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Parasitism of Hessian Fly, *Mayetiola destructor* (Diptera: Cecidomyiidae) on Resistant Wheats by *Platygaster hiemalis* (Hymenoptera: Platygasteridae)

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ABSTRACT

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Laboratory studies were conducted to determine the effects of three wheat cultivars, "Knox 62", "Caldwell" and "Monon", on the Hessian fly *Mayetiola destructor* (Say) and its parasitoid *Platygaster hiemalis* Forbes. The number of Hessian flies that survived from egg to flaxseed stage, the number of Hessian flies parasitized by *P. hiemalis*, and the average number of parasitoids produced within each parasitized pupa were used to determine the cultivar and the interaction effects on the Hessian fly as well as on the parasitoid. The fewest Hessian fly survived, and the smallest parasitism was found on Knox 62 and were significantly different from those on other cultivars. Results showed that a cultivar with highly antibiosis against the Hessian fly could also reduce the effectiveness of this parasitoid. However, resistant cultivars and parasitoid complemented each other in reducing the numbers of the Hessian fly.

(Key words: Hessian fly, resistance, parasitoid, interaction, wheat)

INTRODUCTION

Plant resistance and biological control of insect pests are two major control methods that can be compatible with each other(1). However, this assumption should be carefully examined because the interactions between plant resistance and biological control agents are poorly understood(5). Many authors have reported that resistant cultivars adversely affected the activities of natural enemies(9,13,15). Therefore, more data are necessary to test this concept of compatibility between plant resistance and biological control.

Before resistant wheat cultivars were used widely to control the Hessian fly, sixteen parasitoid species were studied regarding their relative abundance to field populations of the Hessian fly(6,7). These parasitoids parasitized 62% of the Hessian fly in the eastern U.S.(8) and 74% of those in the north-central states(7). Among these sixteen parasitoids, the egg-larval parasitoid, *Platygaster hiemalis* Forbes, is reportedly the most important and effective in North America, and it is the only parasitoid that attacks the fall generation of the fly(3).

Although the biology of *P. hiemalis* has been documented, nothing is known about the effectiveness and compatibility of this parasitoid with wheat cultivar that having genes for the antibiosis mechanism of resistance. Because the parasitoid develops within its developing host, presumably the antibiotic effect of resistant wheat on the Hessian fly also affect the parasitoid.

The objectives of this study were to determine the impact of wheat cultivars carrying different genes for Hessian fly resistance on the parasitoid *P. hiemalis,* and to determine how the combination of plant resistance and parasitoids affect the Hessian fly.

MATERIALS AND METHODS

Biotype M of the Hessian fly which had been selected and maintained over 10 generations in the laboratory was used in this study. This biotype is capable of stunting wheats carrying the H3 gene but not those carrying the H6 gene, based on the definition of this biotype(4). Three wheat cultivars, 'Monon', 'Caldwell' and 'Knox 62', were used. Monon, having the H3 gene for resistance, was the susceptible host plant, and Caldwell and Knox 62 which both have the H6 gene for resistance were the resistant cultivars. The *P. hiemalis* parasitoid used in this experiment was collected in Branch county, Michigan and reared in the USDA-ARS Insect and Weed Control Research Unit laboratories at Purdue University for several generations.

The experiment consisted of six treatments which were divided as nonparasitized and parasitized groups. The nonparasitized groups were plants of Monon, Caldwell, and Knox 62 infested with biotype M only, and the parasitized groups were infested with biotype M plus *P. hiemalis.* Each treatment consisted of 10 plants in a 10 cm diam pot, with 9 replications.

Initially, all six treatments were infested with one mated female Hessian fly of biotype M for two days. Then the three parasitized groups were exposed to an adult female *P. hiemalis* for an additional two days. Each pot was covered tightly with a transparent plastic cage ca. 16 cm high. The top of the cage was vented with a 6 cm hole and was covered with fine plastic screen cloth, and a 3 cm diam hole was opened in the middle of its wall for placing the Hessian fly or the parasitoid into the cage during the infestation. A sponge ball was used to prevent the Hessian fly or the parasitoid from escaping. All experiments were conducted in a controlled environment chamber maintained at 20 ± 1 ℃, and 14 : 10 (L : D) photoperiod.

