A Method for Observing Below-ground Pest-Predator Interactions in Corn Agroecosystems[1]

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ABSTRACT A method was developed and evaluated in no-tillage corn fields to investigate the possibility of direct observations of below-ground pest-predator interactions. Rectangular-shaped plexiglass plates were buried parallel to each plant so that roots and a stage of southern corn rootworm (SCR), *Diabrotica undecimpunctata howardi* Barber, could be observed. These direct observations through plexiglass demonstrated that five predators were able to remove large numbers of SCR stages; however, only one arthropod (*Lasius* spp., Formicidae) was an important predator of all SCR stages. Most arthropods successfully attacked only one or two SCR stages. This method enabled detailed observations of below-ground pest-predator interactions and indicated which soil arthropods were important SCR predators. This method elucidated many aspects of SCR-predator activity that had not been possible to observe in previous experiments.

KEY WORDS Coleoptera, southern corn rootworm, below-ground interactions, soil predators, *Diabrotica undecimpunctata howardi*.

The prevailing concept of soil arthropod research is that it is tedious and difficult to conduct. Usually below-ground pest population dynamics are inferred from yield or crop measurements rather than the processes involved (e.g., interactions between pest-predator-soil environment) (Villani and Wright 1988). Two of the most common problems with the study of soil arthropods are the inability of the researcher to locate the pest and predator, and the disturbance of the soil by the researcher during the investigation (Villani and Gould 1986). To overcome these difficulties, researchers bring the soil into the laboratory or greenhouse where a few chosen parameters are controlled (Fisher 1987). Although these studies are helpful in understanding a few limited aspects of soil insect biology, they are not accurate in elucidating natural field population dynamics.

An example is the study of the southern corn rootworm (SCR), *Diabrotica undecimpunctata howardi* Barber. Only a few studies have examined the natural biotic controls of SCR eggs or larvae in the field (Arant 1929, Fronk 1950, Kirk 1982). These studies were concerned mostly with the natural enemies of the adult and reported only incidental observations of egg or larval predation at the soil surface. These experimental results gave poor indications of the natural enemies of the damaging stages (i.e., immatures) of SCR. This is especially surprising because SCR is a polyphagous pest and can cause much damage to corn, peanuts, cucumber, legumes, and many other crops (Sweetman 1926, Campbell and Emery

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1967, Smith 1982). Current techniques using ELISA or other precipitous, antibody methods rely on the researcher's ability to recover sufficient numbers of predators from the field, which is often difficult in below-ground ecosystems. Additionally, these techniques do not give any information about the biology or ecology of the pest-predator interaction.

To study the natural enemies of immature SCR in the field, a method was developed to permit observations of natural predation of SCR eggs and pupae and, to a lesser extent, larvae.

Materials and Methods

Established fields of no-tillage corn (NT) were located at the Lewiston Peanut Research Station in northeast North Carolina, with a Rains sandy loam soil texture of 73.8% sand, 18.4% silt, 7.74% clay, and 1.9% organic matter. Corn, *Zea mays* L., (var. 'Pioneer' 3187) was planted into a wheat stubble in 32 no-tillage and conventional-tillage (CT) plots in early April 1987. These plots were 25 × 18 m, and contained 91-cm rows. The experiment was set up as a randomized complete-block design and was part of a larger study examining NT, CT, and weedy agroecosystems, (Brust 1989). Only NT plots (16) were used in this study because these systems have high levels of soil biota activity (Edwards 1975, House and Stinner 1987). Wheat was harvested in early April and a preemergence herbicide was applied. The technique demonstrated in this study was used in the field through the month of July when corn silks were beginning to dry and second generation SCR adults were beginning to oviposit.

