CARBAMATE INSECTICIDES

Significant Developments in Eight Years with Sevin Insecticide

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Sevin insecticide (carbaryl), used to control over 150 major pests, is a reliable substitute for chlorinated hydrocarbons in certain cases of resistance development. Notable exceptions are the housefly and spider mite. Its use as a chemical fruit thinner for apples is an interesting diversification. An extensive program of state, federal, and industrial research has resulted in federal registration for most food crops grown in the United States. Because residues are not highly persistent, Sevin is used for preharvest application.

THE development of resistance by certain insect species to chlorinated hydrocarbon insecticides has aroused research interest in alternative chemical classes. The handling hazard of many organophosphates emphasized the need for safer materials. 1-Naphthyl *N*-methylcarbamate (carbaryl, Sevin) was different chemically and less hazardous than many common insecticides. It was synthesized by Lambrech (*17*) in 1953 and subjected to laboratory and preliminary field tests for two seasons (*13*). In 1956 Sevin was released for testing by government specialists in agricultural experiment stations. In 1958 it received the first official recommendation and was sold on an experimental basis.

This article reviews product development experiences with Sevin rather than production, formulation, or analytical procedures.

Toxicology

Of the many insecticidal carbamates investigated as to mammalian toxicity, Sevin is the least hazardous. By analogy, one could compare its relationship to other carbamates with that of malathion to other organophosphates, or methoxychlor to other chlorinated hydrocarbons. The toxicology of Sevin has been pursued continuously at Mellon Institute since 1954. Carpenter and coworkers (*5*) reviewed their findings to 1961, showing that this cholinesterase inhibitor was a relatively safe pesticide as measured against the usual laboratory animals in standard acute and chronic tests. Special studies have disclosed no evidence of carcinogenic potential, no potentiation in joint action with other pesticides, and no adverse effects on animal reproduction. Metabolism studies on guinea pigs showed that a substantial portion of an oral dose promptly appeared in urine as free or conjugated 1-naphthol. This was also demonstrated in tests on dairy cattle by Whitehurst and others (*21*). Dorough and Casida (*9*) have demonstrated additional nonhydrolytic pathways of metabolism. While the identity of potential metabolites in animals is still tentative, this would appear to be of no pharmacological significance because these metabolites would have been formed in the rats and dogs employed in long-range feeding studies. "No effect" levels in these species are reported as 200 and 100 p.p.m., respectively.

Feeding trials by the Fish and Wildlife Service (*8*) and others (*20*) demonstrated that quail, pheasant, chickens, and turkeys could tolerate 10 to 100 times as much Sevin as compounds like DDT, dieldrin, and heptachlor. Effective commercial applications of Sevin for gypsy moth (*7*) and grasshopper control by the Plant Pest Control Division, USDA, and others have resulted in no observable effect on songbirds or nestlings. When used as recommended in direct application to poultry (*12*), no changes were seen in egg production, hatchability, chick survival, or growth.

Published data from the Public Health Service (*14*) and other agencies show Sevin to be less toxic than DDT and many other insecticides to trout, salmon, bluegills, and killifish. It is toxic to certain fresh water fish-food organisms, but populations of these have not been reduced in the field where direct application to waterways is avoided.

Sprays, dips, and dusts applied to cattle, hogs, sheep, goats, and ponies have shown safe margin between effective ectoparasite control and the onset of toxicity. Reduction in weight gains has not been noted in young farm animals exposed to recommended dosages. Tick and flea control work has resulted in accumulation of toxicity data on dogs and cats. Sevin has now been used for some years on pets and farm animals.

Best and Murray (*3*) have published observations on men employed in the Sevin production unit for 19 months. No evidence of adverse effects was found, even though the presence of 1-naphthol conjugates in urine made it obvious that certain employees were absorbing considerable amounts of Sevin.

About 50 cases of intoxication, allegedly due to Sevin, but no human fatalities, have been reported. Less than a dozen of these showed clear-cut cholinesterase inhibition. Three were due to accidental ingestion by children; one, to an intentional overdose by an experimenting scientist; the rest, to overexposure to dusts of sprays by process workers, formulators, or applicators. In the latter, onset of illness consistently resulted in cessation of work and of further exposure. Symptoms were usually subsiding by the time medical observation was obtained and were gone within 3 or 4 hours, whether or not atropine was administered. Because of the spontaneously reversible nature of Sevin as a cholinesterase inhibitor, we do not expect to encounter human fatalities, so long as normal use precautions are followed.

