INFLUENCE OF THREE SOYBEAN GENOTYPES ON DEVELOPMENT OF *VORIA RURALIS* (DIPTERA: TACHINIDAE) AND ON FOLIAGE CONSUMPTION BY ITS HOST, THE SOYBEAN LOOPER (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

Foliage consumption of three soybean genotypes ('Davis', D75-10230 and ED73-371) by nonparasitized soybean looper (SBL), *Pseudoplusia includens* (Walker) (Lepidoptera: Noctuidae), larvae and those parasitized by a South American strain of the tachinid, *Voria ruralis* Fallen, was investigated under laboratory conditions. Although there were no significant ($p>0.05$) differences among genotypes, parasitized and nonparasitized SBL larvae reared on the commercial cultivar Davis consumed slightly more foliage than those reared on either breeding line D75-10230 or ED73-371, but larvae reared on ED73-371 consumed the least amount of foliage. Parasitized SBL larvae consumed significantly ($p\leq0.05$) less (ca. 40%) foliage than nonparasitized larvae, regardless of the soybean genotype. Mortality of parasitized SBL larvae (before the successful development of *V. ruralis*) was greatest (90%) on ED73-371 and least (37%) on D75-10230. The mean number of parasitoid puparia per SBL larva was significantly ($p\leq0.05$) less when larvae were reared on ED73-371.

RESUMEN

Se investigó bajo condiciones de laboratorio, el consumo de follaje de 3 genotipos de frijol de soya ('Davis', D 75-10230, y ED 73-371) por gusanos no parasitados de *Pseudoplusia includens* (Walker) (Lepidoptera: Noctuidae) y por gusanos parasitados por una raza sudamericana del tachínido, *Voria ruralis* Fallen. Aunque las diferencias no fueron significantes ($P>0.05$) entre los genotipos, larvas parasitadas y no parasitadas criadas en la variedad comercial Davis, consumieron ligeramente más follaje que aquellas criadas en D 75-10230 o ED 73-371, pero las larvas criadas en Ed 371 consumieron la cantidad menor de follaje. Larvas parasitadas de *P. includens* consumieron significativamente ($P\leq0.05$) menos (aprox. 40%) follaje que larvas no parasitadas, sin tener nada que ver el genotipo del frijol de soya. La mortalidad de las larvas parasitadas de *P. includens* (antes del desarrollo exitoso de *V. ruralis*) fue mayor (90%) en ED 73-371, y menor (37%) en D 75-10230. El número promedio de pupas del parasitoide por larvas de *P. includens*, fue significativamente ($P\leq0.05$) menor cuando las larvas se criaron en ED 73-371.

The use of resistant host plants is often a major management tactic for reducing populations of plant-feeding insects (Beck and Maxwell 1976, Maxwell and Jennings 1980, Painter 1951). It has been speculated (Glass 1975, Maxwell et al. 1972) that resistant varieties may enhance natural control organisms, and Bergman and Tingey (1979)

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presented a discussion of possible interactions between plant genotypes and biological control. Salto et al. (1983) reported that the use of resistant varieties and biological control using the parasitoid *Lysiphlebus testaceipes* (Cresson) (Hymenoptera: Braconidae) could be compatible components in pest management of the greenbug, *Schizaphis graminum* (Rondani) (Homoptera: Aphididae), in oats. Insects that feed on resistant soybean plants generally require more time for development; subsequently, these insects would be exposed to natural enemies for a longer period of time (Turnipseed and Sullivan 1976).

Resistance to several injurious noctuid pests of soybean, including corn earworm, *Heliothis zea* (Boddie); soybean looper (SBL), *Pseudoplusia includens* (Walker); green cloverworm, *Plathypena scabra* (F.); tobacco budworm, *H. virescens* (F.); and velvetbean caterpillar, *Anticarsia gemmatalis* Hübner, has been identified (Estes 1982, Hatchett et al. 1976, Schillinger 1976). In addition, van Duyn et al. (1971) and Kogan (1972) reported soybean resistance to the Mexican bean beetle, *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae).

