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Effect of timely application of alternated treatments of *Bacillus thuringiensis* and neem on agronomical particulars of cabbage

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Diamondback moth (DBM) *Plutella xylostella* is an economical pest of cabbage. Chemical pesticides constitute so far the major tool for pest management. However, the use of botanical pesticides and microbial is also considered. The objective of this study was to compare the effect of alternating treatments of Bacillus thuringiensis and Neem on agronomic particulars of cabbage as compared to solo and chemical applications. Results showed that the alternation of B. thuringiensis and Neem, performed as well as solo. Agronomic parameters were strongly related to the level of infestation of *P. xylostella* and other pests. The number of leaves was higher in the control and Dimethoate treatments depicting higher response to severe damages, whereas diameters of cabbage heads were higher in the Biobit and Neem treatments. There was no significant difference between the Biobit and the alternated treatment in terms of weight of cabbage. The diameter of cabbage treated with Biobit was higher than those treated with an alternated treatment. However, there was no significant difference between the alternated treatment and Neem. On the other hand, there was significant correlation between agronomic parameters and the presence of parasitoids. The correlation was significantly greater between the number of leaves, diameter and weight of cabbage in the presence of *Oomyzus sokolowskii*. These results indicate that timely application of alternated treatments of *B. thuringiensis* and Neem can be more economically viable as compared to single treatments and should be adopted in integrated pest management programs for cabbage.

Key words: Diamondback moth, biobit, neem, cabbage, integrated pest management, yield.

INTRODUCTION

Cabbage *Brassica oleracea* (Brassicaceae) is one of the most cultivated crops in the world; particularly in Africa where, it is a source of food and income to many communities living in the suburbs of West-African cities (FAOSTAT, 2003). The production of cabbage is however, constrained by various insect pests among them *Plutella xylostella* (Lepidoptera: Plutellidae) the diamondback moth (DBM). This pest can cause severe crop damages (Talekar and Shelton, 1993). Although it is difficult to estimate losses at small scale farming in Africa

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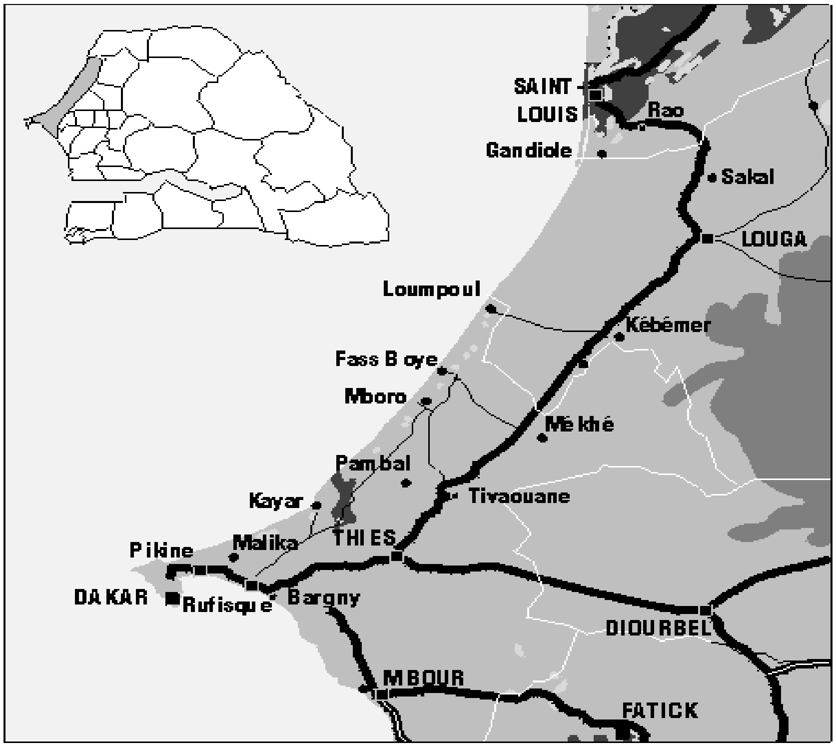

Figure 1. Study site.

(Kibata, 1996), Krishnamoorthy (2004) reported a 52% yield loss on cabbage which is beyond the economical thresholds.

