The Contact Toxicity of Some Pesticide Residues to Hymenopterous Parasites and Coccinellid Predators[1]

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ABSTRACT

Sixty-one pesticides were tested in the laboratory against 5 parasitic hymenopterans and 6 predatory coccinellids, the data to serve as guides for selecting the best materials for destroying pests without undue harm to natural enemies. Test species were exposed in replicated tests to day-old residues of the pesticides under standardized conditions of dosage, temperature, and humidity. The single dosages applied were those most commonly used upon orchard crops. A table presents toxicity levels for each material and natural enemy species in conjunction with a rating of the persistence of each pesticide's toxic residue. The data suggest that the effect of each pesticide upon most kinds of adult parasitic Hymenoptera may be anticipated with a high degree of reliability while the effect upon predatory coccinellids is much less predictable. The materials are discussed with respect to their specificity and the probable impact that their field usage might have upon parasitic Hymenoptera and predaceous Coccinellidae.

In recent years there has been considerable interest in the development of plant protection programs that assure a more compatible use of chemical and biological methods of pest control. These so-called "integrated control programs" operate on the principle that certain chemical control practices can destroy the pests while sparing their effective natural enemies, thereby restricting subsequent pest increase. Among the most useful of these programs are some in which success depends upon the selection of contact pesticides less broadly toxic to the natural enemies than to the pests. Unlike the more intricate practices suggested for special timing or placement of toxicants to avoid pesticide contact with the natural enemies, this type of program requires less supervision and less intimate knowledge of the differences in pest and natural enemy behavior patterns, and is applicable even where a variety of potential pests attack the crop. In addition, it supplies a simple framework upon which special timing and placement practices can be superimposed if found applicable. Despite wide recognition of the potential value of integrating contact pesticide programs with biological control, advancements in this field have been slow. The development of such programs has been retarded by lack of appreciation of basic factual guides for selecting and using the best materials, as well as by incomplete knowledge of patterns of parasite and predator tolerance and susceptibility to the contact pesticides. This paper emphasizes some of the guiding principles for the selection of treatments favoring natural enemies, and defines the general toxicity effects of commercially available pesticides upon parasitic Hymenoptera and predatory coccinellids.

A few basic concepts for the implementation of integrated control have been derived from the results of field experimentation and study of the mechanics through which natural enemy reservoirs are maintained in treated areas. These studies have shown that, with few exceptions, the toxicity of contact pesticides is expressed predominantly against the adult stages of natural enemies, and that many of the pupal stages and even, in some cases, the late larval stages of internal parasites are well-protected against destruction. This fact often permits the preservation of parasite and predator reservoirs if persistence of the pesticide is not extended beyond the period required for pupal metamorphosis. Thus, other considerations being equal, the more fugitive the toxic residue, the better are the prospects for a favorable, natural enemy-pest ratio following treatment. A second important guide to the development of integrated programs is based on the evidence that in most instances any favorable physiological selectivity (i.e. differential toxicity response favoring the natural enemy over the pest) can usually be accentuated by a decrease in the field dosage to a point where somewhat less than 100% of the pest is destroyed. This practice not only lessens the impact of the toxicant upon the natural enemies and assures some food for their survival, but also shortens the period of toxic residue presistence.

It is clear, therefore, that where a favorable selectivity is sought from the use of contact pesticides, there should be broad patterns of tolerance to the toxicant among natural enemies; otherwise, gains made against one pest may be lost against another. Unfortunately, many of the records on the responses of hymenopterous parasites and predaceous coccinellids to contact poisons are from isolated reports which are often contradictory.

The present report is an attempt to appraise the broad toxicity patterns of somewhat high dosages of commercial pesticides to some of the entomophagous species of special interest in California. The study was undertaken primarily as a basis for predicting which of these materials might be used in projected integrated control programs and secondarily to disclose cases of exceptional specificity of the materials to certain natural enemy species for the development of insecticidal check techniques, i.e., techniques for measuring the effectiveness of a natural enemy by the host increase that occurs when the natural enemy is removed by a pesticide. The data have been accumulated since 1956 with new materials being assessed as they came into commercial use. Although adults of a rather large number of other entomophagous species of similar types were tested at various times with many of the pesticides shown, the results are not presented since the tests for the most part consisted of unreplicated trials with species which were poorly adapted to survive a 4-day test period. The important feature of these ancillary tests was, however, that almost all of the parasitic Hymenoptera showed general susceptibility patterns similar to those of the test species recorded here.