The impact of resistant soybean genotypes on populations of parasitoid species is relatively unknown. McCutcheon and Turnipseed (1981) reported that soybean genotype (insect-resistant and susceptible soybean) had no effect on the incidence of parasitism of lepidopteran larvae, although the numbers of parasitized larvae collected from the various genotypes were low and variable.

An understanding of the relationship between insect pests that feed on resistant genotypes and the effect this may have on developing parasitoids within them is important in assessing the possible utilization of parasitoids and resistant genotypes together in an integrated pest management program. The influence of several resistant soybean genotypes on the development of *Microplitis croceipes* (Cresson) (Hymenoptera: Braconidae) and *M. demolitor* Wilkinson, and the effect of parasitization by these *Microplitis* spp. on foliage consumption by their hosts, have been reported recently (Powell and Lambert 1984, Yanes and Boethel 1983). If resistant host plants are to be integrated into a program which also incorporates the use of parasitoids or predators, it is important to know whether the combined action of these tactics is complementary or antagonistic.

The objectives of our laboratory study were to determine: 1) the influence of parasitization by a South American strain of *Voria ruralis* Fallen (Diptera: Tachinidae) on foliage consumption by SBL larvae reared on foliage of three soybean genotypes, and 2) the effect of each genotype on development of *V. ruralis*.

Materials and Methods

A South American strain of *V. ruralis* was collected by G. R. Carner, S. G. Turnipseed, W. C. Yearian and D. Tebeest in Uruguay and Argentina in Jan. and Feb. 1980, and imported into the United States. A laboratory colony was established from these importations, and parasitoid and host colonies were maintained as described by Grant and Shepard (1983). SBL larvae used in this study were held in a rearing chamber at 27±2°C, 60±10% RH, and a photoperiod of L:D 15:9.

The three soybean genotypes used in this study were the commercial cultivar "Davis" (maturity group VI), and breeding lines D75-10230 (10230) and ED73-371 (371) (both in maturity group VII). Davis is susceptible to damage by SBL larvae whereas Estes (1982) reported that 371 and 10230 exhibited moderate levels of antibiosis to SBL, causing an increase in larval mortality and development time, and a reduction in larval weight.

Foliage of each genotype was removed as needed from the upper one-third of field-grown soybean plants (R2 to R4) (Fehr et al. 1971) and placed in a separate plastic container (12 X 16 X 6-cm) lined with moistened paper towels. Plants were grown under the same agronomic conditions and foliage of the same age group was used for each genotype. Foliage was kept fresh in these closed containers and used within 3 h of excision. SBL eggs were obtained from a stock laboratory colony and collectively held in a 200-ml glass container. Immediately after eclosion, ca. 400 first-instar SBL were placed in each of the three containers and reared on foliage of the same genotype throughout their larval life. Leaves and containers were changed as necessary.

Thirty SBL larvae (late-third or early-fourth-instar) were randomly chosen from those which had been fed foliage of each genotype. Parasitization was accomplished by placing two larvae and two or three *V. ruralis* females in a 150-ml plastic cylindrical container (7.5-cm-diam, 4.5.-cm-ht) for ca. 30 min. Earlier observations revealed that this ratio of parasitoids to diet-reared hosts resulted in ca. 2-3 eggs per host and did not cause mortality of parasitized larvae due to superparasitism. After this time, larvae were removed and singly placed in individual petri dishes (100 x 15 mm) containing foliage of the respective genotypes. Moistened filter paper was placed in the bottom of each petri dish to prevent desiccation of the foliage. For comparison, an additional 30 SBL larvae (late-third or early-fourth-instar) were randomly chosen from those fed foliage of each genotype. These larvae (hereafter referred to as nonparasitized larvae) were not exposed to *V. ruralis* and were placed in individual petri dishes containing foliage of the respective genotype and held as previously described.

Surface area of each leaflet was measured every 2 or 3 d with a Licor Model LI-3000® portable area meter (Lambda Instr. Co.), and replaced with additional foliage of the same genotype. This procedure was continued until host larvae died or nonparasitized larvae pupated. Parasitoid development and survival were monitored daily, and parasitoid puparia were weighed 2 or 3 d after pupation.