The cost of pest control is estimated to cost US $ 1 billion each year. Synthetic chemical pesticides are the main tools of pest management (Grzywacz et al., 2010). Due to their adverse effects on the environment and human health, the use of chemical pesticides is being superseded by biological control agents (Verkerk and Wright, 1996; Wright, 2002; Sow et al., 2013a). In addition to that, synthetic chemical pesticides induce resistance among diamondback population (Eigenbrode and Shelton, 1990). Their use is no longer economical in cabbage production.

On the other hand, DBM counts several natural enemies including parasitoids, predators and microorganisms (Rowell et al., 2005). Among the microorganisms, *Bacillus thuringiensis* was found to be very promising in the control of lepidopteran pests (González-Cabrera et al., 2010; Huang et al., 2010). Plant-derived pesticides such as Neem are also considered in Integrated Pest management (IPM) programs for the control of cabbage pests (Liang et al., 2003; Sarfraz et al., 2005; Charleston et al., 2006). However, reports showed that intensive use of *B. thuringiensis* can induce resistance in diamondback populations (Tabashnik et al., 1994; Meyer et al., 2001). Furthermore, the use of *B. thuringiensis* for the control of DBM can also affect beneficials particularly the complex of natural enemies (Monnerat et al., 2000). The alternation of Neem and *B. thuringiensis* is therefore expected to be a promising method for the control of DBM in cabbage (Prasad et al., 2007; Roh et al., 2007). However, agronomical benefit of the use of such technique has not been well studied. Previous experiences have shown that most farmers adopt technologies after being exposed to concrete results of such an innovation. The objective of this paper was to compare the effect of alternated treatments of *B. thuringiensis* and Neem on cabbage pest infestation especially DBM and its repercussions on the agronomical quality of cabbage yield in Senegal.

MATERIALS AND METHODS

Study site

The study was conducted in Malika a district in the Niayes in Dakar, Senegal; 12°54’44” N and 12°08’08” NW, 189 m above sea level (Figure 1). The area is characterized by long dry seasons from November to June with temperatures range of 15 to 20°C and short rainy seasons from July to October with temperatures ranging between 25 and 35°C. Yearly precipitations do not exceed 500 mm between August and September.

Cabbage crops

Cabbage *Brassica oleracea* var. “*Marché de Copenhague*” which, is

Table 1. Correlation between agronomic parameter and insect pest infestations in cabbages

Parameter	No of leaves	Diameter (cm)	Weight (g)	*P. xylostella*
N. of leaves				
Diameter (cm)	0.527*			
Weight (g)	0.201*	0.545*		
P. xylostella	0.221*	0.366*	0.134*	
Other Pests	0.287*	0.150*	0.150*	0.008

*Significant values (except diagonal) at the level of significance alpha=0.050 (two-tailed test).

drought tolerant was used in this experiment. In order to protect cultures from nematodes, Furadan was applied in the soil prior to planting. Poultry manure was applied as fertilizer, 10 days later with intensive water irrigation. After planting additional fertilizers with N-P-K in a ratio 10-10-20 and poultry manure were applied 2weeks after planting. Crops were watered daily using a sprinkler. The experimental design consisted in 35 plots of 2100 plants in a randomized bloc design. Cabbage crop were planted in 35 plots of 60 plants each, placed in six rows of 10 plants each. The spacing between rows was fixed at 40 cm. Treatments were repeated five times.

Phytosanitary applications

Four treatments were used: Biobit, *B. thuringiensis* var. *kurstaki*, Crystal Chemical Company LTD (Europe), Neem (Suneem, *Azadirachta indica* 1% EC), alternation Biobit/Neem (in 10 days interval four times) and Dimethoate (Meteor 400 EC). An untreated control was also included in the experiment. Biobit was applied at 1L for 100 L of water per hectare. As for the Neem treatment, the dosage was 1L/ha. Dimethoate was applied at 1.5 L/ha. Applications started 25 days after planting; crops were treated using manual sprayer every ten days. For the alternated treatment Biobit/Neem, four timely applications were used: Neem was applied first and the last application was Biobit. These alternated applications were stopped 20 days before the other treatments.