A rectangular clear piece of plexiglass (38 cm × 20.3 cm) was buried next to randomly selected corn plants (10 per plot) (Fig. 1). Soil was removed from the nonplant side, and the plexiglass placed against the plant's root system (Fig. 1A). Damage and disturbance to the root and soil system occurred at this time, but the roots of the plant were only exposed to light and heat for a short time. Once the plexiglass was in place, the edges and bottom portions of the plexiglass were covered with soil. A 10-cm wide × 17-cm deep hole was then created next to the plexiglass. The excavated soil was placed into a burlap bag (Fig. 1b), and the bag was placed back into the hole and pressed level with the soil surface. A burlap bag was used because it allowed water infiltration and did not excessively heat or cool the soil within the bag, thus allowing the soil environment on the nonplant side of the plexiglass to remain close to soil moistures and temperatures that were found on the plant side of the plexiglass. In addition, micro- and some mesoarthropods were able to move into and out of the bag from the surrounding area. After 4-5 days, the bag was removed and immature stages were placed on the plant roots. A plastic rod, 25 cm in length, was used to create an opening so SCR stages could be placed directly against the plexiglass sheet, 1-5 cm below the soil surface. This was accomplished by removing the rod and utilizing a hollow tube which was placed into the opening (Fig. 1a). Eggs, larvae, or pupae were placed into the tube and moved into position with a stream of water from a wash bottle. A stream of water alone was also used as a control to assure predators were not attracted to increased soil moisture. Once this was accomplished, the burlap was replaced and leveled. Three to four hours after infestation, the bag was removed and obervations of soil arthropods and SCR were made. A mark was made on the plexiglass to indicate the position of the SCR. More than one stage could be used at any one

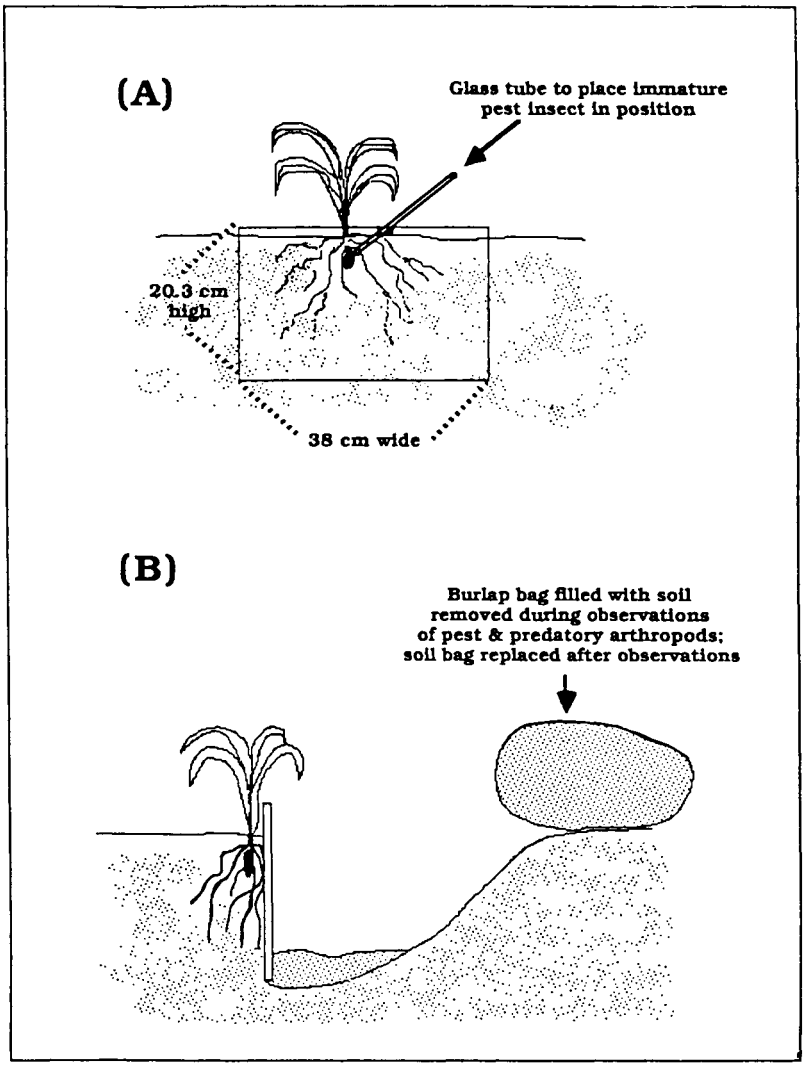

Fig. 1. Diagram of the position of plexiglass plates in the soil in the field adjacent to a corn plant.

observation glass, and the depth at which insects were placed could also be varied. Adjustments in the plexiglass were required in many cases as the root volume changed. Observations were made every two hours over a 24-hour period from 12 noon to 12 noon every 7 days in July 1987. A flashlight fitted with red filter was used to make observations at night.

