Dry Cucurbitacin-containing Baits for Controlling Adult Western Corn Rootworms, *Diabrotica virgifera virgifera* (Coleoptera: Chrysomelidae), in Field Corn

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The *Diabrotica* beetles and their rootworm larvae are probably the most costly insect pests of agriculture in the U.S. The combined attacks of the western corn rootworm (WCR), *D. virgifera virgifera* (LeConte), the northern corn rootworm (NCR), *D. barberi* (Smith & Lawrence), and the southern corn rootworm (SCR), *D. undecimpunctata howardi* (Barber), annually cost the U.S. farmer approximately one billion dollars. In attempts to control larval damage to the root systems of corn, soil insecticides are routinely applied to 50-60% of the corn acreage or as much as 30-40 million acres at costs now averaging $15-20 per acre. In addition, aerial sprays are also applied to as much as 10 million acres to curb adult beetle damage to corn silks, at a cost of $4-5 per acre. Heavy infestations of rootworms may cause an overall loss of 10-12% of corn production.

Understanding of host selection by the Diabroticite beetle lacked focus until the discovery that adults of such pests of Cucurbitaceae as the spotted cucumber beetle or SCR and the striped cucumber beetle were compulsive feeders on bitter Cucurbitaceae containing the tetracyclic triterpenoid cucurbitacins (1). The role of the cucurbitacins in promoting arrest and feeding stimulation by Diabroticite beetles was strengthened by Sharma and Hall (2). It is now apparent that the bitter cucurbitacins evolved as allomones to protect the Cucurbitaceae against herbivore attack (3,4,5). However, through coevolution the cucurbitacins have become kairomones for host selection by the *Diabrotica*. Adults of all the species investigated: *D. balteata*, NCR, *D. cristata*, SCR, *D. u. undecimpunctata*, and WCR are arrested by and feed compulsively on bitter cucurbits (6,7) and these species are responsive to nanogram quantities of pure cucurbitacines B, D, and E (4,5). This affinity for the cucurbitacin kairomones has been utilized to promote host-plant resistance by antixenosis (8) and in the development of insecticide impregnated baits and artificial trap crops for Diabroticite control (4). By devising hybrid cultivars of domestic *Cucurbita* with wild bitter *Cucurbita* (e.g., *C. maxima* x *C. andreana* and *C. pepo* x *C. texana*) high yields of cucurbitacin containing fruits have been produced that have been used successfully in the field control of SCR and WCR beetles (9). Dried, ground bitter *Cucurbita* fruit containing 0.1-0.3% cucurbitacins have been impregnated with 0.1% carbamate or organophosphate insecticides and when broadcast in corn or cucurbits at 11 to 33 kg per ha, have repeatedly given almost complete control of adult rootworms for periods up to a week (4,10). By incorporating a pesticide into a compulsive feeding stimulant the amount of overall environment contamination is drastically reduced.

In 1987, a large field trial was conducted to determine if cucurbitacin baits could reduce WCR beetle populations sufficiently to reduce egg laying and thus prevent larval damage to a subsequent corn crop. A continuous cornfield, 36 by 130 m, with a plant population of 64250 plants/ha at the Pell Farm of the University of Illinois at Urbana was selected for this study. The field was divided into 8 plots by cutting 2 row alleys between plots. The plots were each 0.06 ha in size (18 by 33 m). Four of the plots were located on the north and the other four on the south. The two plots on the north were treated with cucurbitacin bait and the other two were not treated and served as controls. The same arrangement was made with the plots located on the south portion of the field. The rate of bait used was 33 kg per ha (containing 0.1% isophenphos insecticide by weight). Dried Cucurbita baits were produced from TEX x PEP F_2 fruits grown in Arizona; the bait contained ca. 0.3% total cucurbitacins. Weighed samples of the baits were evenly broadcast by hand over the tops of the corn plants (so that a portion of the bait was retained by leaves and silks) on July 22 and August 3 (a second treatment was needed because adult populations of beetles began to exceed the economic threshold of one beetle per plant). Plant pollination was essentially complete by the initial treatment date. Prior to treating the plots, beetles were collected from the center of each plot to determine the sex ratio of the adults and the reproductive status of the females. Abundance of beetles (numbers per 30 or 40 plants in each plot) was also determined using the visual whole plant count method (11). To determine the effect of the bait on the mortality of the beetles, two metal quadrats (27 by 27 cm) were located on the ground in each of six rows within each plot. The fields were visited daily and the dead beetles in the quadrats were brought to the laboratory to determine sex ratio and mating status of the adults. Adult population density (visual plant count) was determined once every few days. At this time, some beetles were also collected and brought to the laboratory to be examined under a binocular microscope for sex ratio and mating status determination. After harvest on October 8, the plots were sampled for WCR eggs using a gasoline powered trencher (12). Four trenches (each 35 cm deep, 13 cm wide, and 175 cm long) were dug in each plot and two 0.5 l of soil were sampled from the pile of soil produced by digging each trench. These samples were processed using an egg extraction device (13).

