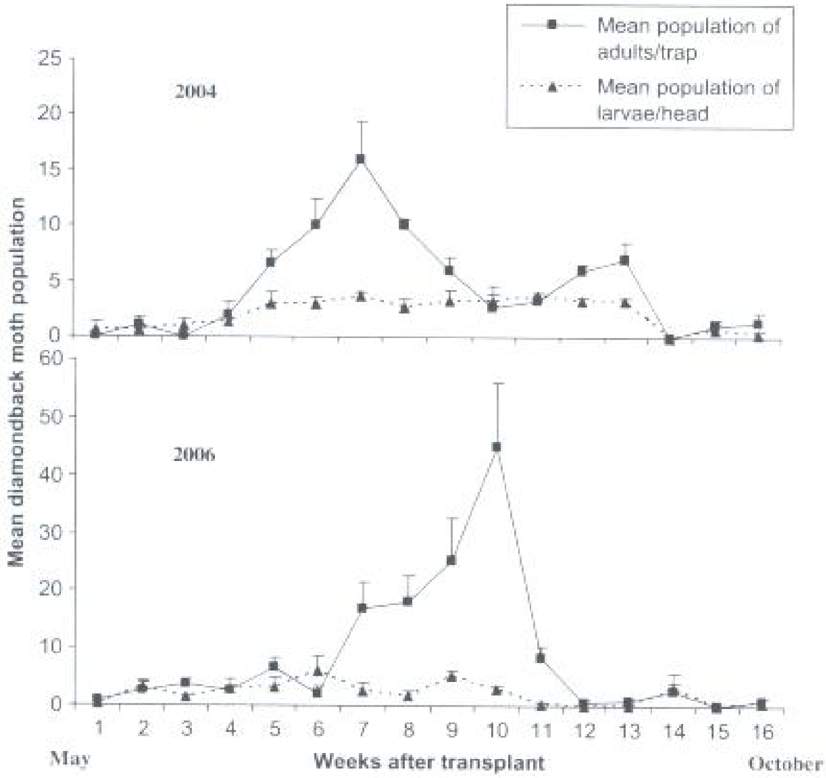

Figure 1: The population dynamics of diamondback *Plutella xylostelle* larva and adult ± SE on cabbage during 2004 and 2006 cropping seasons ($P \leq 0.05$).

Insecticide Effects on Populations of DBM and CHC, Damage, and Yields of Cabbage Heads

DBM larvae numbers from the treated plots were significantly lower than control plots in 2004 and 2006 (Figure 2). The best control results in 2004 were from plots treated with chlorpyrifos and cypermethrin+acetamiprid. The number of DBM larva in chlorpyrifos- and cypermethrin+acetamiprid-treated plots in 2004 were not significantly different, but both were significantly lower than plots treated with neem oil. In 2006, significantly ($P < 0.05$) fewer DBM larvae were present in the plots treated with chlorpyrifos than those treated with neem oil. However, there was no significant difference of DBM larvae in plots treated with chlorpyrifos and cypermethrin+acetamiprid.

Insecticide effects on CHC larvae followed the DBM trend, with the treated plots having significantly lower numbers of larvae than controls (Figure 3). No significant differences were observed among all the treatments.

In both 2004 and 2006, the percentage of unmarketable damaged heads was significantly higher in control plots than in insecticide treated plots

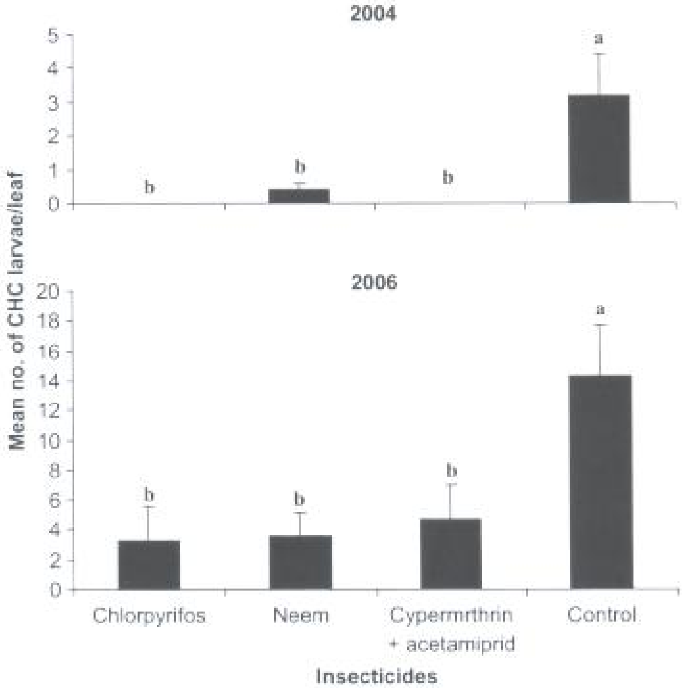

Figure 2: Effects of synthetic (chlorpyrifos and cypermethrin+acetamiprid) and natural (neem) insecticides on numbers of CHC larvae attacking cabbage in 2004 and 2006. Means followed by the same letters are not significantly different ($P > 0.05$, Student-Neuman-Keuls test).