Correlation values (Pearsons product moment (Poole 1974)) were used to elucidate the importance of individual predators in reducing SCR eggs, larvae, and pupae. A comparison was made of the number of encounters of an arthropod with a particular SCR stage and the number of times the arthropod successfully attacked (i.e., began to consume or consumed) the SCR stage.

Results and Discussion

Correlation values (Poole 1974) demonstrated that mites (Mesostigmata: Gamisinae) and *Tyrophagus putrescentiae* (Schrank)) (Acari: Acaridae) and ants (*Lasius* spp., Hymenoptera: Formicidae) were significant ($P \leq 0.05$) SCR egg predators (Table 1). Cantharid (*Chauliognathus* spp., Coleoptera: Cantheridae) larvae, staphylinid (Staphylinidae) larvae, and carabid (Harpalus spp., *Pterostichus* spp., Carabidae) larvae along with centipedes (Geophilomorpha) and ants fed on first and second instars. The cantharid and carabid larvae and ants were also significant ($P \leq 0.05$) third instar predators. Ants were the only important predator of pupae. Few predators were observed in the areas where only an application of water was made.

With the use of the plexiglass, it was possible to observe the predators and their interaction with the various SCR stages. Mesostigmatid mites were able to feed on SCR eggs by piercing the eggs' chorion and drawing out the fluid. They usually fed on first instar larvae by attacking it from behind and thrusting their chelicerae into the larva's cuticle, directly behind its cervical shield. *Tryophagus putrescentiae* would congregate on an egg mass and slowly remove a section of chorion after which they would crawl into the egg and consume the contents (Brust and House 1988). Ants rarely consumed any stage at the spot where they encountered it but instead removed the stage from the observation site. Brust and House (1990) and Risch (1981) have demonstrated that the ant genera found in this study are important predators of rootworm. Carabid, staphylinid, and cantharid larvae attacked SCR larval instars by simply piercing the larva's cuticle and closing their large mandibles. The SCR would thrash about, which apparently made the larva lose a great deal of hemolymph. Several ants (at least 3 - 4) were needed to subdue and carry off a third instar SCR larvae, whereas only large cantharid and carabid larvae (ca. third to fourth instars) were able to successfully attack a third instar SCR larva. There was significantly ($P \leq 0.05$) more activity at night (2000-0500 h) than during daylight (0700-1800 h) observations (Fig. 2). Significantly ($P \leq 0.05$) fewer SCR were removed by predators during the day ($\overline{X} = 3.2$/plexiglass/hour) than were removed at night ($\overline{X} = 7.4$/plexiglass/hour) (Fig. 2). There was a strong correlation ($r = 0.92$, $P \leq 0.01$) between the number of predators observed and the number of SCR that disappeared.

This technique gives a more realistic appraisal of the feeding behavior of an arthropod on a particular prey or stage. Laboratory studies that force a predator and prey together in an unnatural environment are not accurate predictors of what will take place in the field. Of the top 15 predators, listed in this study, only 3 - 7

Table 1. Relationship between the number of encounters of a predator with a SCR stage and the number of successful attacks on that stage.

	Soil Predators								
SCR stage	Mesostig-matid mites	*Tyrophagus putrescentiae*	Cantharid larvae	Carabid larvae	Centipedes	Carabid beetles	Staphylinid beetles	Formicids	Staphylinid larvae
Egg	0.41*	0.62**	0.12	0.04	0.06	0.06	0.02	0.51**	0.01
First instar	0.47**	0.08	0.33*	0.28*	0.21	0.11	0.21	0.39*	0.18
Second instar	0.04	0.02	0.51**	0.35*	0.22	0.03	0.15	0.30*	0.25*
Third instar	0.01	0.01	0.48*	0.27*	0.11	0.02	0.09	0.33*	0.26
Pupae	0.01	0.01	0.10	0.15	0.08	0.10	0.07	0.37	0.05
Overall	0.23*	0.21*	0.43*	0.32*	0.15	0.08	0.10	0.44*	0.23

a Only top 9-most important predatory groups used in analysis, carabid beetles were combined into one group.
b *r* values of encounter of predators with SCR stages correlated with the number of successful attacks by predators on these SCR stages over a one-month period in July 1987. * = $P \leq 0.05$; ** $P \leq 0.01$. n = 500.

