The Repellent Effects of Some Pesticides to Hymenopterous Parasites and Coccinellid Predators[1]

B. R. BARTLETT

Department of Biological Control, University of California, Riverside

ABSTRACT

Two methods were used to measure the repellency of 60 pesticides to the adults of 2 hymenopterous parasites and 2 coccinellids. Method I, for screening general reaction to each of the residues, was based on the number of excrement spots deposited over a 4-day period on sugar cubes sprayed with the 60 pesticides. Method II measured the insects' initial avoidance of noxious odors or irritants from their preferential movement to treated or untreated sectors of a filter paper. Many of the pesticides tested were weak repellents: none was strongly avoided. Zectran® (4-dimethylamino-3,5-xylyl methylcarbamate) and DN-111 (4,6-dinitro-*o*-cyclohexylphenol, *N,N*-dicyclohexylamine salt) were most generally avoided; other pesticides were either more specific or elicited weak aversion responses. Parasites and predators responded to the noxious odors of certain residues, the strongest aversion (23.8%) being that of a parasite to Aramite® (2-(*p*-*tert*-butylphenoxy) isopropyl-2-chloroethyl sulfite).

A research project in the Department of Biological Control of the University of California at Riverside has the broad objective of defining how pesticides can best be selected and used to preserve natural enemies while still providing effective chemical pest control. The phase dealing with comparisons of the physiological selectivity of pesticides as contact poisons having been completed (Bartlett 1963, 1964a, 1964b), investigations were undertaken of some of the less obvious effects of pesticides on natural enemies. This paper concerns the possible repellent effects on some adult parasites and predators of the most commonly used commercial pesticides.

There are a few poorly documented reports in the literature in which a repellent effect on specific entomophagous insects is attributed to a pesticide (Orr 1931, Flanders 1942, Sysoev 1953). Often, however, authors imply that the avoidance of pesticide residues by parasites or predators might explain the otherwise unaccountable decreases of natural enemies sometimes noted in the field after treatment. The scarcity of factual information on this subject is not surprising because of the difficulty of assessing precisely a single behavior reaction which may be elicited by a variety of stimuli, each of which can produce varying qualitative and quantitative reactions under different sets of conditions (Dethier et al. 1960). The purpose of this study was therefore, 1) to devise a simple method for measuring avoidance responses by entomophagous insects, and 2) to use it to examine the repellency potentials of 60 commonly used pesticides to 2 representative species of parasitic Hymenoptera and 2 species of predatory Coccinellidae.

METHODS.—Ideally a method was sought which would detect the final result of orientative movement in response to a combination of olfactory, tactile, and gustatory stimuli and at the same time indicate whether orientation was elicited as an initial contact reaction, such as might stem from a noxious odor, or as an increasing aversion such as might arise from irritation or gustatory distaste. In addition, the repellency test technique should provide results unconfused by differential phototaxis, mingling of odors, or receptor fatigue in the insects. A reasonable mediation of these goals was finally achieved through use of 2 complementary test procedures.

Method I.—This method served as a screening technique for sorting from the 60 pesticides those materials which appeared to be particularly effective in eliciting an avoidance reaction from one or more of the test species. The avoidance of a pesticide from combined causes was indicated by the number of excrement spots accumulating on the sprayed surfaces of variously treated, randomly arranged sugar cubes. The excrement spots were made clearly visible by feeding the test insects for 48 hr before use on honey dyed with blue food coloring. In the case of the coccinellids, prior feeding on the colored honey also resulted in a distinctively colored spot at each location where a beetle fed on a treated sugar cube surface, thereby also providing a measure of their gustatory distaste for any particular residue. Only the coccinellids which fed on dry sugars through a process of regurgitation could be tested for gustatory rejection of a pesticide with this technique. The parasites which fed on the dry sugar through salivation left no distinctive coloration.

The repellency test using Method I was set up as follows: 4 sugar cubes each were sprayed with 60 different pesticides and 4 were left as an untreated control. Treatment of the sugar cubes was according to the procedure described by Bartlett (1963) to provide measured surface deposits at commonly used field dosages. The materials and formulations of the 60 pesticides applied to the sugar cubes were exactly the same as those listed previously (Bartlett 1964a) when these pesticides were tested for toxicity to green lacewings. The treated sugar cubes were placed randomly on an organdie cloth which rested on a ¼-in. mesh screen set 1 in. below the lip of a 12-in. diameter glass funnel which was fitted at the bottom with air suction. Space not covered by the sugar cubes was filled with cotton. An organdie cover over the top of the funnel confined the test insects, which were fed for 2 days on colored honey before being anesthetized and placed in the test arena. Each test with a parasite or predator was set up 6 hr after treatment of the sugar cubes and continued for 4 days with daily replenishment of the test insects, which usually died within a day. Frequent 90° rotation of the funnel during the test equalized any possible variations in the overhead lighting, and the air drawn downward between the sugar cubes prevented mingling of pesticide odors. One test of 2800 *Lindorus lophanthae* (Blaisdell) put in the funnel at the rate of 700/day and another test with a similar number of *Cryptolae-*