Resistance

The ability of a carbamate to control insects that have developed resistance to other classes of compounds, and the possibility of acquired insect resistance to carbamates, are points of great interest. Laboratory selections at the LD_{70} level demonstrated (*18*) no development of resistance in 14 generations of Mexican bean beetle, which is by nature highly susceptible to Sevin. The housefly, against which Sevin is relatively ineffective at the onset, became completely tolerant after five to 10 generations of similar exposure. Cross resistance in strains of houseflies resistant to DDT and parathion was first demonstrated by Eldefrawi (*11*), but was not noted in tests against chlordan-resistant roaches or in USDA tests against resistant body lice.

In 6 years of practical experience, Sevin has effectively controlled codling moth resistant to DDT, Egyptian cotton leafworm resistant to toxaphene, Colorado potato beetle resistant to dieldrin, and numerous other insects. Acquired resistance to Sevin by the grape leafhopper in one locality in California was recorded during this period. In Texas (*1*) the tobacco budworm has become moderately resistant to Sevin, but the degree of resistance is not so great as to DDT. Sevin is a useful alternative in the battle against resistance but not a complete answer to this problem.

Insect Control Uses

Sevin controls a broad spectrum of insects. It has been accepted for registration by the USDA and foreign governments for the control of more than 150 injurious species on over 100 crops and ornamental plants and on certain domestic animals.

Approximately 40% of the millions of pounds used worldwide today is applied to cotton for control of several bollworms, leafworms, weevils, and other pests. Fruit, forage, and vegetable crops share the major balance of total consumption. Use in cattle dips for tick control is growing in foreign countries.

Usual dosages range from 1/2 to 2 pounds of active ingredient per acre on row crops and 3 to 12 pounds per acre on tree fruits applied as wettable powder, flowable, granular bait, or dust formulations. The lack of a true emulsion concentrate has been a deterrent to greater acceptance and has promoted the development of microfine wettable powders compatible with emulsion concentrates of many other pesticides.

Significant exceptions to the pest control spectrum are weakness on aphids and complete lack of effect on most spider mites. Population buildup of spider mites and certain aphids has occurred following Sevin usage in some instances. Tests indicate that this is due to predator and parasite kill and not to direct effect on the mites (*19*) or aphids. Surprisingly, Sevin is highly effective against the closely related arachnid ectoparasites and certain phytophagous eriophyid mites. It is notably weak against dipterous insects, although certain tests against adult mosquitoes have shown outstanding promise.

Plant Response

A satisfactory margin of safety exists for most crop plants at recommended use rates, but is narrowed under wet or very humid conditions for several days following application. The tendency for leaf burn is accentuated by combining wettable powders of Sevin with emulsion concentrates of organophosphates but by proper observation of known precautions, this can normally be avoided. A recent case of specific incompatibility which results in phytotoxicity is the combination of Sevin with the herbicide propanil when the two are used in combination or in sequence for the control of insects and weeds in rice. Specific cases of direct plant phototoxicity at insect control dosages are rare, but have occurred on watermelons in Florida and on the ornamental Boston ivy.

No adverse effects on vegetable or fruit flavor have been encountered. The specific chemical thinning effect of Sevin on apples is worthy of note (*2*). Sevin is more predictable as a thinner for many apple varieties than the well known hormone chemicals and this use is now accepted for registration by USDA and generally recommended and used in the major apple producing areas. This phenomenon of chemical thinning with Sevin has been investigated on many other fruit and vegetable crops; it is not known to occur except on apples.

Residues

The residual characteristics of Sevin are a significant factor. While effective insect control normally extends from 5 to 15 days, the half life of residues on most crops averages 3 to 4 days. Degradation in water is even more rapid. Persistence in soil is not extended; the half life is about 1 week.

Warm-blooded animals rapidly excrete absorbed Sevin (*5*). Analyses of meat, fat, and other tissues of farm animals (*6*) and poultry (*16*) demonstrate that residues of significance persist no more than 7 days and are often undetectable in much less time.

The occurrence of Sevin, naphthol, and naphthol conjugates in the milk of cows on diets containing this insecticide has been investigated in several laboratories (*4, 10, 15, 21*). Within the sensitivity of existing methods, no contamination has been observed. Following the submission of these results to the Food and Drug Administration in 1961, that agency established tolerances of 100 p.p.m. in alfalfa and other forages commonly used in diary feed. Today, when chlorinated hydrocarbons are restricted or banned from use on forage, or even adjacent to forage where dust or spray drift could result in contamination, insecticides like Sevin have become useful alternatives for crop protection.

Joint chairmen of the Symposium on Carbamate Insecticides were W. W. Kaeding and T. R. Fukuto. The keynote address by R. L. Metcalf and T. R. Fukuto appears on page 220.

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