Research on DDT for the Control of Agricultural Insects in Hawaii[1]

By F. G. HOLDAWAY

Entomologist, University of Hawaii Agricultural Experiment Station

(Presented at the meeting of July 10, 1944)

For nearly six months research has been in progress at the University of Hawaii Agricultural Experiment Station on dichlorodiphenyltrichloroethane (DDT). Much more work needs to be done before general recommendations for field application can be made. The results to date are so outstanding, however, as to warrant report and discussion at this time.

In this work I have been assisted by the staff of the entomology department of the Experiment Station and, through a cooperative project, by the entomologists of the fruit fly laboratory of the United States Bureau of Entomology and Plant Quarantine. T. Nishida has assisted with work on rose beetle, greenhouse white fly, and melon fly; William C. Look with work on greenhouse white fly, tomato bug, corn earworm, and melon fly; and O. C. McBride and M. McPhail with work on melon fly. In the studies on melon fly in tomatoes, which have involved the complex of insects of tomato, all cooperators have worked as a team. Each cooperator will figure as a co-author of the technical papers on the various problems on which he has worked. The first technical article, one with T. Nishida on DDT for the control of Chinese rose beetle, has already been forwarded to the Journal of Economic Entomology (3).* One with O. C. McBride on the toxicity of DDT for melon fly (6), and one with T. Nishida and William C. Look on the effect of DDT on greenhouse white fly (4) are in preparation.

Greenhouse white fly, *Trialeurodes vaporariorum* (Westwood)

Although DDT, or "gesarol"[2] as it was known when we obtained our first supplies, was secured initially for work on Chinese rose beetle, the first insect on which it was tested was greenhouse white fly, *Trialeurodes vaporariorum*. This insect has been present in Hawaii for over half a century. Since 1941 it has become a limit-

[1]Published with the approval of the Director as Technical Paper No. 126 of the Hawaii Agricultural Experiment Station.

*Figures in parentheses refer to literature cited at the end of the article.

[2]Gesarol is the trade name for certain of the DDT products prepared and supplied by the Geigy Company Incorporated.

ing factor to green bean production in the Waianae section of Oahu where, up to 60 per cent of the green beans grown on this island were normally produced (2). In the latter part of 1943 and in the early part of 1944 devastating injury similar to that in Waianae occurred in the Waiahole district of Oahu, while reports of serious infestations have been received from the islands of Hawaii and Maui. Heavy infestation of green bean have been observed by the writer at Olinda, Maui.

Considerable progress had been made in the development of an oil spray to which synthetic toxicants were added when DDT was first received and included in the tests which were then being conducted at Waiahole. The results showed DDT to be superior to anything studied heretofore.

In this study various amounts of a 20 per cent mixture of DDT[3] were added to a commercial white oil emulsion spray used at a strength of 1:80. The kill of nymphs ranged from 19.2 per cent with DDT 1:800 (3.3 ounces of the 20 per cent concentrate per 100 gallons) to 94.3 per cent with DDT 1:200 (13.4 ounces of the 20 per cent concentrate per 100 gallons). The first mixture represents a concentration of 0.7 ounces of actual DDT per 100 gallons and the second a concentration of 2.7 ounces of DDT per 100 gallons.

In a second study, three replications of each of the following mixtures were studied: white oil emulsion 1:80 plus DDT (20 per cent strength) 1:200 or a concentration of active ingredient of 2.7 ounces per 100 gallons, and oil emulsion 1:60 plus DDT (20 per cent strength) 1:200. Counts made nine days after application indicated a control of 96.4 per cent with the former mixture and a control of 97.9 per cent with the latter.

In a study of DDT applied as a dust[4] and as a spray,[5] without inclusion of oil, it has been found that DDT used in these ways is capable of killing adult white flies and all stages of nymphs; eggs were not killed, while some pupae were killed and others were not. Young leaves free of white fly infestation at the time of application of the DDT have been kept completely free of adults for four days and almost completely free for eight days by a 2 per cent dust. A 1 per cent dust kept clean leaves almost free from infestation for eight days; a spray of 1 pound active ingredient per 100 gallons kept clean leaves almost completely free for six days.

Adults present to the extent of 100 or more per leaflet at the time of application of a 2 per cent dust started falling in a few minutes. In 10 minutes the leaves were almost free. In 37 minutes a total of

[3] Gesarol AKD 20 Spray containing 20 per cent active ingredient and wetting and spreading agents. This form of DDT was apparently not the best for inclusion with the oil emulsion for a scum rose to the top of the spray.

