TABLE 3—Average Residues of Two Formulations of Diazinon on Fruit and Foliage of Cherry Trees and on Foliage of Apple Trees Immediately after One Application of a Dilute Spray.

Materials	Amount per 100 Gal.	Residues, mmg. per sq. cm.		
		Cherry*		Apple**
		Fruit	Foliage	Foliage
Diazinon, 25% emulsifiable concentrate	2 lb.	2.0	0.4	—
Diazinon, 25% wettable powder	2 lb.	3.5	0.7	2.9

* Means of two replicates.
** Mean of eight replicates.

Summary

Data are given showing the amount of Diazinon residues on cherries and apples, and Sevin residues on apples. Results indicate that Diazinon residues on cherries were similar for a wettable powder formation and an emulsifiable concentrate formulation. The addition of a surfactant to Diazinon and Sevin sprays on apples did not affect the magnitude of the initial residues nor the persistence of the spray residues. Sevin residues on apples were more persistent than Diazinon residues.

The author is indebted to F. E. Brinton for assistance in sampling and chemical analyses.

References

Anonymous. 1959. Control of tree-fruit pests and diseases. British Columbia Dept. Agr. poster, p. 1.

Geigy Agricultural Chemicals. 1956. Methods of analysis for Diazinon. Bulletin, pp. 9-12. New York, N.Y.

Gunther, F. A., and R. C. Blinn. 1955. Analysis of insecticides and acaricides, Pp. 23-24. Interscience Publishers, Inc., New York.

Morrell, C. A. 1957. Trade information letter No. 157. Canada Dept. Natl. Health and Welfare. Mimeo., pp. 1-12.

RESISTANCE TO DDT IN THE CODLING MOTH IN BRITISH COLUMBIA[1]

J. MARSHALL[2]

In 1934 Hough (5) determined that there was considerable variation in the ability of larvae of the codling moth, *Carpocapsa pomonella* L., from Colorado and from Virginia, to penetrate deposits of lead arsenate, and of several other codling moth insecticides. He attributed the variation to difference in vigour. Whatever the reason, from that time until the beginning of the DDT era in orchard pest control in 1946, evidence mounted that lead arsenate was gradually losing its effectiveness in many areas where the insect was a serious pest.

Particularly in arid, or semi-arid, areas such as the Okanagan Valley of British Columbia, DDT was a spectacular success; even indifferent application of the new insecticide proved adequate (6). Orchardists brought to the brink of ruin by the codling moth became successful again, and serious loss of fruit from codling moth injury became a thing of the past. But five or six years later there were hints of trouble. Extra applications of DDT were becoming common although weather conditions were not very favourable for the development of the insect. Spraying technique, however, had radically changed between 1949 and 1952 (7).

[1] Contribution No. 5 from the Regional Research Station, Canada Department of Agriculture, Summerland, British Columbia.

[2] Entomologist.

Air-blast spraying had replaced hand-gun spraying, and some of the new machines were woefully inadequate. We hoped that the trouble lay in the spray equipment, or in its operation.

Then came a disturbing experience. While visiting the deciduous fruit districts of Australia in 1954 I was shown an orchard in the Paracombe district of South Australia that was very heavily infested by the codling moth, although it had received ten thorough applications of DDT. Satisfied that the insecticide was up to strength, the Chief Horticulturist for South Australia, Mr. A. G. Strickland, was of the opinion that the codling moth in that orchard had become resistant to DDT. His opinion was experimentally confirmed by Smith (8).

Shortly afterwards Cutright (2) showed that the codling moth had become resistant to DDT in an orchard in Ohio. A year later Glass and Fiori (3) demonstrated that the same thing had happened in an orchard in New York State; and the following year Hamilton (4) reported that DDT-resistant codling moth was present in two orchards in the State of Washington. The latest published evidence of what is evidently an accelerating tendency comes from California where Barnes (1) has demonstrated the existence of a strain of the codling moth that is about four times as hard to kill with DDT as a strain that had not previously been exposed to DDT (L. D. 50 four times as great).