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The parasite and predator species employed in the tests were selected on the following bases: (1) as being representative members of groups of parasitic Hymenoptera or predatory Coccinellidae, (2) as suitable test organisms with respect to longevity in confinement, (3) as effective biological control agents whose preservation was of practical importance, and (4) because the close relationship of certain species would be likely to expose the frequency of pesticidal specificity among closely allied types of natural enemies. *Aphytis lingnanensis* Compere [Aphelinidae] is an effective external parasite of California red scale, *Aonidiella aurantii* (Maskell) in coastal southern California (DeBach et al. 1955). *Metaphycus luteolus* (Timberlake) [Encyritidae] is a very efficient gregarious internal parasite of brown soft scale, *Coccus hesperidum* L., and other lecaniine scale insects in California (Bartlett 1953a). *Spalangia drosophilae* Ashmead [Pteromalidae] is a parasite of certain dipterous pupae (Simmonds 1953) and now is under investigation for control of the eye gnat, *Hippelates collusor* (Townsend) in California. *Metaphycus helvolus* (Compere) [Encyrtidae] is an effective internal parasite of black scale, *Saissetia oleae* (Bernard) in southern California (Flanders 1942) and is in many respects very similar to *M. luteolus*. *Leptomastix dactylopii* Howard [Encyrtidae] is an internal parasite of certain mealybug species in some areas of the world (Zinna 1959), and is now being propagated by commercial insectaries in southern California for periodic release against the citrus mealybug. Among the six test species of Coccinellidae used, *Cryptolaemus montrouzieri* Mulsant has long been reared by commercial insectaries in California and in other areas of the world for periodic release against mealybugs (Smith & Armitage 1931). The convergent lady beetle, *Hippodamia convergens* Guerin-Méneville, is the most abundant coccinellid attacking aphids in California (Hagen 1962). Test insects of this species were collected as adults while actively feeding upon aphids in the field. *Lindorus lophanthae* (Blaisdell) is an important predator of diaspidine scale insects in a number of world areas (DeBach et al. 1948). *Rodolia cardinalis* (Mulsant) is the well-known vedalia beetle responsible for the striking control of the cottony-cushion scale, *Icerya purchasi* Maskell (Clausen 1956). *Stethorus picipes* Casey is an important predator attacking tetranychid mites (Fleschner 1956). *Hippodamia quinquesignata* Kirby is very closely related to *H. convergens*, but unlike the actively feeding test insects of that species, adults of *H. quinquesignata* were collected for testing during their congregation period in the winter.

In the test results, toxicity levels are presented as (H) high, (M) medium, (L) low, or (0) none. This method was chosen in preference to giving the LT_{50}'s as determined by the tests for convenience in tabular condensation and simplicity in showing broad toxicity patterns and notable cases of digression from expected toxicity. Most of the insects tested were reared in the insectary to obtain newly emerged adults; however, the *Hippodamia* spp. and a part of the *Stethorus picipes* were from a field collection of adults, and the *Rodolia* were reared from field-collected pupae. For each pesticide and natural enemy 4 to 7 replicate trials were used to establish the toxicity levels. From 100 to 300 parasites and 50 to 80 coccinellids were used to determine each species' susceptibility to each toxicant. The total of approximately 3,500 individual tests, here recorded, involved the use of over 100,000 insects.

MATERIALS AND METHODS.—Some specialized testing techniques had to be developed to meet the needs of this examination, and certain defects are apparent in the methods employed. Precise conditions of temperature, humidity, and aeration control had to be provided for reproducibility of results at various times, and it was desirable to use a method which would serve both for toxicity studies on laboratory-prepared residues and, when the occasion demanded, as a technique for bioassaying field-sprayed leaf samples. The testing program was designed essentially as a screening process, recognizing that any specific integrated control program would require further investigation of the full toxicity curve interrelations of the pests and natural enemies involved. The use, therefore, of a single-dosage rate of the pesticide was dictated by these conditions, and by the practical requirement of using a large number of species to establish broad toxicity patterns. Some inaccuracies stemmed from the initial decision to compare LT_{50}'s in the trials. This was recognized, in some cases, as giving an inordinately low value to slow-acting toxicants. Isolation of the natural enemies from their environments may also be subject to criticism, but this seemed to offer the best opportunity for studying the direct-kill component of the materials without intercession of food shortage and dispersal influences which often confuse results in field toxicity tests with entomophagous insects.

