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A NEW SOURCE OF CABBAGE HOST PLANT RESISTSANCE TO THE DIAMONDBACK MOTH (LEPIDOPTERA: PLUTELLIDAE)

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Crucifer vegetable crops include cabbages, broccoli, cauliflower, collards, mustards and other Brassicaceae plants consumed globally. The diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae), is considered the most damaging insect pest to vegetable crucifers with an estimated annual cost of control 2 decades ago of U.S. $1 billion (Talekar & Shelton 1993).

Host plant resistance (HPR) should be the foundation for any integrated pest management (IPM) program (Naranjo et al. 2008), including one for crucifer vegetables. Previous research has shown variable susceptibility in cabbages (*Brassica oleracea* capitata group) to damage *by P. xylostella*, and a major component of this resistance has been associated with a glossy leaf-wax trait (Eigenbrode & Shelton 1990; Stoner 1990; Eigenbrode et al. 1991). However, we are unaware of any commercial insect resistant varieties that have been developed with a glossy leaf-wax trait. Another approach for HPR is the development of cabbages that express insecticidal proteins from the soil bacterium, *Bacillus thuringiensis*. Although this strategy has been successful in the research phase (Shelton et al. 2008), no commercial varieties are available. Thus, there still is a continuing need to search for insect resistant germplasm that can be bred into commercial varieties of cabbages.

Through a colleague in Hungary (Dr. J. Fail), we were informed about a non-glossy cabbage variety purportedly resistant to *P. xylsotella*, but for which we could not find any data confirming its resistance. The purportedly resistant cabbage was provided by Syngenta Seeds (Basel, CH), identified as 'White' and was developed as a cytoplasmic male sterile hybrid whose female parent was 'Izalco' and whose male parent was derived from a triple-cross. This cabbage was compared with a common cabbage cultivar grown in New York, 'Surprise' (Bejo Zaden B.V., Warmenhuizen, The Netherlands) using tests in which we compared the oviposition, development and survival of *P. xylostella* on these 2 cabbages. Because of potential differences in these insect parameters under different environmental conditions, we examined the performance under laboratory, greenhouse and outdoor conditions.

For all tests we used a strain of *P. xylostella* which has been reared in the laboratory on an artificial diet (Shelton et al.1991) in a climatic chamber at 27 ± 1C, 50 ± 10% RH, and with a photoperiod of 16:8 h (L:D). Both cabbage types were seeded into 200-cell, 4.5 cm plug trays with 1 seed per cell filled with Cornell mix soil (Boodley & Sheldrake 1977) and then grown under greenhouse conditions at 20-30°C and 20-40% RH with supplemental lights set for a period of 16:8 (L:D) h. After 6 wk in the greenhouse, plants were transplanted into 15-cm dia. pots filled with Cornell mix and used for the tests described below when the plants had 23 leaves.

In the laboratory, 5 second instar *P. xylostella* were introduced into a plastic cup (300 ml) and provided with fresh leaves on a regular basis from one or the other cabbage type until pupation. Upon pupation, each individual was transferred into a 30-mL plastic cup. Larval period, pupation rate, pupal weight, pupal period and emergence rate were observed and recorded daily. There were 12 replicates of each treatment.

In the greenhouse and under the conditions previously noted, 5 cabbages of both types were placed in a wood-frame cage, and 30 second instars were introduced onto each plant, and their development was followed on a daily basis. Upon pupation, individuals were collected and transferred into a 30-mL plastic cup. After emergence, 15 pairs of male and female *P. xylostella* from both treatments were mated in 473-mL styrofoam containers supplied with a 10% sugar solution. For both cabbage types, larval period, pupation rate, pupal weight, pupal period and emergence rate were recorded daily. Additionally, oviposition over the first 5 d was recorded on fresh plants of the same cultivar at the same age.

In addition to the laboratory and greenhouse trials, 6 cabbages of each type were placed outdoors in the fall of 2010. When cabbages had 23 leaves, 30 second instars were introduced onto each plant and development was followed on a daily basis as in the laboratory and greenhouse tests. Upon pupation, individuals were collected as in the greenhouse test and oviposition was assessed.

