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Effect of the insect growth regulator novaluron on diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), and its indigenous parasitoids

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Research to evaluate effective and selective insecticides through periodic screening is needed to strengthen diamondback moth (DBM) (*Plutella xylostella* L.) management. The efficacy of the insect growth regulator novaluron on DBM and effects on the parasitoids *Diadegma* sp. (Hym.: Ichneumonidae), *Apanteles* sp. (Hym.: Braconidae) and *Oomyzus sokolowskii* Kurdjumov (Hym.: Eulophidae) were evaluated. Novaluron was compared with the microbial insecticide *Bacillus thuringiensis* (*Bt*) var. *aizawai*, the pyrethroid insecticide λ- cyhalothrin and the organophosphate insecticide profenofos. Two replicated experiments were conducted on head cabbage, *Brassica oleracea* var. *capitata*, planted in March and May 2007 at Wonji in the Central Rift Valley of Ethiopia. Infestation by DBM was less with novaluron and *Bt* compared with other treatments for both planting dates. Infestation with λ-cyhalothrin and profenofos was comparable with the untreated control. Yields were greatest with novaluron and were 80 and 32.5% (12.4 and 7.4 t ha^{-1}) greater than the untreated treatment for the first and second plantings, respectively. *Diadegma* sp. accounted for 91% of the parasitoid complex observed. Parasitism of DBM by *Diadegma* sp. ranged between 10 and 43% among treatments. Parasitism was less with λ-cyhalothrin and profenofos compared with other treatments. Owing to its efficacy against DBM and relative safety to its parasitoid, *Diadegma* sp., novaluron can be used in integrated DBM management for low elevation brassica production in the Central Rift Valley of Ethiopia.

1. Introduction

The diamondback moth (DBM), *Plutella xylostella* L. (Lepidoptera: Plutellidae) is a key pest of brassicas in Ethiopia (Ayalew, 2006) and elsewhere (Talekar and Shelton, 1993). Yield loss due to DBM on head cabbage in Ethiopia was estimated to be 36–91% depending on production season (Ayalew, 2006), and DBM has been observed to cause total crop failure in the Central Rift Valley (Ayalew and Ogol, 2006). Insecticide application is common for DBM control in Ethiopia despite its inefficiency because of the insect's ability to quickly develop resistance to traditional insecticides (Chen and Sun, 1986). Efforts are being made to develop cultural and biological alternatives to control of DBM (Schroeder et al., 2000; Sarfraz et al., 2005). In Kenya, biological control of DBM using the larval endoparasitoid *Diadegma semiclausum* (Hellen) (Hymenoptera: Ichneumonidae) enabled highland brassica production without pesticide use within three years of *D. semiclausum* release (Lohr et al., 2007). *D. semiclausum* imported from Kenya and released in the Kofele highlands of Ethiopia in 2008 has established well and suppressed the pest pressure in the released site (Ayalew, unpublished results). However, no efficient parasitoid is so far available for DBM control in lowland brassica production (altitude < 1600 m above sea level). On the other hand, such areas create a favorable environment for rapid multiplication of the insect through shortening the generation time, which in turn triggers development of pesticide resistant DBM populations. Hence, chemical control in the absence of reliable alternatives will remain the major option for managing DBM and other pests in low elevation brassica production (Smith et al., 2002; Hill and Foster, 2003).

Periodic screening of new insecticides with lesser effect on natural enemies is necessary in an integrated pest management (IPM) program (Kfir, 1997; Hasseb et al., 2005). The use of selective insecticides that are not toxic to parasitoids can reduce reliance on insecticides (Cutler et al., 2006). Novaluron is a non-systemic benzoylphenyl urea insect growth regulator with very low toxicity to birds and humans (Ishaaya and Horowitz, 1998). In contrast, pyrethroids and organophosphates are non-selective broad-spectrum insecticides with high toxicity to different groups of organisms. Brassica growers in Ethiopia use older broad-spectrum insecticides (organophosphates, organochlorines and pyrethroids)

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for the control of DBM on brassicas and other insect pests of vegetables which are common among vegetable growers of several African countries (Grzywacz et al., 2010). Insect growth regulator insecticides are selective because of their narrow spectrum of activity, low mammalian toxicity, and are considered IPM compatible. Little is known of the efficacy of novaluron in DBM management and its effects on parasitoids in Ethiopia and neighboring countries. The objective of this research was to assess the efficacy of novaluron in DBM control in cabbage production. The relative safety of novaluron to locally occurring parasitoids of DBM was also assessed at the pre-heading stage (Meier, 1997) which is the critical stage of cabbage to DBM infestation in the area (Ayalew, 2006).

2. Materials and methods

2.1. Site description and experimental design

The experiment was conducted on a farmer's field at Wonji (8°27′N, 39°13′E, alt: 1536 m a.s.l.) in the Central Rift Valley of Ethiopia. The first and second experiments were planted and harvested in March and June, and April and August, respectively, of 2007. These are periods when DBM infestation of cabbage was expected to be severe (Ayalew, 2006; Ayalew et al., 2006). The experiments were spatially separate with randomized complete block designs with three replicates. Plot size was 8 rows of 6 m length with a row spacing of 50 cm and the plant spacing in the row was 30 cm. Spacing between plots within a block and between adjacent blocks were 1 and 1.5 m, respectively.

