EFFICACY OF BACILLUS THURINGIENSIS AND CABBAGE CULTIVAR RESISTANCE TO DIAMONDBACK MOTH (LEPIDOPTERA: YPONOMEUTIDAE)

PAUL W. IVEY AND SETH J. JOHNSON
Department of Entomology, Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station, Baton Rouge, LA 70803, USA

ABSTRACT

Population density estimates were used to determine the effectiveness of a commercial formulation of *Bacillus thuringiensis* Berliner subspp. *kurstaki* and *aizawai* (Agree 50 WP®) and host plant resistance in three cabbage cultivars against the diamondback moth, *Plutella xylostella* (L.). Cabbage plots treated with Agree 50 WP® had significantly fewer larvae per plant compared with untreated ones. The ranking from most to least susceptible of the three main cabbage cultivars grown in Jamaica was 'KY Cross' > 'Early Jersey' > 'Tropicana'. These findings provide evidence that a new cabbage hybrid, 'Tropicana', and products containing effective strains of *B. thuringiensis* may be successfully used for *P. xylostella* management in Jamaica.

Key Words: *P. xylostella*, Agree 50 WP®, plant resistance, Jamaica

RESUMEN

Fueron usados estimados de la densidad poblacional para determinar la efectividad de una formulación comercial de *Bacillus thuringiensis* Berliner subspp. *kurstaki* y *aizawai* (Agree 50 WP®), y la resistencia de tres cultivares de col a la polilla *Plutella xyllostella* (L.). Las parcelas de col tratadas con Agree 50 WP® tuvieron significativamente menos larvas por planta que las no tratadas. El rango de susceptibilidad en orden creciente de los tres cultivares más usados en Jamaica fue "KY Cross" > "Early Jersey" > "Tropicana". Estos hallazgos muestran que un nuevo híbrido de col, "Tropicana", y productos conteniendo cepas efectivas de *B. thuringiensis* podrían ser exitosamente usados para el manejo de *P. xylostella* en Jamaica.

Cruciferous vegetables grown in Jamaica and other Caribbean islands are susceptible to damage by many insect pests: armyworms, *Spodoptera* spp., cabbage looper, *Trichoplusia ni* (Hubner), cabbage white butterfly, *Pieris rapae* L., and diamondback moth, *Plutella xylostella* (L.). A complex of these pests occurs whenever these crops are grown for commerce, and their control is a prerequisite for meeting quality standards for damage- and pest-free produce. Populations of *P. xylostella* frequently account for 75% of the insect pest population and cause crop loss of up to 90%, making it the key insect pest from an economic standpoint (Salinas 1986, Alam 1992).

Historically, farmers have relied primarily on multiple applications of broad-spectrum insecticides for control of *P. xylostella* in Jamaica. Alam et al. (1987) recommended an action threshold of six larvae per plant at the post-transplanting stage of cabbage. Over 18 different insecticides have been used since 1972 (Walton 1989), and between 20-22 insecticide applications over a growing season are not uncommon. As a result, many insecticides from the organophosphate, carbamate, and pyrethroid groups are now ineffective because of insecticide resistance (Alam 1992, Robinson et al. 1995). Reports of low efficacy of Biotrol® and Thuricide® (products containing the *kurstaki* strain of *Bacillus thuringiensis* Berliner) in controlling *P. xylostella*, presumably due to insecticide resistance, led Alam (1992) to question their reliability. Because of pest management problems, environmental degradation, and occupational and public health risks associated with insecticides, it is imperative to find an integrated pest management (IPM) approach for *P. xylostella* management which utilizes tactics such as host plant resistance and microbial control.

The utility of host plant resistance as an insect pest management tactic is well established (Painter 1951, Lim 1992). Dickson et al. (1984, 1986) reported the release of four cabbage breeding lines possessing resistance to *P. xylostella*. Results of genetic and other studies indicated that the host plant resistance exhibited by these cabbage breeding lines was associated with the glossy dark-green leaf found in the cauliflower Plant Introduction (PI) 234599 (Dickson et al. 1990, Stoner 1990, Eigenbrode & Shelton 1992). However, *P. xylostella*-resistant cabbage cultivars are not generally commercially available. Use of microbial agents for controlling *P. xylostella* has been most successful with *B. thuringiensis*; certain strains of this bacteria are highly effective against early instars (Hofte & Whiteley 1989). Furthermore, *B. thuringiensis* is environmentally benign and non-toxic to beneficial organisms, many of which are natural enemies of *P. xylostella*. Because the *kurstaki* strain of *B. thuringiensis* is already of questionable reliability in Jamaica (Alam 1992), and field resistance in *P. xylostella* has been reported in the Philippines (Kirsch & Schmutterer 1988), Hawaii (Tabashnik et al. 1990), Malaysia (Syed 1992), mainland USA (Shelton et al. 1993), and in Central America (Perez & Shelton 1997), it is unwise for farmers to rely solely on this microbial insecticide. To thwart the development of resistance to this insecticide and preserve its longevity and effectiveness, a more integrated approach should be developed. Combining the use of *B. thuringiensis* and host plant resistance for *P. xylostella* control is plausible. A new product, Agree 50 WP® (wettable powder), containing both *kurstaki* and *aizawai* strains of *B. thuringiensis* and a new cabbage cultivar, 'Tropicana', reputed resistant to *P. xylostella*, has recently become available to farmers. Before the advent of this new cultivar, two hybrids ('KY Cross' and 'KK Cross') and an open-pollinated cultivar ('Early Jersey') were available to growers in Jamaica. In 1995, marketing of 'Tropicana' began by the leading distributor of agricultural inputs with claims of resistance to *P. xylostella*. However, the relative resistance of these cultivars to *P. xylostella*, under local conditions, has not been empirically studied. Therefore, toward achieving our long range goal of IPM of *P. xylostella*, the objective of this study was to determine the efficacy of Agree 50 WP® and evaluate the relative resistance of cabbage cultivars grown in Jamaica to *P. xylostella*.