The pesticide residue deposits for testing were obtained in the laboratory by mist atomization of commercial spray materials onto heavy wax paper surfaces. Formulations and high dosage rates conforming to those applied to orchard crops were used. Spray formulations consisted largely of wettable powders (W.P.) and, to a lesser extent, emulsifiable concentrates (E.C.), with a few emulsions (E) and soluble powders (Sol. P.), depending on predominant field usage. Frequent replacement of commercial materials during the long test period undoubtedly was responsible for some variation in the test results. The author believes, however, that differences between various samples of the toxicants were negligible with all materials except lindane. The only other major variation was with the fugitive residue materials where very slight differences in degradation rates during the 24-hour residue holding period sometimes influenced toxicity.

The spray was applied from a stainless steel Waring blendor tank of 1-liter capacity with a DeVilbiss M.C.B. type nozzle at 20 psi. Standardization of deposits of pesticide residues for testing was accomplished by atomization of the liquid sprays onto the heavy wax paper surfaces until a desired droplet size had accumulated. When the accumulated droplet size was visually comparable to that on a wax paper with a known weighed deposit, which had been photographed and used as a model, further applications were made with the same machine setting and exposure time. The degree of uniformity of the deposits obtained was shown by the results of 10 trial sample weighings of the total liquid deposit upon the wax papers. These trials indicated that the reproducibility of the deposit could be assured within a range of error of $\pm 17\%$. Within this range of accuracy, the uniform

amount of spray liquid applied to the wax papers produced an average deposit of 12.87 ± 0.46 mmg./cm². of the pesticide with the equivalent of each pound of pesticide per 100 gallons in the spray liquid.

After the treated wax papers were dried for 24 hours, they were used as the basal surface of a modified Munger cell test cage as previously described by Bartlett (1953b). The test cage cells were fashioned of a center piece of $\frac{1}{8}$ in. plexiglass having a 10-sq.-cm. circle piece cut from its midsection, with separate plexiglass plates placed on either side for bottom and top. The treated paper was inserted between the center and bottom surfaces. These were all held together with clip fasteners to form an easily demountable and easily cleaned cage in which the insects were clearly visible. The insects were placed in the cell while under ether anesthesia. A light film of honey applied to the inner top of the cell supplied the insects with food and restricted their activity largely to the treated wax paper surface. Two small screen-covered circular holes on opposite sides of each cell top were used to draw air through the cell. This was accomplished by attaching a capillary glass tube connected to a suction pipe into one of the holes. An air flow of 3 to 4 air changes per minute drawn from the air-conditioned room through the test cells maintained a constant 80° F. and 50% R.H. in the cells during the test. The conditioned air flow assured optimum survival of the test insects and restricted abnormal fumigation effects.

During the 4-day test period, mortality counts were made of the dead insects in each cell by detachment of the cell from the capillary air suction tube and direct examination of the insects under a binocular microscope. The time required for 50% kill of the test insects (LT_{50}) was determined for each individual cell from eye-fitted mortality curves corrected for natural mortality by Abbott's (1925) formula. For presentation of the data in table 1, the toxicity of each material to each test species was designated as high (H) if 50% mortality occurred during the first day, medium (M) if 50% kill was attained during the next 3-days' exposure, low (L) if there was an appreciable mortality but less than 50% kill before the termination of the 4-day test, and (0) if there was no kill. Conflicting results among different replicated trials are indicated in table 1 by showing the range of toxicity encountered in the various replicates.

RESULTS AND DISCUSSION.—The toxicity of 61 different pesticides to adults of 5 species of hymenopterous parasites and 6 coccinellid predators is shown in table 1. The values of persistence have been roughly estimated as low (L), medium (M), or high (H) based on information from many sources, principally on the chemical half-lives of the materials when used in like formulations on plant foliage (see Hoskins 1961). These values are admittedly speculative when translated into terms of specific toxicity to insects, but at present there is almost no exact biological assay data on this subject.