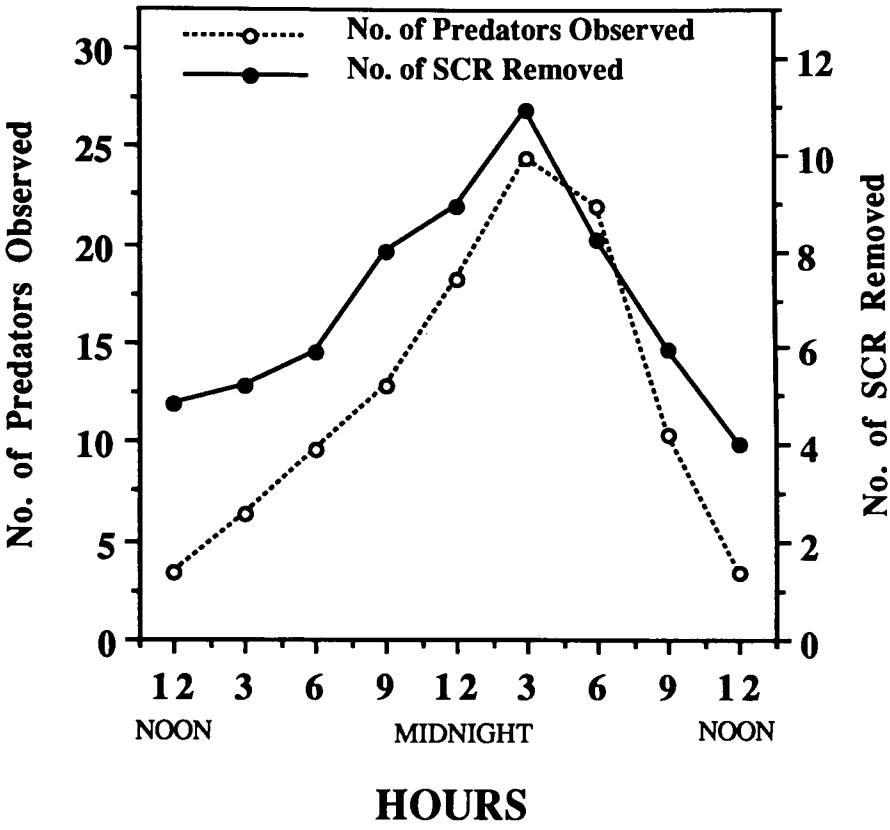

Fig. 2. Mean number of below-ground predators observed attacking southern corn rootworm over a 24-hour period in a no-tillage corn system and the number of SCR removed from the observation area over the same period.

consistently fed on SCR, and then only on certain stages. Yet, all but *T. putrescentiae* would have been considered a predator (Arant 1929, Fronk 1950, Thiele 1970). Therefore, it is not appropriate to simply sample an area for the number of generalist predators that are present and assume that they will feed on a particular pest species. Fronk (1950) found several adult carabids and a staphylinid that attacked SCR larvae at the soil surface. However, in this study, adult carabids and staphylinids, many of which were the same genus as in Fronk's study, fed very little on any SCR stage. Risch (1981) found ants to be important predators of *Diabrotica* eggs in field experiments. In fact, the removal of eggs in his study (ca. 80%) was much higher than this study (ca. 45 - 50%). Risch (1981) placed the eggs in petri dishes covered with a thin layer of soil on the soil surface of a field, which probably made the eggs a more accessible food source for ants as compared with eggs that are buried deeper in the soil. Eggs handled in this way would be

especially available to ants that were primarily surface scavangers as opposed to subterranean species as were found in my study. Southern corn rootworm eggs are normally found at least 2 - 5 cm below the soil surface unless the soil is water saturated (Sweetman 1926, Arant 1929, Campbell and Emery 1967).