To correct for shrinkage or expansion of foliage, 10 leaflets of each genotype were individually held in petri dishes in the same manner except that no larvae were placed on them. These leaflets also were removed, remeasured, and replaced with fresh leaflets every 2 or 3 d.

Data were analyzed by an analysis of variance procedure ($p \leq 0.05$), and by Duncan's multiple range test for mean separation at the 0.05 level of significance.

Results and Discussion

Mean foliage consumption per nonparasitized larva was not significantly different among the three soybean genotypes. However, nonparasitized SBL larvae reared on foliage of Davis soybean consumed slightly more foliage than those reared on either 10230 or 371, whereas larvae reared on 371 consumed the least amount of foliage (Table 1). Mean foliage consumption per nonparasitized SBL larva ranged from 76.12 to 82.38 cm^2. These results closely approximated those of Reid and Greene (1973) who reported that SBL larvae reared on "Bragg" soybean consumed 81.96 cm^2 of foliage with ca. 97% of this foliage consumed during the last three larval stadia. King (1981) reported that total foliage consumption of Bragg soybean per SBL larva was 68.65 cm^2.

Parasitized SBL larvae consumed less 371 foliage than foliage of 10230 or Davis, although the average foliage consumption per parasitized larva was not significantly different among genotypes (Table 1). SBL larvae parasitized by South American *V. ruralis* consumed significantly less (ca. 40%) foliage than nonparasitized larvae, regardless of the soybean genotype. Soo Hoo and Seay (1972) reported that fourth- and fifth-instar cabbage looper, *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), parasitized by an indigenous *V. ruralis* produced only 56.3% of the frass of a nonparasitized larva when fed "Romaine" lettuce. They interpreted this as a 43.7% reduction in feeding by parasitized larvae.

Estes (1982) reported that 10230 and 371 were somewhat resistant to SBL as indicated by mortality (56 and 48%, respectively) of first-instar SBL after 2 d when reared on foliage (V9 to V10) of those genotypes. Our data indicated that mortality of nonparasitized SBL larvae reared on foliage of the three genotypes differed only slightly, ranging from ca. 27 to 37%. It should be emphasized, however, that for purpose of our study, we selected late-third or early-fourth-instar SBL which had successfully developed on foliage of these genotypes.

Mortality of parasitized SBL larvae (before the successful development of *V. ruralis*) was greatest (90%) when larvae were reared on 371 and least (37%) when reared on 10230 (Table 1). Early mortality of parasitized larvae reared on foliage of 371 was ca. 2.5 times greater than mortality of nonparasitized larvae reared on 371. Apparently, host mortality was enhanced due to the combined effects of the resistant genotype 371 and the presence of developing parasitoids. No similar negative interaction was detected between the developing parasitoid and host larvae when larvae were fed foliage of 10230; early mortality of parasitized larvae was only slightly greater (ca. 10%) than that of nonparasitized larvae.

Mean number of parasitoid puparia which developed on SBL larvae reared on Davis or 10230 was significantly greater than those on larvae reared on 371 (Table 2). Approximately 57% of the parasitized SBL larvae reared on 10230 yielded *V. ruralis* puparia. In addition, these parasitized larvae yielded an average of 2.35 puparia per host. Although only ca. 23% of those larvae reared on foliage of Davis soybean yielded *V. ruralis* puparia, they produced the highest average number of parasitoid puparia (2.71 puparia per host). This high average number of puparia per host when reared on Davis suggests possible high rates of superparasitism, and may have been responsible for the increase in mortality of parasitized larvae reared on this genotype (Table 1). Only ca. 7% of the parasitized larvae reared on 371 yielded parasitoid puparia, and these larvae produced the lowest number of puparia (1.5 per host).