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mus montrouzieri Mulsant produced an average of 12 excrement spots and 21 excrement spots/cube, respectively, in 4 days' time. The light blue regurgitation marks produced at the rate of 0.4/sugar cube by *Lindorus* and 9.2/cube by *Cryptolaemus* were easily distinguished from the dark-colored excrement spots. The difference in numbers of excrement and feeding spots between the 2 coccinellid species was caused by the more rapid death of *Lindorus*. Compensation for this mortality effect was sought in later parasite tests by varying the number of insects used. A total of 8000 *Metaphycus luteolus* Timberlake (Encyrtidae) and 12,000 *Aphytis melinus* DeBach (Aphelinidae) in separate tests produced averages of 6 and 2.4 excrement spots/sugar cube, respectively, after 4 consecutive days of exposure.

Several features reduced the value of this method as a quantitative technique. The sugar cubes used as a basic arrestant not only provided no measurement of the parasite's feeding but even with the coccinellids there was considerable doubt as to whether the regurgitation marks were positively identified with reingestion. Considerable inaccuracy in measuring repellency by this procedure also probably arose from sensory fatigue in the test insects and from differences in the lability of some of the residues. Probably also the use of fewer test materials would increase precision.

Method II.—The second testing technique was designed to study the discrete avoidance stimuli which might be responsible for particular cases of repellency shown in the previous screening trials. This procedure consisted of recording the comparative resistance of the insects to moving onto treated and untreated pieces of filter paper. This measured only the responses of the insects at their initial encounter with the boundary of residues having an immediately effective noxious odor or irritant effect. The observed hesitancy of the insects on close approach to the residue margins indicated their recognition of a noxious odor, whereas avoidance after an initial contact but before feeding indicated response to an irritant.

Repellency tests for examination of the initial rejection by parasites or predators of a treated surface were used with the same 4 insect test species with, however, only 8 selected pesticide-natural-enemy combinations in which repellent effects had been indicated in the screening tests. The modus operandi for this test procedure consisted of spraying 1 sector of a filter paper with a standard dosage of the test material, substituting the treated sector and a water-sprayed sector at opposite positions on a fresh filter paper, and placing this on a fine screen set ½ in. below the rim of a glass funnel fitted with bottom air suction and at the top with an organdie cover. The parasites were temporarily anesthetized with CO_2 then placed in approximately equal numbers on the 2 opposite untreated starting sectors of the paper. Counts of the comparative number of entries made by the recovered insects into the opposing treated and untreated sectors of the filter paper measured the insects' tendency to avoid the residue. Rotation of the funnel through 90° for each of the 4 replicates of a test equalized any variations in light intensity. The papers were treated 6 hr before use. The movement of 40 previously unexposed test insects to either the treated or untreated area for each of the 4 replicates was checked, thus providing data on the orientation responses of 160 insects with each trial of an insect and pesticide combination. This method was checked for efficiency in an initial test of a filter-paper sector quadrant treated with xylene which, when used immediately after treatment, resulted in complete avoidance of the margins of the treated quadrant by the insects.

RESULTS.—Because of the unwieldiness and bulk of the tabulated data obtained from the screening of the 60 pesticides on 4 insects, and because the few statistically valid cases of repellency demonstrated among the combinations tested were relatively unimportant as compared with the general trends disclosed in the succession of tests, there is no practical point in presenting more than a brief summary of the general findings and of the response patterns of the natural enemies as disclosed by these experiments.

The results obtained from the Method I test procedure (sugar-cube-excrement spot tests) demonstrated that an overall, i.e. combined odiferous, irritant, or gustatory distaste reaction, was elicited in one combination or another by approximately ½ the pesticides tested. The overall repellency of only 2 of the materials was shown to be relatively nonspecific, i.e. statistically valid repellency shown to 3 or more of the test species. These materials were DN-111 (4,6-dinitro-*o*-cyclohexylphenol, *N,N*-dicyclohexylamine salt) and Zectran® (4-dimethylamino-3,5-xylyl methylcarbamate).

Trends toward either overall weak repellency or possibly in some cases insect-specific repellency (i.e. statistical significance shown to only one species of natural enemy) were suggested from the data obtained with almost half of the potent carbamate, chlorinated hydrocarbon, and organic phosphate insecticides, from the botanical rotenone, the fungicides zineb and sulfur, the acaricides Aramite® (2(*p-tert*-butylphenoxy) isopropyl-2-chloroethyl sulfite), dinocap, demeton, schradan, and from the light-medium grade of oil. The lack of any indication of repellency by kerosene suggested that the tackiness of the heavier oil might account for its being avoided. The lack of any overall repellency by materials like benzene hexachloride, calcium arsenate, chlorobenzilate, cryolite, Genite 923® (2,4-dichlorophenyl benzenesulfonate), lindane, lime-sulfur, nicotine sulfate, ryania, and sabadilla were in some cases difficult to explain solely on the absence of noxious odors or irritant properties.