[4] Gesarol AX (3 per cent) dust diluted with talc.

[5] Gesarol AKD spray containing 20 per cent active ingredient.

only six remained on nine leaflets. The effect of a 1 per cent dust was similar, though the action was initially somewhat slower. (Sprays apparently removed the adults mainly by mechanical action.) "Crawlers" hatching from eggs present at the time of application succumbed before becoming 2nd instar nymphs with a 2 and a 1 per cent dust and with a spray of 1 pound active ingredient per 100 gallons.

"Crawlers" and other young nymphs present at the time of application are all killed by a 2 per cent dust within four days, and, although somewhat more slowly, within eight days, by a 1 or a 0.5 per cent dust. Nymphs are all killed within six days by a 2 per cent dust. Data available on the effect of DDT on pupae are somewhat variable. They indicate that some pupae are controlled by DDT while others are not. Some batches of pupae were killed 100 per cent in six days by a dust with as low a concentration as 0.5 per cent and by a spray of 1 pound active ingredient per 100 gallons; on the other hand some batches were not controlled even by a 2 per cent dust. The reason for this variation in survival of pupae has not yet been determined. It would appear that age might be a factor.

Thus the evidence to date indicates that it may not be necessary to use oil for the control of white fly. Subsequent work will determine more conclusively the most satisfactory method of application.

CHINESE ROSE BEETLE, *Adoretus sinicus* Burmeister

Chinese rose beetle, *Adoretus sinicus* (Scarabaeidae) is the most important foliage-consuming insect of green bean. When the beetles are abundant, the leaves are skeletonized. The beetle is also a major insect of Maui red bean, eggplant, and roses, and at times, causes serious injury to Chinese cabbage, broccoli, litchi, corn, peanut, grapes, okra, dasheen, and soy bean. It has been present in Hawaii for at least 48 years.

Over 40 materials or mixtures had been studied in a search for an insecticide to control rose beetle. A cage method, especially devised for work with this insect, was used in these investigations. Toxicity is measured by the survival of a standard number of beetles introduced after materials under test have been applied to the plant, and also by comparative amounts of foliage consumed. The only material found to be highly toxic to rose beetle was acid lead arsenate. Since this chemical commonly causes foliage injury, it has not been recommended for general use on beans, and the search for a material toxic to the beetle without phytotoxic properties has been continued.

DDT was secured especially for trial against rose beetle. The results obtained have been outstanding. After the first night's exposure, mortality was 10 per cent with acid lead arsenate 3 pounds per 100 gallons, 45 per cent with a spray of DDT containing ½ pound of active ingredient per 100 gallons, 65 per cent with a spray of 1 pound active ingredient per 100 gallons, and 82 per cent with a 3 per cent DDT dust. One hundred per cent mortality was secured in three days with the 3 per cent dust, in four days with a spray of 1 pound per 100 gallons, and in eight days with a spray of ½ pound per 100 gallons. With a spray of acid lead arsenate 3 pounds per 100 gallons, 10 per cent of the beetles were still alive at the end of eight days. Later results indicated that a 2 per cent dust is even more toxic than a 3 per cent dust, and a 1 per cent dust is nearly as toxic as a 3 per cent dust. The results indicate that DDT applied as a spray and apparently acting in the main as a stomach poison is more than eight times as toxic to the beetle as acid lead arsenate.

After exposure of one night, mortality with a spray containing ⅛ pound of active ingredient per 100 gallons was twice as great as that secured with a spray of acid lead arsenate of strength 4 pounds per 100 gallons. Thus in the initial stages of the test, DDT was over 32 times as toxic as acid lead arsenate.

The early result with the dusts suggested that the beetles succumb with practically no consumption of the dusted foliage. Moreover, many of the beetles confined with a dusted plant are unable to crawl into the soil after they have been on the plant. This observation has been studied further by introducing beetles into an otherwise empty cage dusted with a 2 per cent dust of DDT.

Fifteen out of 36 beetles (42 per cent) confined overnight were dead the following morning. Those still alive were placed in a clean cage with a clean plant for food. All were dead after eight nights and practically none of the foliage of the clean plant had been consumed. A similar group of beetles subjected to 33⅓ per cent lead arsenate under similar conditions was affected to a negligible extent; after one night one beetle (3 per cent) was dead; after eight nights only five were dead, whereas all were dead after exposure to the DDT dust for a single night. Both these sets of observations suggest that death can follow if the beetles merely walk over a dusted surface.