In interpreting the toxicity data in table 1, it may reasonably be assumed that (0-L) or (L) toxicity ratings would not cause the destruction of field populations of natural enemies. This conclusion appears justified from the results of two field tests in which *Aphytis chrysomphali* Mercet was observed to re-enter a DDT-treated citrus orchard and *Rodolia cardinalis* to re-enter a malathion-treated orchard coincident with the degradation of the respective pesticides to a (0-L) toxicity level when the residues on the field-treated leaves were bioassayed in the laboratory. Medium toxicities with materials of medium persistence would ordinarily be expected to give complete natural enemy destruction at the dosages used. But with proper dosage adjustments, these materials at times might permit some retention of natural enemy reservoirs. Ordinarily, (M) or (H) toxicity levels in combination with materials of (H) persistence would be intolerable to the natural enemies. Such materials should be restricted to conditions of use where there is no contact of parasites or predators with toxic residues if natural enemy preservation is desired. However, fugitive residues may greatly modify the effect of a toxicant on natural enemies. Materials such as demeton, Dylox®,[2] nicotine sulphate, oil, schradan, and even naled, Phosdrin®, rotenone, and TEPP, because of their non-persistence, may not eliminate all natural enemy reservoirs. Dosage adjustments of many of these may be expected to favor the preservation of species having special protective habits or protected stages of development.

The general uniformity shown in the toxicity responses of the hymenopterous parasites, both in the data presented here and in other tests on parasite species not recorded suggests that the general patterns of susceptibility of this group may be predicted with some degree of certainty. The greatest inconsistency shown in this pattern was that of the extraordinary tolerance of *Leptomastix dactylopii* to a number of the organic phosphate materials.

In contrast to the more or less uniform effects of the pesticides upon parasitic Hymenoptera, a very diverse response was shown among the coccinellids. In addition, the suspected variations among the immature stages of the coccinellids indicate the improbability of predicting the responses of members of this group without trial. Only with a few broad-spectrum materials may the reactions of individual species of coccinellids be anticipated with confidence.

A number of the materials tested were relatively non-toxic to most parasitic Hymenoptera and predatory coccinellid adults. These included Aramite®, bordeaux, captan, chlorobenzilate, cryolite, DN-111®, ferbam, nicotine sulphate, sabadilla, tartar emetic, tetradifon, and zineb. Oil with its tacky effect upon delicate parasite adults may doubtfully be placed in this group. Calcium arsenate, lead arsenate, ovex, and rvania were toxic to some species but not to others. Although many of the acaricides were relatively non-toxic to most of the species tested, other acaricides such as demeton, Genite 923®, lime sulphur, Neotran®, schradan, Sulphenone®, and sulphur showed wider toxicity ranges among the various species.

At the high dosages used, many of the materials were broadly toxic to most of the entomophagous species tested. Among these were BHC, Chlorthion®, DDT, Delnav®, Dilan®, dimethoate, endrin, ethion, Guthion®, malathion, methoxychlor, parathion, Phosdrin®, Sevin®, endosulfan, and Zectran®. Rotenone, carbophenothion, and toxaphene at high dosages may doubtfully be placed

[2] The proprietary materials used in this study are listed at the end of this paper.

Table 1.—The contact toxicity[a] of pesticide residues to some adult parasitic Hymenoptera and predatory Coccinellidae.