One week after infestation with the flies, the number of eggs laid and the number that hatched in each pot were determined. Three weeks after infestation, each plant was dissected under a binocular microscope, and the following observations were recorded: plant phenotypic reaction to Hessian fly infestation (resistant or susceptible), the number of matured larvae and the number of dead ones in each plant, the number of Hessian flies emerged, the number of mature larvae parasitized, the size of the parasitized larvae, and the average number of *P. hiemalis* emerged per parasitized larva. Data were analyzed by the PROC ANOVA program in the Statistical Analysis System(14)

RESULTS

The mean percentage of mature larvae that developed from the three wheat cultivars differed significantly from each other (Table 1). The Monon cultivar, with the H3 gene, was susceptible to the biotype M and, as expected, had the highest percentage of progeny developed to the flaxseed stage. By comparison, Knox 62 wheat with the H6 gene was resistant and allowed significantly fewest larvae to survive. Caldwell wheat reacted intermediately to the infestation of this biotype among cultivars. Significantly more larvae survived on Caldwell than Knox 62 but fewer than on Monon.

The impact of the wheat cultivars with different genes for resistance on the parasitoid was shown in Table 1. The percentage of the mature larvae parasitized by *P. hiemalis* differed significantly among cultivars. *P. hiemalis* parasitized significantly fewer biotype M larvae on Knox 62 wheat than on Caldwell and Monon. Percentage of larvae parasitized was significantly lower on Caldwell than those on Monon.

Table 1. Mean percentage of Hessian fly larvae developed and parasitized by *P. hiemalis* on three wheat cultivars

Cultivar	Gene for resistance	Total no. of eggs oviposited	Mean % of larvae ± S.E.	
			developed	parasitized
Monon	H3	1199	90.5 ± 4.1 a[1)]	73.3 ± 7.6 a
Caldwell	H6	706	33.1 ± 7.2 b	27.5 ± 7.7 b
Knox 62	H6	1226	13.7 ± 4.9 c	8.7 ± 2.1 c

1) Means in each column followed by the same letter are not significantly different ($P<0.01$).

The size of the mature larvae that developed on each cultivar differed significantly among cultivars (Table 2). The larvae on Monon wheat were larger than those on Knox 62 and Caldwell in both the nonparasitized and parasitized treatments. There was no effect of the treatment on the size of the mature larvae that developed on each cultivar. The mean number of *P. hiemalis* that emerged per parasitized larva was not significantly different among cultivars (Table 2).

The combined effect of the wheat cultivars and parasitoid on the percentage of Hessian flies that survived to the mature larvae varied with cultivar (Table 3). Caldwell plus *P. hiemalis* allowed the fewest biotype M that survived to mature larvae. The effect of the parasitoid was significant when it combined with the Caldwell and Monon cultivars. The parasitoid significantly reduced the survival rate of biotype M that infested the susceptible Monon.

Table 2. Mean size of Hessian fly larvae and the mean number of *P. hiemalis* emerged per parasitized larva of Hessian fly

Cultivar	Gene for resistance	Mean size(mm) ± S.E.		No. parasitoid emerged/larva
		Non-parasitized	Parasitized	Mean ± S.E.
Monon	H3	3.33 ± 0.04 a[1)]	3.36 ± 0.08 a	4.78 ± 0.33 a
Caldwell	H6	3.07 ± 0.04 b	2.98 ± 0.06 b	4.09 ± 0.25 a
Knox 62	H6	2.84 ± 0.09 b	2.92 ± 0.15 b	4.08 ± 0.63 a

1) Means in each column followed by the same letter are not significantly different (P<0.01).

Table 3. Mean survival rate of Hessian fly in different treatments of wheat cultivar with or without *P. hiemalis*

Cultivar	Gene for Resistance	Mean % survival ± S.E.	
		Non-parasitized	Parasitized
Monon	H3	96.3 ± 1.0 a[1)]	15.5 ± 5.5 c
Caldwell	H6	44.5 ± 6.0 b	2.5 ± 1.2 d
Knox 62	H6	8.6 ± 2.3 cd	5.8 ± 3.5 cd

1) Means followed by the same letter are not significantly different (P<0.01).