Sampling methods

Samples were collected randomly by selecting 10 cabbage heads in the central row of each plot. The number of insects such as larva and pupae of *P. xylostella* and cocoons of parasitoids was recorded. Other insect pests including larvae of *Hellula undalis* Fabricius (Pyralidae), Aphididae and Aleyrodidae within a cabbage were all collected and counted in each treatment. Eggs and larvae of *P. xylostella* which, were inside the leaves were not considered. In each treatment, the diameter of each cabbagehead plant was measured with a ruler. The cabbage heads were weighted at harvest with an electronic balance. The yield of cabbage was recorded for each treatment. The samplings started 10 days planting and were performed every ten days.

Data management

Data were normalized and subjected to ANOVA, and post-ANOVA comparisons of means were made using Student-Newman-Keuls test. The relations between agronomic features and pest infestation and the presence of parasitoids was determined using Pearson's correlation. The level of significance was kept at 5% in all data analysis.

RESULTS

Interactions between agronomic parameters and insect pest infestations

The results show that agronomic features of cabbages such as the number of leaves, the weight and the diameter of cabbageheads were related to the level of pest (Table 1). However, there was no relation between the infestation of DBM and other pests (Table 1).

Infestation levels of *Plutella xylostella* and other pests

There were significant differences between treatments on the infestation levels of *P. xylostella* ($F_{(4, 24)} = 63.14$; $P < 0.0001$) and other pests ($F_{(4, 24)} = 14.16$; $P < 0.0001$). *P. xylostella* infestation was significantly higher in the chemical treatment and in the control. There were no significant differences between the treatments Biobit, Neem and Biobit/Neem. The infestation of other insect pests was higher in the control and was significantly different from the other treatments. However, there was no significant difference between the other treatments (Figure 2).

Effect of treatments on agronomic parameters and yield

There were significant differences between treatments on the weight ($F_{(4,24)} = 4.19$; $P = 0.002$), the diameter ($F_{(4,24)} = 2.39$; $P = 0,049$) and the number of leaves of cabbages ($F_{(4,24)} = 3.63$; $P = 0.006$). The highest weights were recorded on the Biobit treatment and were not significantly different from Neem and the alternation Biobit/Neem. However, there were significant differences between Biobit and Dimethoate and the control. There were no significant differences between Neem, Biobit, Dimethoate and the control (Table 2).

The diameter of cabbage was higher in the Biobit treatment but was not significantly different from the Neem treatment. There were no significant differences between Neem and Biobit/Neem, Dimethoate and the control (Table 2). In terms of number of leaves, there