Materials and Methods

In September 1995, a field experiment was initiated on the farm of the College of Agriculture, Science, and Education, Port Antonio, Portland, Jamaica. Three cabbage cultivars, 'Tropicana', 'Early Jersey' (Petoseed, Saticoy, CA), and 'KY Cross' (Takii Seed, Kyoto, Japan), were subjected to two different treatment regimes: Agree 50 WP® (Ciba-Geigy, Greensboro, NC) applied weekly and untreated controls. Cultivars and treatments were replicated four times in a completely randomized experimental design with a split-plot treatment arrangement. Main plots were cultivar and sub-plots were Agree 50 WP® and untreated controls. Individual plots were 2.73 m × 4.45 m and were separated by a distance of 1.52 m. Four-week-old seedlings of the three cabbage cultivars, raised in outdoor seedbeds, were planted 0.45 m apart on raised beds spaced 0.91 m apart. Standard cultivation practices for cabbage production were employed. Plots were sampled for *P. xylostella* once per week for seven weeks, between 18 November and 30 December, by counting larvae on the leaves of 10 plants in each plot. Agree 50 WP® [3.8% (AI) (25,000 IU per ml) (*B. thuringiensis* subspp. *kurstaki* and *aizawai*)], was applied to the appropriate plots once per week, at the rate of 83 g in 15 liters of water using a Solo 475 Knapsack Sprayer (Solo Incorporated, Newport News, VA). The data were subjected to analysis of variance using PROC GLM (SAS Institute 1989).

RESULTS

P. xylostella larval population density per plant was significantly affected by cabbage cultivar (F = 20.94; df = 2, 18; P = 0.0001) and insecticide treatment (F = 52; df = 1, 18; P = 0.0001). The ranking of cultivars from most to least susceptible to *P. xylostella* was 'KY Cross' > 'Early Jersey' > 'Tropicana'. Plots treated weekly with Agree 50 WP® had significantly (F = 52; df = 1, 18; P = 0.0001) fewer larvae per plant compared with untreated plots (Table 1).

The interaction between cabbage cultivar and insecticide treatment was marginally significant (F = 3.38; df = 2, 18; P = 0.0567). Further examination of this interaction was done using PROC PLOT (SAS Institute 1989). The cell means for the levels of the two factors, insecticide treatment and cabbage cultivar, as shown in Table 1, indicated that the 'Tropicana' cultivar supported fewer larvae per plant across insecticide treatments compared with the other two cultivars.

DISCUSSION

Based on larval population density estimates, the 'Tropicana' cultivar was superior to the other two cultivars in resisting attack from *P. xylostella*. To our knowledge, before this study, cabbage cultivars available to growers in Jamaica had never been evaluated under local conditions regarding their relative susceptibility to *P. xylostella*. The existence of host plant resistance to *P. xylostella* in a commercially cultivated cabbage cultivar, such as 'Tropicana', is significant because of the economic importance of this insect pest related to the intractable problem of its widespread development of resistance to conventional insecticides. Several authors have reported on breeding and the potential for using resistant cabbage cultivars for *P. xylostella* management (Dickson et al. 1984, 1986, 1990, Stoner 1990, Eigenbrode & Shelton 1992), but host plant resistance in a commercially available cabbage cultivar has hitherto not been reported.