Development of *V. ruralis*, as reflected by puparial weight, was apparently enhanced when host larvae were reared on foliage of 10230. Parasitoid puparia which developed on SBL larvae reared on 10230 were significantly heavier than those which developed on larvae reared on either 371 or Davis, while those puparia which developed on larvae reared on 371 weighed significantly less than those on the other two genotypes (Table 2). Puparia which developed on larvae reared on 371 weighed an average of 49.5

TABLE 1. INFLUENCE OF SOYBEAN GENOTYPE ON MEAN FOLIAGE CONSUMED AND PERCENT MORTALITY OF NONPARASITIZED AND PARASITIZED *Pseudoplusia includens* LARVAE.

Soybean genotype	$\bar{x}$ (±SE) foliage (cm^2) consumed per larva		Percent mortality of *P. includens*	
	Nonparasitized	Parasitized	Nonparasitized	Parasitized[1]
Davis	82.38 ± 2.45 a[2] (161.90)[3]	51.63 ± 1.75 b	33.33	70.00
D75-10230	78.43 ± 2.65 a (156.70)	47.22 ± 1.75 b	26.67	36.67
ED73-371	76.12 ± 3.03 a (164.61)	46.38 ± 2.93 b	36.67	90.00

[1]Mortality refers to the death of *Pseudoplusia includens* larvae before the successful development of fly puparia.
[2]Means within a row followed by different letters are significantly different at the 0.05 level (t-test).
[3]Values in parentheses indicate mean weight (in mg) of *Pseudoplusia includens* pupae which developed on each genotype.

TABLE 2. INFLUENCE OF SOYBEAN GENOTYPE ON THE MEAN NUMBER OF PUPARIA DEVELOPING PER HOST AND MEAN PUPARIAL WEIGHT (mg) OF *Voria ruralis* REARED ON *Pseudoplusia includens* LARVAE.[1]

Soybean genotype	$\bar{x}$ (±SE) number puparia per host	$\bar{x}$ (±SE) weight (mg) per puparium
Davis	2.71 ± 0.57 a	13.21 ± 1.70 a
D75-10230	2.35 ± 0.31 a	18.33 ± 1.04 b
ED73-371	1.50 ± 0.50 b	6.67 ± 1.33 c

[1]Means within a column followed by the same letter are not significantly different at the 0.05 level of probability (Duncan's multiple range test).

to 63.6% less than those which developed on larvae reared on Davis or 10230, respectively, even though there were fewer parasitoid puparia per host.

Our results indicated a possible beneficial interaction between the soybean genotype 10230 and *V. ruralis* as indicated by percent successful parasitization and mean weight per parasitoid puparium. Although percent mortality of first-instar SBL reared on 10230 was ca. 56% (Estes 1982), those larvae that survived to third or fourth instar were suitable for successful development of *V. ruralis* indicating possible compatibility of 10230 soybean and this parasitoid for suppressing SBL populations. On the other hand, our data suggest a possible negative interaction between the resistant soybean genotype 371 and *V. ruralis*, as indicated by an increase in host mortality which resulted in an overall reduction of parasitoid production and puparial weight.

Our data emphasize that third-level trophic relationships, as suggested by Price et al. (1980), should be considered in designing an integrated pest management program for soybean. The attractiveness and suitability of certain soybean genotypes may influence a parasitoid's movement into an area and its ultimate success as a natural enemy. Knowledge of parasitoid-host-plant interactions is important for the possible utilization of resistant soybean plants and parasitoids together in an integrated pest management program for the SBL. It is necessary to weigh the value of the resistant plants against possible negative effects that these plants may have on production of parasitoids and other natural enemies in the field.

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REFERENCES CITED

BECK, S. D. AND F. G. MAXWELL. 1976. Use of plant resistance, pp. 615-636, *in* C. B. Huffaker and P. S. Messenger (Eds.), Theory and Practice of Biological Control. Academic Press, New York. 788 pp.

BERGMAN, J. M. AND W. M. TINGEY. 1979. Aspects of interaction between plant genotypes and biological control. Bull. Entomol. Soc. America 25: 275-279.

ESTES. T. 1982. Influence of susceptible and resistant soybean genotypes upon the biology of *Anticarsia gemmatalis* and *Pseudoplusia includens*. M.S. thesis, Clemson University, Clemson, South Carolina. 51 pp.