In addition to the 3 trials in which second instars were placed on the plants and their development was followed, we also assessed if there was any difference in ovipositional preference between the 2 cabbages. Oviposition choice was as-

TABLE 1. GROWTH AND DEVELOPMENT OF *PLUTELLA XYLOSTELLA* ON CABBAGES IN THE LABORATORY, GREENHOUSE AND OUTDOORS. SECOND INSTAR *P. XYLOSTELLA* WERE PLACED ON CABBAGES WITH 23 LEAVES. NORMAL CABBAGE ('SURPRISE'); RESISTANT CABBAGE ('WHITE'). MEANS (±SE) MARKED WITH SAME LETTERS ARE NOT SIGNIFICANTLY DIFFERENT BETWEEN CABBAGE TYPES, T TEST (T > 0.05).

Treatments	Larval period (days)	Pupation rate (%)	Pupal weight (mg)	Pupal period (days)	Emergence rate (%)	Fecundity (eggs / adult)
Laboratory (n = 12)						
'Surprise'	9.7 ± 0.16 a	81.5 ± 5.75 a	4.5 ± 13 a	3.7 ± 0.12 a	64.6 ± 6.01 a	—
'White'	12.4 ± 0.18 b	15.0 ± 6.09 b	3.5 ± 0.17 b	3.4 ± 0.24 a	15.0 ± 6.09 b	—
Greenhouse (n = 5)						
'Surprise'	12.9 ± 0.21 a	60.0 ± 7.23 a	5.2 ± 0.12 a	3.1 ± 0.11 a	50.0 ± 6.41 a	153.9 ± 11.63 a
'White'	15.9 ± 0.38 b	18.0 ± 11.48 b	5.0 ± 0.25 a	3.2 ± 0.26 a	14.0 ± 9.27 b	92.7 ± 14.24 b
Outdoor (n = 6)						
'Surprise'	24.2 ± 0.21 a	45.6 ± 6.81 a	6.1 ± 0.15 a	3.1 ± 0.10 a	36.7 ± 5.83 a	205.5 ± 14.99 a
'White'	24.8 ± 0.42 a	12.2 ± 4.99 b	4.7 ± 0.17 b	3.3 ± 0.25 a	10.0 ± 4.47 b	136.0 ± 22.31 b

sessed as described by Liu et al. (2002). Briefly, 1 cabbage of each type was placed in a 1 m^3 cage and 2 male and 2 female newly emerged *P. xylostella* adults were introduced into each cage and allowed to mate and lay eggs for 48 h. The number of eggs laid on both plants was recorded. This experiment was replicated 4 times.

Data on larval period, pupation rate, pupal weight, pupal period, emergence rate and fecundity, and ovipositon choice bioassays were analyzed using a Student's t-test. Statistical calculations were preformed with SAS version 9.1 package (SAS Institute 2001). For all tests, $\alpha < 0.05$.

In 5 of 6 comparisons, 'White' cabbage significantly prolonged the larval period and reduced pupation rate when compared with 'Surprise' cabbage (Table 1). Most importantly, the emergence rate on 'Surprise' cabbage was always significantly higher (>3.5-fold) than on 'White'. Under greenhouse and outdoor conditions, the number of eggs laid by *P. xylostella* reared on 'Surprise' cabbage was significantly higher (>50%) than the number of *P. xylostella* reared on 'White' cabbage. When given a choice between ovipositing on either cabbage type, females laid >10-fold fewer eggs per plant on 'White' cabbage (7.3 ± 2.50) than on 'Surprise' cabbage (97.8 ± 18.72) (P = 0.003). These data suggest that 'White' cabbage has 2 types of resistance: an antibiosis factor that retards larval development and a non-preference factor that decreases oviposition. The actual mechanism(s) for each, and whether they are linked or independent, requires further research.

SUMMARY

Laboratory, greenhouse and outdoors studies indicated that a cabbage provided by Syngenta Seeds (Basel, CH), identified as 'White' which was developed as a cytoplasmic male sterile hybrid whose female parent was 'Izalco' and whose male parent was derived from a triple-cross, was highly resistant to *P. xylostella*. This resistance does not appear to be related to any glossy leaf characteristic nor genetic engineering with *B. thuringiensis,* and thus may represent a novel source of resistance to *P. xylostella*. This cabbage should be evaluated further for resistance to other pests.

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