(Figure 4). However, in 2006, the percentage of plants with damaged heads was significantly lower in chlorpyrifos-treated plants than in those of neem oil (Figure 4). Various formulations of insecticides belonging to organophosphate, carbamate, and pyrethriod groups have been effectively used on cabbage lepidopterans in different parts of the world (Alam et al., 1987; Maxwell and Fadamiro, 2006; Walton, 1989). Resistance to the group of synthetic insecticides tested in this study has been developed by cabbage lepidopterans in some parts of the world (Hines and Hutchison, 2001; Ivey and Johnson, 1997; Liu et al., 2002), Insecticide resistance has not developed in the rainforest ecology of southern Nigeria. Farmers are just beginning to adopt cabbage production and it is neither extensive nor intensive. The problem of insect resistance in cabbage production could likely surface as production stabilizes across large areas and identical mode of action insecticides are applied in large quantities. Use of neem seed oil extract proved efficacious against DBM and CHC. Its use can be recommended to small-scale farmers due to its natural availability in most parts of sub-Saharan Africa. Besides the use of hexane to extract neem oil, ground seeds can be pressed without solvent to release oil and can be used by low-income farmers. In a trial carried out elsewhere (Anon.,

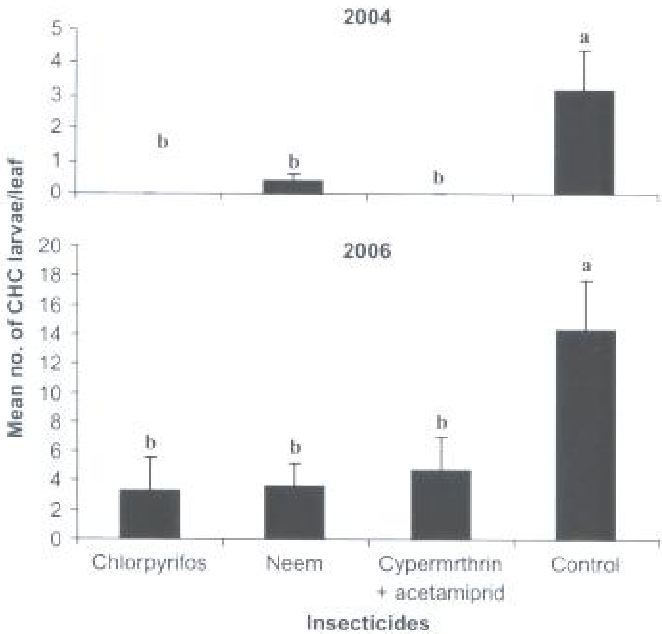

Figure 3: Effects of synthetic (chlorpyrifos and cypermethrin+acetamiprid) and natural (neem) insecticides on numbers of CHC larvae attacking cabbage in 2004 and 2006. Means followed by the same letters are not significantly different (P > 0.05, Student-Neuman-Keuls test).

2002b), aqueous neem seed extract was also found to be effective against DBM and significantly increased yield over plots treated with the synthetic insecticide profenofos.

The control plots had the lowest yields in 2004 and 2006. Yields of plots treated with insecticides were not significantly higher than the control. The yields ranged between 9.2 and 10.2 kg/plot and 17.2 and 21.55 kg/plot in 2004 and 2006, respectively. Higher yields were obtained in 2006 due to a better climatic condition. An important factor associated with cabbage damage has been the marketability of heads. Therefore, the higher damage observed in the control, which was as high as 34%, may result in economic loss.

Traditionally in Nigeria, management of lepidopterous pests of cabbage in the producing areas of northern Nigeria has been dominated by insecticide-based control programs with no biological control (Luka Kefas, unpublished data). At the high rate at which DBM is developing resistance to commonly used brands of synthetic pesticides, broadening the choice of pesticides will be helpful to farmers. In the present study, chlorpyrifos, cypermethrin+acetamiprid, and neem seed oil were effective against DBM and CHC on cabbage. These insecticides can be utilized by producers while new alternatives are tested for release. Despite the higher efficacy observed in the tested synthetic insecticides compared to neem oil, use of the latter can be recommended to

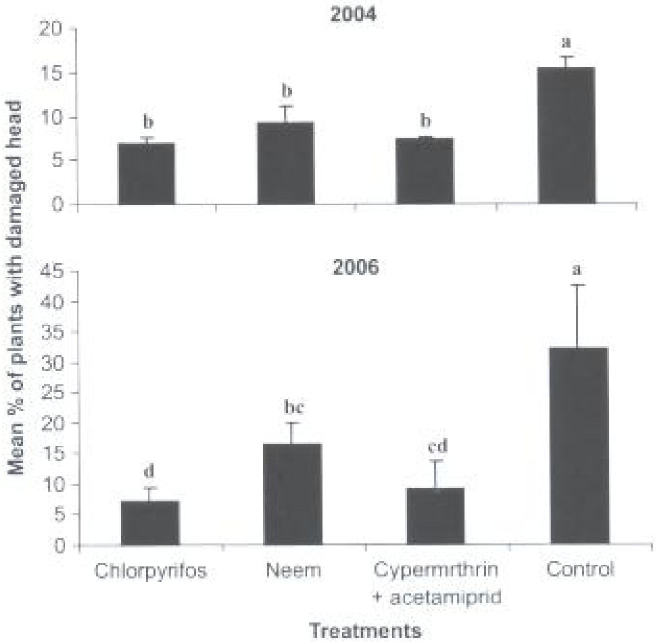

Figure 4: The effects of synthetic and natural insecticides on the percentage of cabbage plants with damaged heads during 2004 and 2006 cropping seasons. Means followed by the same letters are not significantly different ($P > 0.05$, Student-Neuman-Keuls test).

vegetable growers due to its cheaper cost and less hazardous attributes in agriculture and the environment. More effective control of cabbage insect pests using neem extracts may be achieved by increasing the number of applications. It may also be advisable to quickly plow under plant refuse to remove the possibility of increasing populations of the insects.

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