Material	Formulation	Dosage, Lbs. Actual/100 Gal.	Deposit Mg. G./Sq. Cm.	Persistence	Parasitic Hymenoptera[d] (A)	(B)	(C)	(D)	(E)	Predatory Coccinellidae[d] (F)	(G)	(H)	(I)	(J)	(K)
Aldrin	40% W.P.	.50	6.44	L-M	M	M	H	M	M	0-L	L-M	L-M	L	L-M	0
Aramite ®[b]	15% W.P.	.45	5.79	L-M	L-M	0-L	L	0	L	0-L	0	0-L	0	L	0
BHC	10% γW.P.	.20γ	2.57	M-H	M	M-H	H	H	H	M	0-M	H	H	M	L
Bordeaux mixture	10-10-50 2 pkg.	40.0	579.15	H	0	0-L	0	0	0	0-L	0	0-L	0	0-L	0
Calcium arsenate	70% $Ca_3(AsO_4)_2$	3.0	40.62	H	0-L	L-M	0	L	M	M	0-M	M	M-H	M	L
Captan	50% W.P.	1.0	12.87	H	0-L	L	0	0	0	0	0	0-L	0	0	0
Carbophenothion	25% W.P.	.25	3.22	M-H	H	H	H	H	M	L-M	H	L-M	M	M	M
Chlorobenzilate	25% W.P.	.25	3.22	H	0-L	0-L	0	0	0	0	0	0	0-L	0	0
Chlordane	40% W.P.	1.0	12.87	M	M-H	M	H	M	M	0-L	0	L	0-L	M	0
Chlorthion ®	25% W.P.	.50	6.44	M	H	H	H	H	H	0-L	H	L-H	H	M-H	H
Cryolite (natural)	95%	2.85	36.68	H	0-L	0-L	0	0	0	0	0	L-M	0-L	L	0
DDT	50% W.P.	1.0	12.87	H	H	H	H	H	H	H	L	M	H	L-M	0-L
DDT+Kerosene	50% W.P.	.75+1.5 gal.	9.65+kero.	H	H	H	H	H	H	M	L	L-M	M	L-M	0-L
Delnav®	25% W.P.	.25	3.22	H	H	H	H	H	H	0-L	M	L-M	M-H	H	M-H
Demeton	2 lbs./gal. E.C.	.25	3.22	L-M	H	M-H	M-H	M	H	0-L	0-M	L-M	M-H	0-L	L-M
Diazinon	25% W.P.	.50	6.44	M	H	H	H	H	M	L-M	H	M	H	H	M-H
Dieldrin	50% W.P.	.50	6.44	M-H	M-H	M-H	H	M-H	M	M	0-L	L-M	M	M	0-L
Dilan ®	25% W.P.	1.0	12.87	M	H	H	M-H	H	H	H	H	H	H	H	H
Dimethoate	4 lbs./gal. E.C.	.50	6.44	M	H	H	H	H	H	L-M	H	M	H	H	M
DN-111®	20% W.P.	.20	2.57	M	0-L	0-L	0-L	0	0	0-L	0	0-L	0-L	L	0
Dylox ®	50% Sol. P.	.50	6.44	L	H	H	H	H	0	0	M-H	0-L	M	L	L-M
Endosulfan	25% W.P.	.50	6.44	M-H	H	H	H	H	H	H	H	H	H	H	M
Endrin	50% W.P.	.50	6.44	H	H	H	H	H	H	H	H	H	H	M	M
Ethion	25% W.P.	.50	6.44	M-H	H	H	H	H	M	M	M	M	H	H	M
Ferbam	67% W.P.	1.34	17.24	H	0-L	0	0	0	0	0-L	0	0	0	0	0
Genite ®	50% E.C.	1.0	12.87	L-M	M-H	L-M	M	M	M	0	0	0	0	0-L	0
Guthion ®	25% W.P.	.50	6.44	M	H	H	H	H	H	H	H	H	H	H	M
Heptachlor	25% W.P.	.50	6.44	M	M-H	M	H	M-H	H	0-L	0	L-M	0	L-M	0-L
Karathane ®	25% W.P.	.25	3.22	H	H	M-H	L-M	M	H	0	0	0	0	L	0
Kelthane ®	18.5% W.P.	.50	6.44	M-H	M	M	M	L-M	M	0-L	0	L	L	L	0