One major problem with this observation method was the unknown disappearance of the different stages. Movement of the larvae away from the observation site was probably the major reason for most of the unknown losses; however, with the ease and low cost of this technique, it was possible to have many sites in the field that permitted many observations of pest-predator interactions. Another problem was the drying of the soil around the plexiglass. This created an environment that few soil arthropods would enter, and most of the mobile SCR stages would leave. If the area around the root and plexiglass became dry, it was necessary to establish another observation site, which would not be conducive to long-term (i.e., over a period of months) comparisons between observation sites in different systems. At times, moist soil could be added to fill the space, but plant roots seldom grew back into this area. Observations of predators and SCR were excellent at night because neither was disturbed by the light or heat of the day. In addition, on hot, dry days, the predators became much more active at night, or at least were more active at the observation sites.

More studies are needed to test this method under different environmental and cropping conditions. However, the versatility, ease of installment, and amount of useful information obtained from this method should make it useful in determining soil pest-predator interactions in the field.

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References Cited

Arant, F. S. 1929. Biology and control of the southern corn rootworm. Ala. Polytech. Inst. Agric. Bull. 230.

Brust, G. E. 1989. Abiotic and biotic effects on southern corn rootworm oviposition preference, survival and interactions with predators in corn and peanut agroecosystems. Ph.D. Thesis, N.C. State University, Raleigh. 263 pp.

Brust, G. E., and G. J. House. 1988. A study of *Tyrophagus putrescentiae* (Acari: Acaridae) as a facultative predator of southern corn rootworm eggs. Exp. Appl. Acarol. 4: 335-344.

Brust, G. E., and G. J. House. 1990. Effects of soil moisture, no-tillage and predators on southern corn rootworm (*Diabrotica undecimpunctata howardi*) survival in corn agroecosystems. Agric. Ecosyst. Environ. (in press).

Campbell, W. V., and D. A. Emery. 1967. Some environmental factors affecting feeding, oviposition and survival of the southern corn rootworm. J. Econ. Entomol. 60: 1675-1678.

Edwards, C. A. 1975. Effects of direct drilling on soil fauna. Outlook on Agric. 8: 243-244.

Fisher, J. R. 1987. Greenhouse method for studying development and survival of *Diabrotica virgifera virgifera* (Coleoptera: Chrysomelidae). J. Econ. Entomol. 80: 286-289.

Fronk, W. D. 1950. Cultural and biological control of the southern corn rootworm in peanuts. J. Econ. Entomol. 43: 22-24.

House, G. J., and B. R. Stinner. 1987. Arthropods in conservation-tillage systems. Entomol. Soc. Am. Misc. Publ. 65. 52 pp.

Kirk, U. M. 1982. Carabids: minimal role in pest management of corn rootworms. Environ. Entomol. 11: 5 - 8.

Poole, R. W. 1974. An introduction to quantitative ecology. McGraw-Hill, New York.

Risch, S. 1981. Ants as important predators of rootworm eggs in the Neotropics. J. Econ. Entomol. 74: 88-90.

Smith, J. C. 1982. Virginia peanut insect control recommendations. Va. Coop. Ext. Serv. Publ., pp. 31-35.

Sweetman, H. L. 1926. Results of life history studies of *Diabrotica 12-punctata* Fabr. (Chrysomelidae: Coleoptera). J. Econ. Entomol. 19: 484-490.

Thiele, H. U. 1970. Carabid beetles in their environment. Springer-Berliner, New York. 274 pp.

Villani, M. G., and F. Gould. 1986. Use of radiographs for movement analysis and life-history studies of soil insects. Environ. Entomol. 15: 462-464.

Villani, M. G., and R. J. Wright. 1988. Use of radiography in behavioral studies of turfgrass-infesting scarab grub species (Coleoptera: Scarabaeidae). Entomol. Soc. Am. Bull. Fall: 132-143.