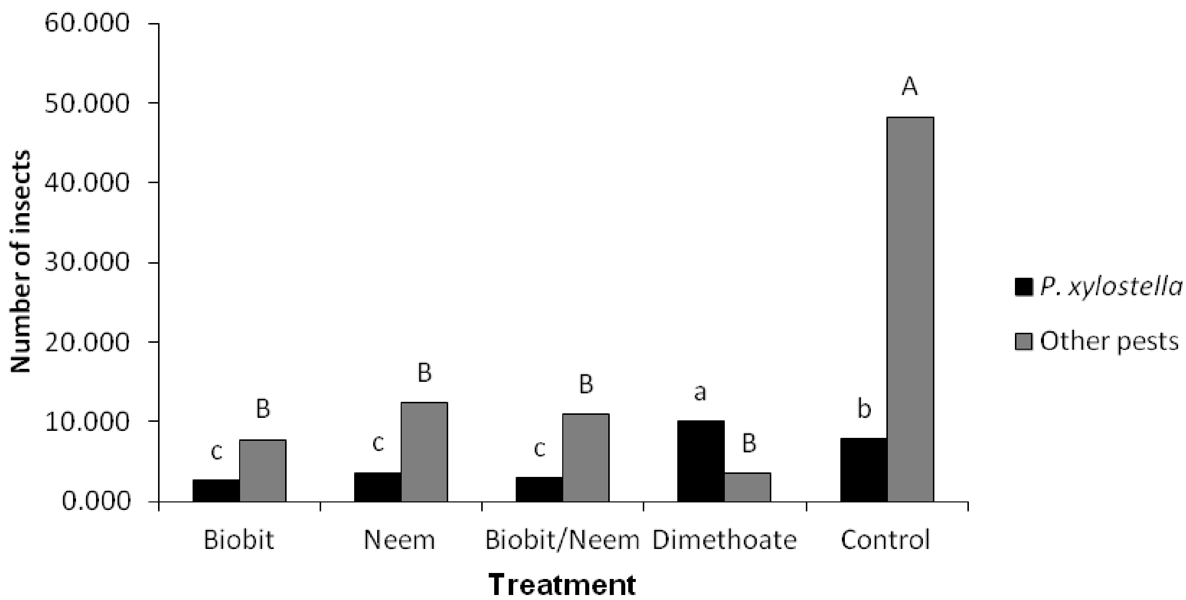

Figure 2. Infestation levels of *P. xylostella* and other pest on cabbage treated with Biobit, Biobit/Neem, Neem and Dimethoate. Means bearing the same small letters are not significantly different in ANOVA SNK. Means bearing the same capital letters are not significantly different in ANOVA SNK.

Table 2. Agronomic features of cabbage treated with Biobit, Neem, Biobit/Neem and Dimethoate.

Treatments	Weight (g)	Diameter (cm)	Number of leaves
Biobit	197.6^{a}	31.9^{a}	17.3^{b}
Neem	158.2^{ab}	30.3^{ab}	19.6^{ab}
Biobit/Neem	146.4^{ab}	29.2^{b}	18.8^{ab}
Dimethoate	119.4^{b}	30.2^{ab}	20.2^{a}
Control	118.9^{b}	30.6^{ab}	20.8^{a}

Within columns, means bearing same small letters are not significantly different in ANOVA SNK.

were no significant differences between Neem, Biobit/Neem, Dimethoate and the control. However, there were significant differences between Biobit and Dimethoate and between Biobit and the control (Table 2). The yield of cabbage was significantly different between treatments ($F_{(4,24)}$ = 177.69; P < 0.0001; Figure 3). It was significantly higher in treatment Biobit with 12.2 t/ha. There were no significant differences between alternated treatment and the treatments Biobit and Neem (P>0.05). However, the yield was significantly lower in plants treated with Dimethoate and in control; respectively yields of 7.2 t / ha and 7.1 t / ha.

Interactions between agronomic parameters and parasitoids

There was a significant relation between the agronomical characters of cabbages: weight, diameter and number of leaves and the presence of parasitoids (Table 3). The weight the diameters of cabbageheads and the number of leaves were significantly correlated to the presence of *O. sokolowski.* The presence *A. litae* was only correlated to the weight and the diameter of cabbages whereas *Cotesia plutellae* and *Brachimeria* sp. were only correlated to the weight (Table 3).

DISCUSSION

The level of pest infestation was significantly different between treatments however; *P. xylostella* infestation was not significantly different between the treatments Biobit, Neem and the alternation Biobit/Neem. Although significantly higher in the control, the level of infestation of other pests was not significantly different between Biobit, Neem, Biobit/Neem and Dimethoate. These results suggest that apart from damages caused by *P.*

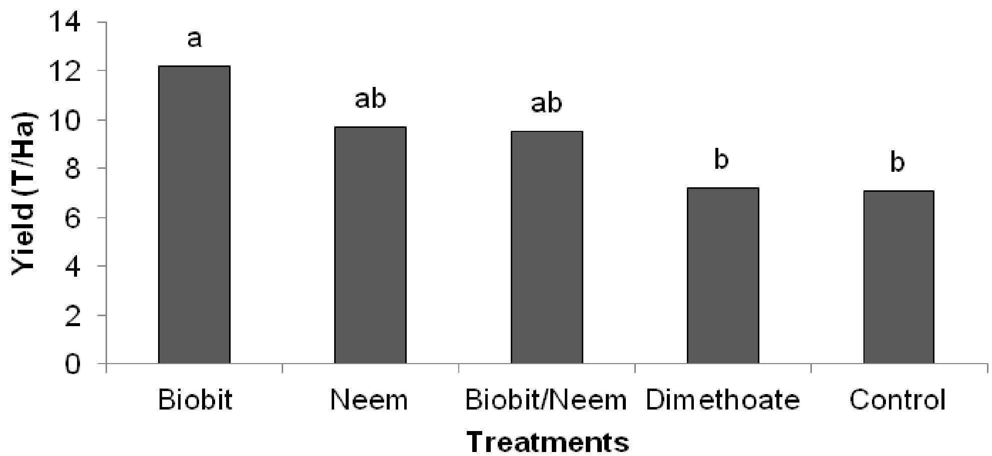

Figure 3. Effect of Biobit, Biobit/Neem, Neem and Dimethoate application on the yield. Means bearing the same letters are not significantly different in ANOVA SNK.