Analysis of the data revealed that: (1) beetle abundance declined abruptly after treatment (Table 1; 84.8% versus 37.6% for the treated and untreated plots, respectively). During the period from July 27 to August 1, the number of beetles per plant in the treated and untreated plots increased and exceeded the economic threshold of one beetle per plant, therefore, baits were reapplied on August 3. Again, beetle densities declined sharply in the treated plots. Beetle abundance never exceeded the economic threshold after this application both in the treated and untreated plots probably due to the effectiveness of the bait, climatic conditions, and declining attractiveness of the crop, (2) the highest beetle mortality due to baiting was achieved one day after treatment (Table 2). The magnitude of beetle mortality generally decreased as time progressed. This reduction in mortality might have been due to the reduction in bait efficacy as it aged and to the reduction in beetle populations (resulting from the removal of a large part of the population by the baiting and reduced attractiveness of the corn crop), (3) the sex ratio (male:female) of the beetles collected prior to and post-treatment was 0.62, whereas this ratio for the dead beetles collected from the quadrats in the baited plots was 1.56. This could indicate that the males were more susceptible to or were more likely to come in contact with the bait than the females, (4) ovarian development of the beetles collected from the untreated plots was higher (reproductively more mature) than those collected from the baited plots for the first 10 days after treatment during which time the bait had its highest efficacy. This suggests that the females in the untreated plots had the opportunity to remain alive and develop further, whereas the existing females in the treated plots were killed by the bait. Ovarian development for the beetles collected from treated and untreated plots became similar after this 10 day period, (5) although the baited plots (mean of 0.19 eggs per 0.5 l of soil) contained fewer WCR eggs than the control plots (mean of 0.25 eggs per 0.5 l of soil), the difference was not significant at the 5% level (t-test). Due to the great variability investigators often encounter with sampling rootworm eggs, root damage ratings of corn grown in the baited and control plots will be examined in the summer of 1988.

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Table 1. Average number of beetles per plant in treated and control plots and percent beetle reduction between two consecutive sampling dates (Pell Farm, Urbana, IL 1987)

				% reduction	
Date	No. plants	Bait	Check	Bait	Check
7/22	160	3.49	3.56	84.8	37.6
7/24	120	0.53	2.22	3.8	41.0
7/27	120	0.51	1.31		
8/1	120	1.32	1.47	87.9	42.2
8/4	120	0.16	0.85	12.5	61.1
8/7	120	0.14	0.33	57.1	66.7
8/11	120	0.06	0.11		
8/17	120	0.12	0.12	100.0	100.0
8/31	120	0.00	0.00		

Table 2. Number of dead male and female beetles collected in quadrats (n = 48) from treated and control plots (Pell Farm, Urbana, IL 1987)

	Bait		Control	
Date	male	female	male	female
7/23	262	113	0	0
7/24	164	119	0	0
7/25	113	96	2	3
7/27	76	60	0	0
7/29	29	14	1	0
8/4	81	52	0	0
8/5	25	23	0	0
8/6	21	21	0	0
8/7	38	27	0	0
8/8	35	25	0	0
8/10	10	7	0	0
8/11	5	5	0	1
8/13	3	3	0	0
8/14	5	0	0	0
8/17	0	0	0	0
Total	867	555	3	4