In British Columbia we continued to hope that reports of increasing codling moth infestations could be ascribed to faulty spraying, as indeed most of them appeared to be. But in June 1958 came word of a situation in an orchard near Kelowna that was evidently in a different category. Despite the application of four first-brood sprays of 50 per cent DDT wettable powder at the recommended dosage of 12 pounds per acre, about half of the crop was infested by codling moth larvae of the first brood by mid-June. This, in fact, was a considerably heavier infestation than in the non-sprayed trees in the Entomology Laboratory orchard at the same date. Without delay we commenced a laboratory experiment to determine if, finally, we had to deal with DDT-resistance.

Moths were reared simultaneously from infested apples taken from the Kelowna orchard (designated as Glenmore stock), and from apples taken from either the Entomology Laboratory orchard, or from a relatively isolated abandoned orchard (designated as laboratory stock). The laboratory orchard, from which about 80 per cent of the laboratory stock was taken, had never been sprayed with DDT, nor any other chlorinated hydrocarbon. Although, to the best of our knowledge, the abandoned orchard had received no DDT, it is possible that, for several years after the introduction of DDT (in 1946), it had received DDT in limited amount.

Female moths from both stocks were allowed to lay eggs on waxed paper. Small pieces of paper hearing a total of 5 or 10 eggs, about to hatch, were pinned to non-sprayed apples, and to apples that had been sprayed to the beginning of drip with a water-suspension of 50 per cent DDT wettable powder and then allowed to dry. Spraying was done with a small De Vilbiss atomizer under constant air pressure of 15 pounds per square inch. Before the apples were sprayed the calyx basins and the stem basins of the fruits were filled with melted paraffin wax to restrict entries to a uniformly-sprayed surface. The apples were suspended by threads from racks in the insectary (Fig 1), and examined for codling moth entries two weeks after the eggs had been pinned to them. In all, 3000 eggs were used in the experiment.

The apples, variety Spartan, were sprayed with three concentrations of 50 per cent DDT wettable powder (Fig. 2): 0.5 gram, 1.5 grams and 4.5 grams per liter — amounts roughly equivalent to 4 pounds, 12 pounds and 36 pounds per acre. Chemical analyses of the apples showed the following