Studies on the phytotoxicity of DDT in the field have indicated no foliage injury and no reduction of yield from 1 and 2 per cent DDT dust, or from DDT sprays of 2 pounds per 100 gallons and 1 pound per 100 gallons. On the other hand, under some conditions a 3 per cent dust has caused foliage injury. The toxicity studies indicate, however, that 3 per cent dust is stronger than necessary to effect complete and rapid control. Although infestation by rose beetles was low when the studies on phytotoxicity were conducted an increase in yield was secured in the plots treated with DDT.

MELON FLY, *Dacus cucurbitae* Coq.

Melon fly has been present in Hawaii since before 1898 (1). It is a major pest of cucurbits and tomato, and at times, a pest of green bean. To date it has defied control by measures other than cultural control. The most toxic material discovered was tartar emetic, the toxicity of which has been worked out by entomologists of the fruit fly laboratory of the United States Bureau of Entomology and Plant Quarantine. A bait spray of 2 to 4 pounds per 100 gallons effects a kill of 50 per cent of the flies in an average time of 47 hours and a kill of 100 per cent in an average time of 96 hours. Flies which have partaken of tartar emetic are stimulated to early oviposition before they die. Thus tartar emetic is not an ideal material for controlling melon fly, and, in field studies has yielded results of so variable a nature as to prevent its being recommended as a general control measure.

The early test in which DDT was studied as a bait spray by the same method as that used for tartar emetic[6] indicated that it was unsatisfactory; the kill was much slower than with tartar emetic. In observations on DDT for the control of Chinese rose beetle, it was found that beetles walking over dusted leaves apparently succumbed without consuming dusted foliage. This suggested a trial of DDT dust for melon fly control. The initial studies in which the dust was applied to tomato and cucumber plants were not satisfactory since the flies, as a result of positive phototropic responses, congregated on the cages and spent little time on the dusted plants. Results from one of these tests, however, were such as to indicate that the dusts had promise if a satisfactory technique could be devised to demonstrate their effectiveness.

Two different procedures, both of which have proved satisfactory, have been used. In the first, the toxicity of DDT to the flies was measured; in the second, the ability of DDT to protect susceptible fruits was demonstrated. In the first procedure the inside of empty cages was dusted with the DDT dust. Then food and water were introduced followed by the flies. Six replicated tests, each involving 50 flies, were carried out in the insectary at different times with flies from different batches. Flies confined in cages dusted with 1 or 2 per cent DDT dusts started to fall in 15 minutes; 50 per cent were down in less than 2 hours; and all were down in 3 hours. With a 2 per cent dust, the first death occurred 6 hours after the introduction of the flies; all were dead in 24 hours. With a 1 per cent dust all were dead in 32 hours.

For comparison with DDT, nicotine and rotenone have been studied by the same method as that used for DDT dusts. Flies have been subjected to 3 and 4 per cent nicotine dusts and to rotenone dusts of 0.5 and 1 per cent concentration. Flies that walked over

[6]This method is described by Plummer (8).

a surface dusted with nicotine dust dropped rapidly but revived; flies that walked over a surface dusted with rotenone were apparently affected to a slight extent but were not killed. Flies which fall as a result of DDT do not revive when removed to a clean cage. Thus flies are put out of action at the time at which they fall, namely in from 15 minutes to 3 hours.

In the second procedure young cucumbers, approximately half-grown, were dusted with 2 per cent DDT dust and confined with 50 flies of approximately equal numbers of males and females. The undusted fruits yielded 32 larvae. The dusted fruits yielded none. Thus DDT is apparently capable of protecting fruits from oviposition.

It is apparent that DDT dusts are yielding toxicity results superior to those secured heretofore with tartar emetic. It also appears that if the normal place of oviposition is covered with a film of dust, oviposition is apparently prevented. The promising results secured to date in the cage tests are being applied to field studies. Such results as have been secured to date from preliminary studies in the field are gratifying, and hold out promise of ultimate success.