Lead arsenate (acid)	32% As_2O_5	3.0	40.62	H	0	0-L	0	0-L	0	0-L	0-L	0-L	L-M	0-L	0
Lindane[c]	25%γ W.P.	.25γ	3.22γ	L-M	L-H	M-H	H	0-H	L-H	0-L	0	L-H	L-M	L	0
Lime-sulphur soln.	29% CaS_x	5.0 gals.	536.48	H	H	M	L-M	M	M	0-L	0	0-L	0	0	0
Malathion	25% W.P.	.50	6.44	M	H	H	H	H	H	H	H	H	H	H	H
Malathion+oil	25% W.P.+L.M. oil	.25+1.67 gal.	3.22+oil	M	H	H	H	H	H	H	M-H	M-H	M-H	L-M	M-H
Methoxychlor	50% W.P.	1.0	12.87	M-H	M-H	H	M-H	H	H	H	H	H	H	H	M
Naled	8 lbs./gal. E.C.	.50	6.44	L	H	M	H	M-H	0	0-L	H	0-L	H	M	M-H
Neotran ®	40% W.P.	.60	7.70	M	M	M	L-M	M	M-H	0	0	0-L	0-L	L	0
Nicotine sulphate soln.	+Cal. caseinate	.75 pt.	10.06	L	L	0	0-L	0	0	0	0	0-L	0-L	0	0-L
Oil, light-medium	92% UR. E.	1.67 gals.	157.12	L	L	0-L	0	L	0	0	0	0-L	0	0	0
Ovex	50% W.P.	.75	9.66	M	L-M	L	0-L	0	L	0	0	0-L	0-L	L	0
Parathion	25% W.P.	.50	6.44	M	H	H	H	H	H	H	H	M-H	H	H	H
Parathion+oil	25% W.P.+L.M. oil	.25+1.67 gal.	3.22+oil	M	H	H	H	H	L	L	H	L-M	M	L-M	M-H
Perthane ®	25% W.P.	.50	6.44	M-H	M	M	M-H	M-H	M	0	0	0-L	0	L	0-L
Phosdrin ®	4 lbs./gal. E.	.25	3.22	L	H	H	H	H	M	M-H	H	M-H	H	H	H
Phosphamidon	4 lbs./gal. E.	.25	3.22	L-M	H	H	H	H	H	M	M	H	H	H	M
Pyrophyllite	powder	4.0	51.48	H	0	0	0	0	0	0	0	0	0	0-L	0
Ryania	100% gr. stems	4.0	51.48	M	0	0	0-M	0	0-L	0	0-L	L-M	0-L	0	0
Rotenone	6.4% from gr. root	.256	3.30	L-M	H	M	M	H	H	H	0-L	H	H	H	0-H
Sabadilla	20% gr. seed	.8	10.30	L	0	0	0	0	0	0-L	0	0-L	0	0-L	0
Schradan	4 lbs./gal. E.C.	.25	3.22	L-M	H	M	M	M-H	L	0	0	L	L-M	L	0-L
Sevin ®	50% W.P.	.50	6.44	M-H	H	H	H	H	H	H	H	H	H	H	H
Sulphenone ®	50% W.P.	1.5	20.31	H	M-H	M	H	M	M	M	0-L	M	L-M	L-M	0-L
Sulphur	325 mesh W.P.	3.0	40.62	H	H	M	L-M	M-H	M	0-L	L	L	0-L	0	0
Tartar emetic+sugar	100%	2.0+2.0	25.74	L-M	L	L	0	0	0	0	0	0-L	0-L	0-L	0
TDE	50% W.P.	1.0	12.87	M-H	H	H	H	M-H	H	L	0-L	L-M	M	M	0-L
Tetradifon	25% W.P.	.37	4.75	H	0	0	0	0	0	0	0	0	0	0-L	0
TEPP	20% E.	.25	3.22	L	M-H	L-M	L-M	L-M	0-L	0-L	0	L	L	0	0-L
Toxaphene	40% W.P.	2.0	25.74	M-H	H	H	H	H	H	M	L-M	M	M	M	L
Zineb	75% W.P.	1.3	16.73	H	0	0	0	0	0-L	0	0	0	0-L	0	0
Zectran ®	25% W.P.	.50	6.44	M	H	H	H	H	H	H	H	H	H	H	H