The data obtained by Method I on taste repellency of the materials to *Lindorus* provided almost no reliable information because of the scarcity of feeding marks. The abundance of feeding spots left by the *Cryptolaemus* beetles, however, provided good avoidance data for that species. Sugar cubes treated with aldrin, captan, oil, Perthane® (a mixture of 1,1-dichloro-2,2-bis(*p*-ethylphenyl ethane (95%) and related reaction products (5%)), tartar emetic, and toxaphene were definitely distasteful. It was inferred from the data trends shown by the 4 test species that some distastefulness occurred with Kelthane® (1,1-bis(*p*-chlorophenyl)-2,2,2-trichlorethanol), lead arsenate, lime-sulfur, phosphamidon, and trichlorfon. There was no evidence of distaste for residues of benzene hexachloride, calcium arsenate, carbaryl, DDT, rotenone, ryania, or Zectran.

The results obtained from the Method II tests with 8 selected pesticide-natural-enemy combinations were in some respects disappointing. The differential movement of 160 insects for each combination was inadequate for the statistical demonstration of anything other than moderately strong repellent action. Only with Aramite, where there was 23.8% less movement of the *Metaphycus* to the treated than untreated areas, was there shown a statistically positive repellent action. In this case, the marked hesitancy of the insects at the instant of their approach to the margins of treatment indicated their detection of a noxious odor. Less marked hesitancy was noted in the reactions of *Aphytis* to trichlorfon and *Lindorus* to DN-111, where there was 17.6% and 11.3% less movement to the respective treatments. In none of the other tests was this hesitancy apparent although less movement to the treated areas was recorded for *Cryptolaemus* to DDT (7.4%), *Lindorus* to Zectran (11.2%), *Aphytis* to tepp (6.2%) and *Metaphycus* to carbaryl (0.8%). The response of *Cryptolaemus* to rotenone was notable. Whereas there was no preferential movement by this coccinellid to the untreated area and no hesitancy to entering the rotenone-treated area, within about 3 sec after movement to the treated sector an obvious avoidance reaction was noticeable.

The combined evidence from the results obtained with the 2 test methods used above with 4 species of natural enemies strongly points to the existence of some repellent action by many of our common pesticides to both hymenopterous parasites and coccinellid predators. The information obtained suggests that this stems sometimes from a noxious odor and sometimes, particularly with coccinellids, from a delayed irritant effect. None of the 60 pesticides tested aroused strong avoidance reactions in the parasites and predators tested. Therefore, it seems unlikely that any of the materials are sufficiently repellent to parasitic hymenopterans or coccinellid predators in the field that they would cause beneficial species to vacate treated areas. And, in general, there appears to be little prospect for the effective use of any of these materials as pesticide additives to keep natural enemies away from destructive residues.

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Aldrin Resistance in Corn Rootworm Beetles[1]

E. W. HAMILTON

Entomology Research Division, Agr. Res. Serv., USDA, Brookings, South Dakota

ABSTRACT

The LD_{50} values for aldrin and diazinon, in micrograms of insecticide per insect, were determined for adult corn rootworms over large areas in the Northcentral States. Results indicated that resistance to aldrin in western corn rootworm, *Diabrotica virgifera* LeConte, is present in western Iowa, northern Kansas, northwestern Missouri, southwestern Minnesota, and southeastern South Dakota. Northern corn rootworm, *Diabrotica longicornis* (Say), is resistant to aldrin in localized areas of Illinois, Iowa, Minnesota, and Wisconsin. Both species were quite susceptible to diazinon in the areas studied.

Ball and Weekman (1962), reporting on a 1961 study, confirmed the presence of an aldrin and heptachlor resistant strain of western corn rootworm, *Diabrotica virgifera* LeConte, in the south central area of Nebraska. The appearance of resistance in all of central and eastern Nebraska in 1962 (Ball and Weekman 1963) indicated that the resistance of western corn rootworm to aldrin and heptachlor would probably occur in the States adjoining Nebraska. In 1962, Bigger (1963) also reported the presence of a resistant strain of northern corn rootworm, *Diabrotica longicornis* (Say), near El Paso, Ill. In 1963 a coordinated, regional survey of the resistance pattern for the western and northern corn rootworm was instigated for the Northcentral Cornbelt States.

Data from the following States were obtained and submitted by the researchers indicated for compilation in this report: Illinois (J. H. Bigger, unpublished data), Kansas (C. C. Burkhardt, unpublished data), and Wisconsin (J. W. Apple and K. K. Patel, unpublished data).[2]

The purposes of this survey were: to determine the median lethal dose (LD_{50}) for aldrin and diazinon against corn rootworm, to correlate dosage-mortality

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[2] Other cooperators supplying insect samples for analysis are: Dr. H. C. Chiang, University of Minnesota; Dr. Don Peters, Iowa State University; Dr. Benjamin Kantack, South Dakota State College; Dr. M. L. Fairchild, University of Missouri; W. H. Steffan, Pioneer Hi-Bred Corn Co., Algona, Iowa.