TOMATO BUG, *Cyrtopeltis varians* Distant

Tomato bug, which causes blossom shedding, has been in Hawaii since 1924—a comparatively short period of years. It is an insect of the low elevations and especially of the summer months. During the last two or three years it has assumed much greater importance, and must be ranked as a major insect, for, with the introduction of the variety Bounty which is suitable to low elevation conditions, tomato production has increased to a considerable extent under the conditions which are favorable to the bug.

Pyrethrum dust containing 2 per cent pyrethrins, rotenone dust 0.5 to 1.0 per cent, nicotine dust carrying 3.8 to 4 per cent nicotine, and lethane have been found to control tomato bug. Because of the present lack of pyrethrum and rotenone and the risk of foliage injury with lethane, the brunt of control has so far been carried by nicotine.

For effective control of tomato bug by these contact insecticides, applications are needed at as short an interval as five days during the period of flowering and fruit setting.

We have found that DDT dusts of 1 and 2 per cent concentration and a spray of 1 pound per 100 gallons, will control tomato bug satisfactorily. Moreover, the data so far secured indicate that DDT has the following advantages over the insecticides used to date: (1) the time during which the plants are protected is greater than the time of protection with the other insecticides studied to date;

(2) a build up of nymphal population is largely prevented because the eggs are prevented from hatching or the nymphs succumb soon after hatching.

Corn earworm, *Heliothis armigera* (Hübner)

Corn earworm is a major insect of tomato and is the most widespread tomato-attacking insect in Hawaii. In recent years infestation has become so common that successful tomato production requires regular applications of a suitable insecticide. Cryolite has been found to be a suitable insecticide which controls many other insects of tomato besides corn earworms. In our studies on DDT dusts applied to tomato, we have observed that applications of cryolite for control of corn earworm were not necessary when DDT was applied. These observations are in line with those already reported by Johnson (5) who has demonstrated that a 1 per cent dust of DDT was as effective as undiluted calcium arsenate and a 3 per cent dust was significantly more effective.

Discussion

The evidence to date indicates that greenhouse white fly and Chinese rose beetle, the two most important insects of green bean not yet satisfactorily controlled, are controlled by a dust of 2 per cent strength. A 3 per cent dust, however, is detrimental to bean plants under some conditions, and further work is necessary on the effect of DDT on the plant and on other bean insects.

On tomato, the prospects are bright for controlling the three most important insect pests and several others with the one material—DDT. Studies are also in progress on some of the other insects of tomato.

In studies to date on cabbage, it has been found that a 1 per cent dust of DDT controls cabbage webworm as efficiently as a 50 per cent cryolite dust.

The conclusion has been reached that DDT is a remarkable insecticide with great potentialities for the control of many agricultural insects in Hawaii; some of these are insects, capable of devastating injury, which have hitherto defied control. However, it must be demonstrated that the strengths of insecticide necessary for the control of the respective insects are not detrimental to the crop plants. Work is also necessary to determine the best methods of applying DDT, the optimum concentration and time interval for applications, the range of concentration safe for use on various crop plants, and the compatibility of DDT with other materials such as fungicides. Practical use of DDT on vegetable crops is also dependent on work which will be done elsewhere on the toxicity of

DDT to human beings and also on a determination of the safe tolerance of DDT on food crops.

LITERATURE CITED

1. Back, E. A., and Pemberton, C. E. 1917. The melon fly in Hawaii. U. S. Dept. Agr. Bul. 491, 64 pp.
2. Holdaway, F. G. 1943. Report on white fly infestation on green beans at Waianae, Oahu. Proc. Haw. Ent. Soc. 11 (3) : 266-267 and 273-274.
3. Holdaway, F. G., and Nishida, T. 1944. The toxicity of DDT to *Adoretus sinicus* in Hawaii. Jour. Econ. Ent. 37 (4) : 558-559.
4. Holdaway, F. G., Nishida, T., and Look, Wm. C. DDT effective in controlling the white fly *Trialeurodes vaporariorum* on green beans in Hawaii (In preparation).
5. Johnson, G. V. 1944. DDT for control of the tomato fruitworm. Jour. Econ. Ent. 37 (1) : 151-152.
6. McBride, O. C., and Holdaway, F. G. DDT highly toxic to melon fly *Dacus cucurbitae* Coq., a major pest of cucurbits and tomato in Hawaii (In preparation).
7. Plummer, C. C. 1943. Tests against the Mexican fruit fly pp. 107-111 in Laboratory procedures in studies of the chemical control of insects. Am. Ass. Ad. Sci. Pub. No. 20.