[a] Toxicity expressed as H = High toxicity, i.e. LT-50 < 24 hours.
M = Medium toxicity, i.e. LT-50 > 24 hours and < 100 hours.
L = Low toxicity, i.e. LT-50 > 100 hours.
0 = No toxicity.

[b] ® = Registered names chemically defined at end of paper.

[c] Variation in pesticide samples made it impossible to assess this material precisely.

[d] A = *Aphytis lignanensis*; B = *Metaphycus luteolus*; C = *Spalangia drosophilae*; D = *Metaphycus helvolus*; E = *Leptomastix dactylopii*; F = *Cryptolaemus montrouzieri*; G = *Hippodamia convergens*; H = *Lindorus lophanthae*; I = *Rodolia cardinalis*; J = *Stethorus picipes*; K = *Hippodamia quinquesignata*.

in this group. Lindane posed a special problem in assessment inasmuch as four of the commercially drawn samples provided high toxicity while four others provided virtually no kill. This was the only material in which sample lots appeared to vary considerably.

Virtually none of the materials tested were toxic to coccinellid adults while showing no toxicity to parasitic Hymenoptera. The material most closely approaching this was calcium arsenate. In contrast, many of the pesticides were toxic to parasite adults but less destructive to the adult coccinellids, Among these were Genite 923®, Karathane®, Kelthane®, lime sulphur, Neotran®, and sulphur. To a lesser extent this specificity was indicated with aldrin, chlordane, DDT, demeton, Dylox®, heptachlor, schradan, and Perthane®.

Pronounced differences in susceptibility of the various parasite species to individual pesticides, i.e., specificity within the parasite group, was shown with only 2 materials. The most striking example of this occurred with *Leptomastix dactylopii* which, as previously mentioned, was tolerant to a number of the organic phosphates. Differences in toxicity to various parasites occurred to some extent in the tests with calcium arsenate. Contrarily, specificity in coccinellids was evident with many materials including BHC, calcium arsenate, carbophenothion chlordane, Chlorthion®, cryolite, DDT, Delnav®, demeton, diazinon, dieldrin, dimethoate, Dylox®, heptachlor, lead arsenate, lindane, naled, parathion at the lower dosages, phosphamidon, Perthane®, rotenone, schradan, Sulphenone®, TDE, and toxaphene.

The data in table 1 discloses no detectable difference in toxicological specificity between the closely allied parasitic species *Metaphycus luteolus* and *M. helvolus*. Likewise the only difference in the response of the closely related *Hippodamia* spp. was that *H. quinquesignata* was slightly more tolerant to a number of the toxicants. The general tolerance shown by this species might be due to its restrained activity during the tests.

The toxicity of the test materials commonly regarded as stomach poisons was of particular interest since there is little valid information as to how these substances affect entomophagous species. Lead arsenate's somewhat specific toxicity to *Rodolia cardinalis* was in accord with its known destructive effect on this species in the field, while the ineffectiveness of cryolite upon *Cryptolaemus montrouzieri* contradicted field records. The destructive effect of calcium arsenate appeared too rapid to be attributed to accidental ingestion and stomach poison activity. How these toxicants affect entomophagous insects as stomach poisons requires further study.

The proprietary materials used in this study were:

Aramite® (2-(*p-tert*-butylphenoxy)isopropyl 2-chloroethyl sulfite)

Chlorthion® (*O*-(3-chloro-4-nitrophenyl) *O,O*-dimethyl phosphorothioate)

Delnav® (a mixture of 2,3-*p*-dioxanedithiol *S,S*-bis (*O,O*-diethyl phosphorodithioate)(70%) and related compounds)

Dilan® (a mixture of 1 part of 1,1-bis (*p*-chlorophenyl)-2-nitropropane (Prolan®) and 2 parts of 1,1-bis(*p*-chlorophenyl)-2-nitrobutane(Bulan®))

DN-111® (4,6-dinitro-*o*-cyclohexylphenol, *N,N*-dicyclohexylamine salt)

Dylox® (dimethyl 2,2,2-trichloro-1-hydroxyethylphosphonate)

Genite 923® (2,4-dichlorophenyl benzenesulfonate)

Guthion® (*O,O*-dimethyl *S*-(4-oxo-1,2,3-benzotriazin-3(4H)-ylmethyl) phosphorodithioate)

Karathane® (a mixture of dinitro(1-methylheptyl)phenyl crotonate (78%) and dinitro (1-methylheptyl)phenol and retaled compounds (22%))

Kelthane® (1,1-bis(*p*-chlorophenyl)-2,2,2-trichloroethanol

Neotran® (bis(*p*-chlorophenoxy)methane)

Perthane® (a mixture of diethyl diphenyl dichloroethane (95%) and related reaction products (5%))

Phosdrin® (a mixture of the *alpha* isomer of 2-carbomethoxy-1-methylvinyl dimethyl phosphate (not less than 60% and related compounds (not more than 40%))

Sevin® (1-naphthyl *N*-methylcarbamate)

Sulphenone® (*p*-chlorophenyl phenyl sulfone)

Zectran® (4-dimethylamino-3,5-xylyl methylcarbamate)

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