Table 3. Relation between agronomic features and the presence of parasitoids in cabbage plantation

Parasitoids	Weight (g)	Diameter (cm)	N. of leaves
Oomyzus skolowski	0.105*	0.137*	0.085*
Apanteles litae	0.099*	0.135*	-0.009
Cotesia plutellae	0.048*	0.043	-0.019
Brachymeria sp.	0.060*	0.036	0.020

*Significant values (except diagonal) at the level of significance alpha=0.050 (two-tailed test).

xylostella, the contribution of the other pests in the damage on cabbage is negligible.

The application of *B. thuringiensis* against DBM and other lepidopteran pests has been recommended by many authors (Lereclus et al., 1993; Kibata, 1996). *B. thuringiensis* seems to present many advantages. Although, there were no significant differences between Biobit, Neem and the alternation, the application of *B. thuringiensis* recorded the highest weights and the diameters of cabbageheads. However, there were no significant differences between Biobit, Neem and the alternation. This suggests that alternated treatment of Biobit and Neem which, is timely applied only on four occasions, could achieve similar results than solo treatment of Biobit and Neem. Similar findings have been demonstrated by many scientists (Wright, 2002; Prasad et al., 2007; Roh et al., 2007). As for the number of leaves, results showed that the control recorded the highest values. The Biobit treatment was the lowest however, not significantly different from Neem and Biobit/Neem. The importance of the number of leaves could be considered as response to challenges or stresses causes by P. xylostella damages on the plants (Ayalew, 2006). As larvae of DBM develop on cabbage leaves, they prevent physiological processes such as photosynthesis and respiration. As a response, more leaves are generated by the plant to bypass the stress (Wojciechowska and Leja, 1999; You and Yang, 2001).

The higher yield observed in the treatments plants Biobit, Neem and alternating treatment could be explained by the low infestation levels of *P. xylostella*. The use of *B. thuringiensis* based formulations can increase yields (Huang et al., 2005; Cattaneo et al., 2006; Herdt, 2006). According to the Horticulture Development Centre (HRC), the standard yield of cabbage is estimated between 10 and 20 t / ha. Yield reductions are also due to damage *Hellula undalis*. The presence of other pests in the cabbages, particularly *H. undalis* (Lep., Pyralidae) whose larvae eat the terminal bud of newly planted cabbages, thus inducing growth of the axillary buds which produce unmarketable multiple heads at harvest (Goudegnon et al., 2000). In this study, there were no significant differences between treatments on the presence of other pests. The low yields observed in the treatment with dimethoate and controls are primarily caused by the damage of *P. xylostella*. According to Ayalew (2006), the yield losses in cabbage may vary considerably depending on the levels of pest infestation. The application of *B. thuringiensis* and Neem has been regarded as less harmful to beneficials such as parasitoid wasps and natural enemies as compared to chemical pesticides (Roh et al., 2007).

Results of this study showed that, there were significant relation between the presence of parasitoids and the agronomic features. The parasitoid *O. sokolowski* and *A. litae* seem to be more contributors to the agronomic features of the cabbage which is a considerable gain to the farmer. The study revealed that as far as cabbage production is concerned, it is better to rely on biocontrol agents than to apply synthetic chemical pesticides. This could be explained by negative effects of synthetic chemicals on the complex of natural enemies and the induction of resistance to pest populations. The use of alternated treatment can therefore be an opportunity to mitigate both pest infestation and manage the apparition of resistance. It has been demonstrated that uncontrolled application of *B. thuringiensis* could be the source of resistance induction in DBM (Chilcutt and Tabashnik, 1999; Monnerat et al., 2000).

As a conclusion, cabbage is one of the most difficult crops to grow and to sell in Africa particularly in Africa; this is due to heavy physical damages that occur on the leaves and discourage costumers. On the other hand, the use of high rates of synthetic chemicals can compromise the quality of cabbages exempted from damages. The study showed that by using four timely applications of Biobit and Neem, it is possible to achieve an efficient biological control against the DBM and to produce safe cabbage crops. The technique is cost-effective and therefore can be recommended to farmers in developing countries.

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