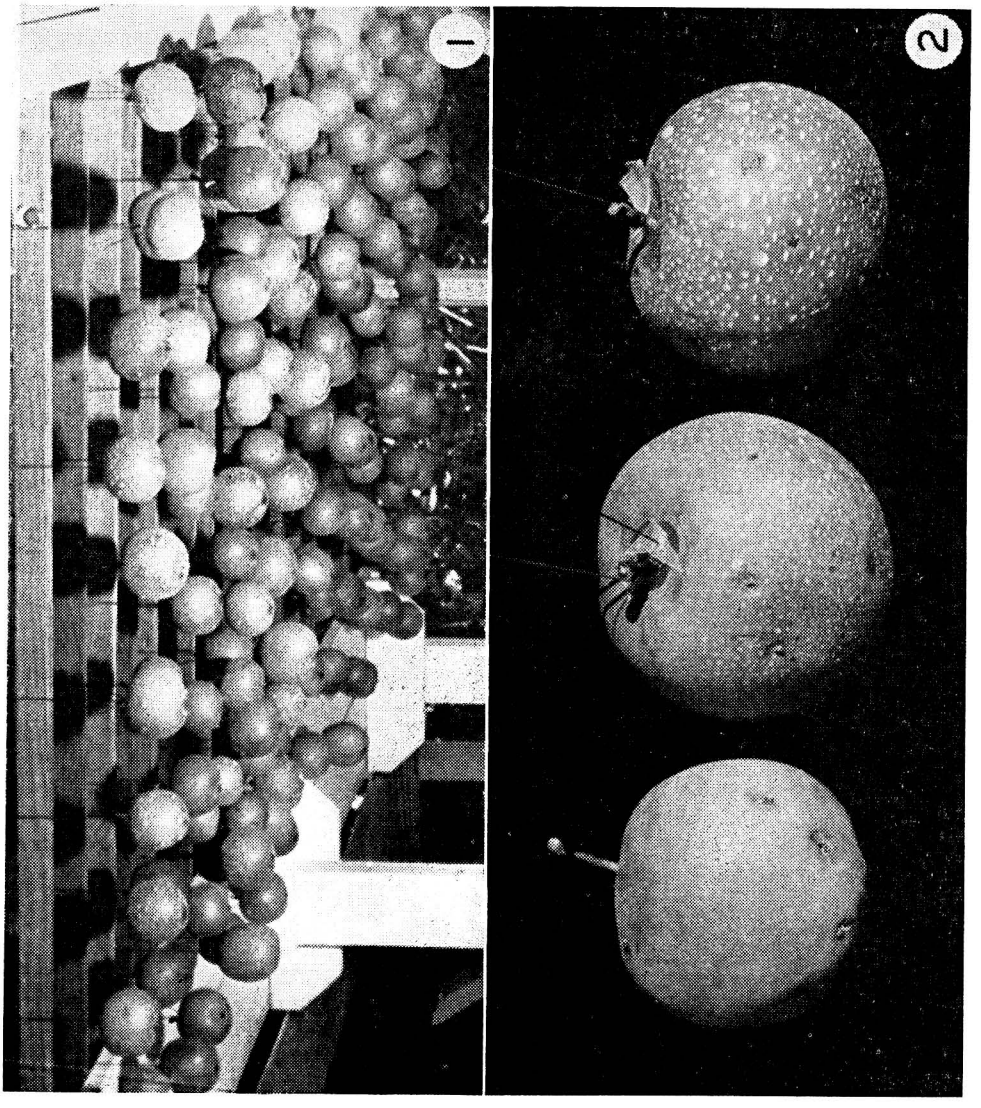

Fig. 1.—Apples suspended by threads in insectary for codling moth entry.

Fig. 2.—Apples sprayed with three concentrations of DDT showing deposits and codling moth entries.

average DDT deposits as parts per million: 1.07, 3.61, and 7.61 respectively. Analysis of the commercial 50 per cent DDT wettable powder that was used in the experiment showed it to be as guaranteed: Actual DDT 50 per cent, para para isomer content of the DDT 80 per cent.

The eggs of the two stocks of insects hatched in approximately the same numbers, 75.2 per cent to 98.7 per cent according to date of deposition. The larvae of the laboratory stock were just as capable of penetrating non-sprayed apples as those of the Glenmore stock (Table 1); presumably, therefore, they were just as vigorous. This is contrary to Hough's conclusions of twenty-five years ago with Colorado larvae resistant to a number of insecticides, and with non-resistant Virginia larvae; he found the non-

TABLE 1. Entries by resistant (Glenmore stock) and non-resistant (laboratory stock) codling moth larvae in non-sprayed and in DDT-sprayed apples.

DDT 50% w.p. gm./1.	Equivalent pounds per acre	DDT deposit p.p.m.	Stock	No. eggs	Entries % Non-sprayed apples	Entries % DDT-sprayed apples
0.5	4	1.07	Glenmore	300	91.4	89.6
			Laboratory	300	85.8	10.0
1.5	12	3.61	Glenmore	600	86.0	65.1
			Laboratory	600	86.1	4.4
4.5	36	7.61	Glenmore	600	90.4	49.4
			Laboratory	600	90.9	0.8

resistant larvae less vigorous. On the other hand, the laboratory stock larvae were far less capable of penetrating a DDT deposit than the Glenmore ones. The capacity of the Glenmore larvae to enter fruit sprayed with DDT at a dosage roughly equivalent to 36 pounds of 50 per cent wettable powder per acre was the more striking because the spray deposit was more uniform than in the orchard, and so, presumably more effective. Actually, at that dosage, three times as great as the official recommendation, over fifty times as many of the Glenmore larvae made successful entries as did the laboratory larvae.

Although the codling moth appears to be more difficult to control in the Glenmore orchard than in any other orchard in British Columbia, several growers in the Osoyoos, Oliver, and Keremeos areas have lately been having great trouble in keeping the insect at a low level, despite as many as six applications of DDT at recommended dosage. Hundreds of other growers are having to apply from one to three more codling moth sprays than they found necessary for some five years after DDT came into general use. In view of the clear experimental evidence of the development of resistance to DDT in the Glenmore orchard, and the strong circumstantial evidence of grower experience, it is evident that, to a varying degree, the effectiveness of DDT against the codling moth is declining.