DISCUSSION

The resistance of Caldwell and Knox 62 expectedly affected the number and the survival rate of the Hessian fly (Tables 1 and 3). These results were expected because both cultivars carry the H6 gene are resistant to biotype M, whereas Monon carries the H3 gene should be susceptible. The resistance of these cultivars decreased the rate of parasitism by *P. hiemalis* (Table 1). This was presumably caused by the antibiotic effect of these resistant wheat cultivars on the first instar larvae of the Hessian fly, not the parasitism. The antibiotic effect of resistant plants on parasitoids have been reported by several authors. Campbell and Duffey(2) found the α-tomatine in the resistant tomato is toxic to *Hyposoter exiguae,* a parasitoid of *Heliothis zea.* Yanes and Boethel(16) reported that the emergence of *Microplitis demolitor,* an exotic parasitoid of the soybean looper, was decreased when its host fed on resistant soybean. Results of this study therefore showed that the resistant plant could impact the effectiveness of natural enemies by modifying the population or physiology of their prey(12).

Our study supports the concept that plant resistance and biological control are compatible with each another in reducing the total number of Hessian flies (Table 3). Similar results have been found on the interaction of resistant barley and sorghum and the parasitoids on greenbug(15), on the oat plant resistance and parasitism by *Aphelinus asychis* against cereal aphids(10), and on the effects of resistant soybeans and lima beans and parasitoid on the Mexican bean beetle(9).

Results from this study showed that the interaction between resistant wheat and parasitism by *P. hiemalis* varied with the level of cultivar resistance in wheat. Compatibility was particularly higher on Caldwell than on Knox 62 which has the highest level of resistance to Hessian fly in this experiment. Kauffman and Flanders$^{(9)}$ suggested that the potential of a parasitoid to suppress Mexican bean beetle populations increases with the level of cultivar resistance. Their different conclusion is understandable and presumbly due to different species of parasitoids and crops. The parasitoid they studied attacks larvae of the Mexican bean beetle, whereas *P. hiemalis* parasitizes the eggs of the Hessian fly. Bean cultivars with higher levels of resistance may have an adverse effect on the mobility of the Mexican bean beetle, thus resulting in higher parasitism. On the other hand, higher levels of resistance in wheat may kill the larvae of the Hessian fly as well as *P. hiemalis*. As a result, compatibility with the parasitoid was lower in wheat with higher levels of resistance.

Caldwell plus *P. hiemalis* showed the best combination for the control of biotype M in this study because it allowed the fewest flies to survive. One of the reasons is presumably because Caldwell, carries the H6 gene for resistance, is lower than that of Knox 62. Knox 62 is reported to carry the H6 gene and another genetic factor of the Seneca type of resistance$^{(17)}$. Consequently, a higher percentage of the biotype M flies survived on Caldwell, and a higher percentage of larvae parasitized by *P. hiemalis*.

Results also show that this parasitoid can serve as a major factor for reducing the total numbers of Hessian flies on susceptible cultivars. *P. hiemalis* caused about 80% mortality of the Hessian fly on Monon. However, the effectiveness of its parasitism decreases as the number of gene for Hessian fly resistance in the cultivar increases.

Currently, control of the Hessian fly depends primarily on the use of resistant cultivars. However, the evidence also shows that the release of highly resistant cultivars results in the development of virulent biotypes because of the selection pressure of resistant wheats. Also, highly resistant cultivars are incompatible with the parasitoid based on the results of this experiment. Fortunately, not every wheat cultivar will cause these problems. Recently, Maas et al.$^{(11)}$ reported that wheat cultivars with the Marquillo type of resistance are unlikely to induce virulent biotypes because this type of resistance would break down at high temperature, thus allowing avirulent flies to survive; which in turn to slow the rate of change in population virulence. Therefore, wheat cultivars with this type of resistance are presumably compatible with the parasitoids and may be desirable in the integrated management of the Hessian fly.