2.2. Treatments

There were six treatments including novaluron 100 g l^{-1} EC (Rimon 10 EC, Makhteshim, Beer-Sheva. Israel) applied at 0.5 l ha^{-1}, λ- cyhalothrin 50 g l^{-1} EC (Karate 5 EC, Syngenta, Brits, South Africa) applied at 0.32 l ha^{-1}, profenofos 720 g l^{-1} EC (Selecron 720 EC, Syngenta, Basel, Switzerland) applied at 0.6 l ha^{-1}, *Bacillus thuringiensis* var. *aizawai* (Xen Tari) applied at two different rates of 0.25 and 0.5 kg ha^{-1}, and the untreated control which was sprayed with water only. Treatments were applied weekly beginning about two weeks after transplanting on 11 April and 16 May until about two weeks before harvest on 6 June and 18 July for totals of 9 and 10 applications for the first and second experiment, respectively. Treatments were applied using a knapsack sprayer at 600 l ha^{-1} with a flat fan nozzle.

The precipitation, and mean daily maximum and minimum temperatures, for the months of experimentation were 313 mm, 14.3 °C and 29.3 °C (first planting), and 587 mm, 15.3 °C and 27.6 °C (second planting), respectively. The cabbage variety was Copenhagen Market. Fertilizer application consisted of a mixture of urea (50 kg ha^{-1}) and diamonium phosphate (150 kg ha^{-1}) a day before transplanting, and urea (50 kg ha^{-1}) at the early heading stage. Weed control was done by hand pulling. No other pesticides were applied throughout the experimental period. Fields were furrow irrigated twice weekly for the first three to four weeks after transplanting and weekly thereafter until maturity.

2.3. Data collection

To assess the effects of treatments on DBM density, five plants per plot were randomly sampled weekly prior to treatment application from the central rows and the number of larvae and pupae were recorded. Plot level DBM infestation was scored based on percent infested plants (1 = 0–5%, 2 = 6–20%, 3 = 21–40%, 4 = 41–60%, and 5 = >60%) at the pre-heading and heading stages (Meier, 1997). At harvest, yield data were recorded by discarding damaged outer leaves and heads of less than 4 cm diameter from the central six rows.

Treatment effects on indigenous parasitoids were assessed by collecting 5–25 immature DBM, larvae and pupae, depending on their availability from each treatment at the pre-heading stage (Meier, 1997). The procedure described in Ayalew and Ogol (2006) was followed to rear the insect and determine level of parasitism.

2.4. Statistical analysis

Analysis of variance (ANOVA) was performed on mean DBM number, damage level taken at pre-heading and heading stages of cabbage and yield. Data on DBM number and damage score were checked for normality before subjecting the data to ANOVA. Damage score values were $\sqrt{(X+1)}$ transformed. Mean and standard error values on DBM density on each sampling date of both plantings were analyzed. Significant means were separated using S–N–K test. The SAS statistical software (SAS, 1999) was used for analysis. Treatment effects and Pearson correlation coefficients were considered significant at $P < 0.05$.

3. Results

3.1. Effect on DBM density and damage

The number of DBM was highest in λ-cyhalothrin followed by profenofos and the untreated in the first planting respectively ($F = 18.76$; $df = 5,12$; $P < 0.0001$) (Table 1). In the second planting, it was highest in untreated, followed by λ-cyhalothrin and profenofos ($F = 38.98$; $df = 5,12$; $P < 0.0001$) (Table 1). The number of DBM was not significantly affected in the first planting but reduced in the second planting with profenofos compared with the untreated check and λ-cyhalothrin treatment. Novaluron was most effective in reducing DBM in both seasons. Differences between the two rates of *Bt* were not significant for DBM number or damage with the exception that DBM number was more with the *Bt* low rate in the second planting (Table 1). DBM number was consistently lower across the sampling dates in novaluron treatment than the rest in both plantings. On the other hand, high DBM number in most of the sampling dates was observed from λ-cyhalothrin, profenofos and untreated control in both plantings (Figs. 1 and 2). The damage score was significantly higher in λ-cyhalothrin, profenofos and untreated compared with the *Bt* treatments and least with novaluron (Table 1).

Table 1
Mean Diamondback moth density and its damage level at pre-heading and heading stage of head cabbage treated with different pesticide treatments for two planting dates in the central Rift Valley of Ethiopia in 2007.

Treatments	First planting			Second planting		
	DBM Number[c]	Damage[d]		DBM number	Damage	
		pre-head	head		pre-head	head
Novaluron	0.6c*	1.4c	1.4b	1.3d	1.4b	1.4b
λ-cyhalothrin	19.8a	2.4a	2.4a	16.6a	2.2a	2.3a
Profenofos	16.7a	2.3a	2.3a	12.1b	2.2a	2.3a
Bt var. *aizawai*[a]	9.6b	1.8b	1.6b	9.6b	1.6b	1.8b
Bt var. *aizawai*[b]	7.1b	1.7b	1.7b	4.9c	1.5b	1.6bc
Untreated	15.3a	2.3a	2.1a	16.7a	2.1b	2.2a

*Means in a column with same letter are not significantly different at P = 0.05 (S–N–K test).
[a] Rate of application 0.25 kg ha^{-1}.
[b] Rate of application 0.50 kg ha^{-1}.
[c] DBM number is mean value of eight samplings.
[d] Damage score values are $\sqrt{(X+1)}$ transformed.