FEHR, W. R., C. E. CAVINESS, D. T. BURMOOD, AND J. S. PENNINGTON. 1971. Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. Crop Sci. 11: 929-931.

GLASS, E. H. 1975. Integrated pest management: Rationale, potential, needs and improvement. Entomol. Soc. America 141 pp.

GRANT, J. F. AND M. SHEPARD. 1983 Influence of humidity on the development of a South American strain of *Voria ruralis*, a larval parasitoid of the soybean looper. J. Georgia Entomol. Soc. 18: 444-448.

H.ATCHETT, J. H., G. L. BELAND, AND E. E. HARTWIG. 1976. Leaf feeding resistance to bollworm and tobacco budworm in three soybean plant introductions. Crop Sci. 16: 227-280.

KING, E. W. 1981. Rates of feeding by four lepidopterous defoliators of soybeans. J. Georgia Entomol. Soc. 16: 283-288.

KOGAN, M. 1972. Feeding and nutrition of insects associated with soybeans. 2. Soybean resistance and host preferences of the Mexican bean beetle, *Epilachna varivestis*. Ann. Entomol. Soc. America 65: 675-683.

MAXWELL, F. G. AND P. R. JENNINGS (EDS.). 1980. Breeding Plants Resistant to Insects. Wiley and Sons, New York. 683 pp.

MAXWELL, F. G., J. N. JENKINS, AND W. L. PARROTT. 1972. Resistance of plants to insects. Advances in Agron. 24: 187-265.

MCCUTCHEON, G. S. AND S. G. TURNIPSEED. 1981. Parasites of lepidopterous larvae in insect resistant and susceptible soybeans in South Carolina. Environ. Entomol. 10: 69-74.

PAINTER, R. H. 1951. Insect Resistance in Crop Plants. Macmillan, New York. 520 pp.

POWELL, J. E. AND L. LAMBERT. 1984. Effects of three resistant soybean genotypes on development of *Microplitis croceipes* (Hymenoptera: Braconidae) and leaf consumption by its *Heliothis* spp. (Lepidoptera: Noctuidae) hosts. J. Agr. Entomol. 1: 169-176.

PRICE, P. W., C. E. BOUTON, P. GROSS, B. A. MCPHERON, J. N. THOMPSON, AND A. E. WEIS. 1980. Interactions among three trophic levels: influence of plants on interactions between insect herbivores and natural enemies. Ann. Rev. Ecol. Syst. 11: 41-65.

REID, J. C. AND G. L. GREENE. 1973. The soybean looper: pupal weight, development time, and consumption of soybean foliage. Florida Entomol. 56: 203-206.

SALTO, C. E., R. D. EIKENBARY, AND K. J. STARKS. 1983. Compatibility of *Lysiphlebus testaceipes* (Hymenoptera: Braconidae) with greenbug (Homoptera: Aphididae) biotypes "C" and "E" reared on susceptible and resistant oat varieties. Environ. Entomol. 12: 603-604.

SCHILLINGER, J. A. 1976. Host plant resistance to insects in soybeans, pp. 579-593. *in* L. D. Hill (Ed.), World Soybean Research. Interstate Printers and Publishers, Inc. Danville, Ill. 1073 pp.

SOO HOO, C. F. AND R. S. SEAY. 1972. Effects of parasitism by *Voria ruralis* on the feeding behavior of larvae of *Trichoplusia ni*. Israel J. Entomol. 7: 37-40.

TURNIPSEED, S. G. AND M. J. SULLIVAN. 1976. Plant resistance in soybean insect management, pp. 549-560. IN L. D. Hill (Ed.), World Soybean Research. Interstate Printers and Publishers, Inc. Danville, Ill. 1073 pp.

VAN DUYN, J. W., S. G. TURNIPSEED, AND J. D. MAXWELL. 1971. Resistance in soybeans to the Mexican bean beetle. I. Sources of resistance. Crop Sci. 11: 572-573.

YANES, J., JR. AND D. J. BOETHEL. 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.