We are concerned with both the genetical aspects of this problem and the role of the orchardist in it. Is the grower's role a passive one, or might his spraying affect the rate of development of resistance to insecticides? Will a low concentration of an insecticide select resistant strains of an insect more rapidly than a high concentration? Are trees, oversprayed on the bottoms and undersprayed on the tops, more likely to accelerate the selection of insecticide - resistant strains of insects than trees unformly covered with spray mixture? Is it desirable to use one insecticide for several years, then, before insecticide-resistance becomes evident, change to another for several years? Is a mixture of insecticides of significantly different chemical composition preferable to a single insecticide? Are highly toxic insecticides likely to select resistant strains of insects more rapidly than less potent ones? These have become significant questions for the fruit grower, and doubtless they will become even more so while chemical control remains our main line of defence against orchard pests. In an attempt to provide answers a new project is underway in which the Entomology Laboratories at Vineland Station, Ontario, and at Summerland, British Columbia, are collaborating.

Summary

1. The presence of a strain of the codling moth resistant to DDT has been experimentally demonstrated in British Columbia.
2. Over 50 times as many larvae from the resistant strain penetrated a heavy deposit of DDT as did larvae from a strain that had not been annually subjected to DDT sprays.

3. The fertility of the eggs of the two strains did not differ; nor did the capacity of the two stains of larvae to penetrate non-sprayed fruits.
4. DDT-resistance is evidently fairly widespread in the orchards of the South Okanagan area, but the degree of resistance is variable.

Acknowledgments

Much of the work in this experiment was done by these members of the staff of the Summerland Entomology Laboratory: Dr. M. D. Proverbs, Messrs. K. Williams, J. Newton and J. Ogilvie, and by Mrs. Bernice McDonald.

References

1. Barnes, M. M. 1958. A strain of codling moth in California resistant to DDT. J. Econ. Ent. 51: 693-694.
2. Cutright, C. R. 1954. A codling moth population resistant to DDT. J. Econ. Ent. 47: 189-190.
3. Glass, E. G., and B. Fiori. 1955. Codling moth resistance to DDT in New York. J. Econ. Ent. 48: 598-599.
4. Hamilton, D. W. 1956. Resistance of the codling moth to DDT sprays. J. Econ. Ent. 49: 866-867.
5. Hough, W. S. 1934. Colorado and Virginia strains of codling moth in relation to their ability to enter sprayed and unsprayed apples. J. Agr. Res. 48: 533-553.
6. Marshall, J. 1952. Applied entomology in the orchards of British Columbia. Proc. Ent. Soc. British Columbia (1951). 48: 25-31.
7. Marshall, J. 1958. Concentrate spraying in deciduous orchards. Canada Dept. Agr. Pub. 1020. **pp.** 1-47.
8. Smith, L. C. 1955. DDT-resistant codling moth. J. Dept. Agr. South Australia 59: 12-15.

OUTBREAKS OF GRANARY WEEVILS IN HOMES

G. J. SPENCER

University of British Columbia, Vancouver, B.C.

I have twice encountered two remarkable outbreaks of *Sitophilus granarius* Linn. the granary weevil, in homes in Vancouver; in both cases the telephoned reports were so alarming that I made special trips to investigate and in neither instance could I account for the situation.

In the first case, beetles had been issuing from under the quarter-round on the north and east sides of a first-floor back-bedroom for two days and were still streaming southwards and spilling over into the hall. Across the hall in the living room, beetles were slowly crawling around having apparently issued from under the quarter-round on the south side. Most remarkable of all, was a sheet of beetles some four feet across, in the grass of the lawn on the west side, between the houses. There was no indication where these lawn insects came from; they were slowly crawling around and around in a black carpet-like mass.

I enquired of the people if they had any shelled corn or grain stored in the basement or any forgotten sack of cereal of any kind; they had never had anything of the sort in the two years that they had lived there. I inspected the whole basement with greatest care and found no trace of any possible breeding material. I asked if they had ever kept chickens; they said they had not but the previous owners had kept poultry in the garage at the back of the lot, adjoining the lane, two years ago.

The only explanation I could give for this black horde of weevils was that the previous owners had kept sacks of corn or other grain in the basement as poultry feed, that rats or mice had stolen the feed and stored it somewhere in the walls, that the weevils had infested the feed until it was exhausted and were finally issuing from their breeding place in the huge populations which they had at-