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LITERATURE CITED

1. Adkisson, P. L. and Dyck, V. A. 1980. Resistant varieties in pest management strategies. *in* Breeding Plants Resistant to Insects. F. G. Maxwell and P. R. Jennings, eds., p.233-252. John Wiley, New York.
2. Campbell, B. C. and Duffey, S. S. 1979. Tomatine and parasitic wasps: Potential incompatibility of plant antibiosis with biological control. Science 205:700-702.
3. Gahan, A. B. 1933. The serphoid and chalcidoid parasites of the Hessian fly. USDA Misc. Publ. 174, 148pp.
4. Gallun, R. L. 1977. Genetic basis of Hessian fly epidemics. Ann. N. Y. Acad. Sci. 287:223-229.
5. Herzog, D. C. and Funderburk, J. E. 1984. Plant resistance and cultural practice in-

teractions with biological control. *In* Biological Control in Agricultural IPM System. Hoy, M. A. and D. C. Herzog, eds., p.67-88. Acad. Press, New York.

6. Hill, C. C. 1926. *Platygaster hiemalis* Forbes, a parasite of the Hessian fly. Jour. Agr. Res. 32:261-275.
7. Hill, C. C. 1953. Parasites of the Hessian fly in the north central states. USDA Circular No. 923, 15pp.
8. Hill, C. C. and Smith, H. D. 1928. Status of the parasites of the Hessian fly, *Phytophaga destructor* (Say), in Pennsylvania, Maryland, and Virginia. Jour. Agr. Res. 36:151-155.
9. Kauffman, W. C. and Flanders, R. V. 1985. Effects of variably resistant soybean and lima bean cultivars on *Pediobius foveolatus* (Hymenoptera: Eulophidae), a parasitoid of the Mexican bean beetle, *Epilachna varivestis* (Coleoptera: Coccinellidae). Environ. Entomol. 14:678-682.
10. Kuo, H. L. 1986. Resistance of oats to cereal aphids: effects on parasitism by *Aphilinus asychis* (Walker). *in* Interactions of Plant Resistance and Parasitoids and Predators of Insects. D. J. Boethel and R. D. Eikenbary, eds., p.125-137. Halsted press, New York.
11. Maas, F. B., Patterson, F. L., Foster, J. E. and Hatchett, J. H. 1987. Expression and inheritance of resistance of 'Marquillo' wheat to Hessian fly biotype D. Crop Sci. 27:49-52.
12. Painter, R. L. 1951. Insect Resistance in Crop Plants. MacMillan, New York 520pp.
13. Rabb, R. L. and Bradley, J. R. 1968. The influence of Host plants on parasitism of eggs of the tobacco hornworm. J. Econ. Entomol. 61:1249-1252.
14. SAS Institute Inc. 1982. User's Guide: Statistics. SAS Inst. Inc., Cary, NC.
15. Starks, K. T., Muniappan, R. and Eikenbary, R. 1972. Interaction between plant resistance and parasitism against the greenbug on barley and sorghum. Ann. Entomol. Soc. Amer. 65:650-655.
16. Yanes, J. and Boethel, D. J. 1983. Effect of a resistant soybean genotype on the development of the soybean looper (Lepidoptera: Noctuidae) and an introduced parasitoid, *Microplitis demolitor* Wilkinson (Hymenoptera: Braconidae). Environ. Entomol. 12:1270-1274.
17. Woottipreecha, S. 1971. Studies of genetic synthesis of new races of Hessian fly, *Mayetiola destructor* (Say). Ph. D. thesis, Purdue University. 187pp.

摘要

陳炳輝、J. E. Foster 1990 ***Platygaster hiemalis* Forbes在抗性小麥品種對癭蚊之寄生** 植保會刊 32:317~322.（1.台灣省農業試驗所應用動物系，2.前美國農部研究主持人兼普渡大學教授，現任美國內布拉斯加大學昆蟲系教授兼系主任）

室內測定Knox 62、Caldwell及Monon三種小麥品種與寄生蜂 *Platygaster hiemalis* Forbes 及二者之交感作用對小麥癭蚊存活數、被寄生數及自被寄生癭蚊蛹羽化之 *P. hiemalis* 蜂數等之影響，結果顯示Knox 62品種上，癭蚊之存活率與被寄生率均最低且與其他品種者差異顯著，此說明具高度抗生作用之小麥品種可減低癭蚊密度但亦能影響該種蜂之寄生效果，雖然如此，一般而言，抗蟲小麥品種與 *P. hiemalis* 寄生蜂二者可相輔相成，合力降低小麥癭蚊之族群密度。

（關鍵字：小麥癭蚊、抗性、寄生蜂、交互作用、小麥）