It appears that the ability of the 'Tropicana' cabbage cultivar to resist *P. xylostella* is based on leaf texture; the epidermis of its leaves is relatively thicker, especially as plants approach the heading stage, compared with those of the other two cultivars. Importantly, there have not been any reports of complaints from consumers regarding the texture of 'Tropicana'. Because first instars of *P. xylostella* are leafminers and must tunnel into the leaf to feed, the thicker epidermis of 'Tropicana' may have been too great a challenge for the mandibles of neonate larvae. These neonates may starve to death, desiccate, drown or be washed from leaves, and be vulnerable to predators. Eigenbrode and Shelton (1992) found that neonate *P. xylostella* larvae had greater movement on resistant cabbage breeding lines than on susceptible ones. Also, Tanton (1962) found that leaf texture affects the number of nibbles and subsequent leaf area of *Brassica rapa* L. consumed by *Phaedon cochleariae* F. In addition, Iheagwam (1981) reported that penetrability of the leaf tissue of *Brassica oleraceae* L. influences the degree of exploitation by *Aleyrodes brassicae* Walker. And, Martin et al. (1975) found a negative correlation between internode hardness of *Saccharum officinarum* L. and susceptibility to attack by neonate *Diatraea saccharalis* (F.) larvae.

TABLE 1. MEAN NUMBERS (± SEM) OF *PLUTELLA XYLOSTELLA* LARVAE PER PLANT ON THREE CABBAGE CULTIVARS TREATED WITH AGREE 50 WP®.

Cultivar	No. larvae per plant		Overall cultivar means ± SEM[2]
	Agree 50 WP®	Untreated	
Tropicana	0.30 ± 0.21	1.55 ± 0.39	0.93 ± 0.31
Early Jersey	0.88 ± 0.25	4.23 ± 0.33	2.55 ± 0.66
KY Cross	2.23 ± 0.70	4.95 ± 0.40	3.59 ± 0.64
Overall treatment means ± SEM[1]	1.13 ± 0.34	3.58 ± 0.48	—

[1]Treatment means significantly different (ANOVA *F* test; α = 0.05).
[2]Cultivar means significantly different (Waller-Duncan K-ratio *t* test; α = 0.05).

Agree 50 WP® proved to be effective in controlling *P. xylostella*. This was probably due primarily to the presence of the *aizawai* strain of *B. thuringiensis*. There are differences in the crystal protein toxin profiles of *B. thuringiensis* subsp. *kurstaki* and subsp. *aizawai*; the former produces Cry IA (a), Cry IA(b), Cry IA(c), Cry IIA, and Cry IIB, whereas the latter produces Cry IA (a), Cry IA(b), Cry IC, Cry ID, and Cry IIB (Hofte & Whiteley 1989). Shelton et al. (1993) found differential responses between *P. xylostella* populations treated with two formulations containing *B. thuringiensis* subsp. *kurstaki* (Javelin WG® and Dipel 2X®) and populations treated with *B. thuringiensis* subsp. *aizawai* (ZenTari®). Commercial formulations of *B. thuringiensis* subsp. *kurstaki*, for example, Biotrol® and Thuricide®, have been used in Jamaica for many years to control *P. xylostella* but their reliability is now questionable (Alam 1992). However, formulations of *B. thuringiensis* subsp. *aizawai* have only recently begun to be more widely used. So, *P. xylostella* populations have no prior exposure to this strain of *B. thuringiensis*. In fact, *B. thuringiensis* subsp. *aizawai* was first used against *P. xylostella* in Jamaica in 1995.

The existence of a significant interaction makes it necessary to exercise caution when making statements about the main effects (cabbage cultivar and insecticide treatments), even though both were statistically significant with *P* values of 0.0001 (Freund & Wilson 1993). The consistently lower numbers of larvae on the 'Tropicana' cultivar, compared with 'Early Jersey' and 'KY Cross', across plots treated with Agree 50 WP® and in untreated plots, clearly show that the 'Tropicana' cultivar was superior to the other two cultivars in resisting *P. xylostella*. Also, from the interaction between cabbage cultivar and insecticide treatment, it can be inferred that the 'Tropicana' cultivar may be compatibly combined with use of Agree 50 WP® for successful management of *P. xylostella*.

Regarding the effect of these two control tactics on armyworms and cabbage looper, past experience has shown that tactics which are successful in controlling *P. xylostella* simultaneously also controlled armyworm and cabbage looper populations. Usually, insecticides are more effective against other insects in the crucifer pest complex than *P. xylostella*. In fact, for the duration of the study, armyworms and cabbage loopers were not encountered.

Considering the low efficacy and tenuous reliability of commercial formulations of *B. thuringiensis* subsp. *kurstaki* against *P. xylostella* in Jamaica (Alam 1992), the effectiveness of Agree 50 WP® (*B. thuringiensis* subspp. *kurstaki* and *aizawai*) seen in this study makes continued use of toxins of *B. thuringiensis* for controlling this insect a viable option, especially when combined with the 'Tropicana' cabbage cultivar. However, we do not recommend that formulations containing both the *kurstaki* and *aizawai* strains of *B. thuringiensis*, such as Agree 50 WP®, be used extensively as this may allow for the development of resistance in *P. xylostella* to the *aizawai* strain without losing its resistance to the *kurstaki* strain. It might be a better strategy to alternate both strains.

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