INVESTIGATIONS IN THE CONTROL OF THE TOBACCO LEAF-MINER, *GNORIMOSCHEMA OPERCULELLA* ZELL. (LEPIDOPTERA: GELECHIIDAE), WITH D.D.T. AND "GAMMEXANE."

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SUMMARY.

1. Experiments in the control of the tobacco leaf-miner, Gnorimoschema operculella Zell., with D.D.T. and "Gammexane" were conducted at Mareeba in northern Queensland.

2. Effective control was obtained with 0·1 and 0·2 per cent. D.D.T. sprays and 1·0 and 2·0 per cent. D.D.T. dusts applied immediately after transplanting, followed by regular fortnightly treatments up to a maximum of five applications in all. A total of three applications made at fortnightly intervals also afforded a high degree of protection to the crop.

3. "Gammexane" at the high concentration was inferior to D.D.T. even at the low concentration of the latter; in addition, the sprays and dusts containing it had such a pronounced phytocidal effect on the tobacco plants that their use had to be discontinued before the termination of the experiment.

INTRODUCTION.

The tobacco leaf-miner, *Gnorimoschema operculella* Zell., was early recognized as a major pest of tobacco in northern Queensland. Atherton (1936) obtained only partial control with frequent applications of a 50 per cent. lead arsenate dust, while other insecticides tested proved of little value. The fact that no external feeding takes place and the larvae are thus virtually inaccessible during the period of feeding may in a large measure account for the inadequacy of these insecticides. The recent advent of D.D.T. and the promising results obtained from its use against this species in other crops prompted the investigation reported here.

SCOPE OF THE INVESTIGATION.

It had already been demonstrated in a preliminary tobacco seed-bed experiment (Caldwell, 1945) that the phytocidal effect of solvent naphtha-D.D.T.-"Wetsit"* sprays, when used at concentrations for the present adopted as standards in experimental work, was limited to a negligible degree of stunting, from which the plants rapidly recovered once applications had ceased. In the

* Sodium alkyl naphthalene sulphonate plus pine oil.

meantime, insecticides containing "Gammexane"† had become available and they were included for trial, though there had been no opportunity to test their phytocidal effect beforehand. The materials used were impregnated dusts containing D.D.T. or "Gammexane" in a pyrophyllite diluent mayonnaise emulsions of both insecticides, and a solvent naphtha—"Wetsit" emulsion of D.D.T.

All insecticides were tested at two levels, the concentrations referred to hereunder being given in terms of the para para isomer of dichloro-diphenyl-trichloroethane and the gamma isomer of benzene hexachloride, respectively. Low levels of sprays were 0·1 per cent. for D.D.T. and 0·026 per cent.‡ for "Gammexane," and of dusts 1·0 per cent. and 0·26 per cent.‡ respectively. The high levels were in each case twice the above concentrations. Provision was made for a comparison between a total of three and a total of five regular applications at fortnightly intervals, commencing immediately after the seedlings were transplanted into the field.

EXPERIMENTAL DETAILS.

Crop Conditions and Insect Incidence.

The experiment was conducted at Paddy's Green, Mareeba, where conditions are typical of the dry-farmed areas of the district. The technique of planting was such that four days were occupied in planting out the experimental crop of approximately two acres. The operation was restricted to the afternoons and extended from November 26 to November 29, 1945. The seedlings were of the variety Virginia Bright Leaf and were healthy and fairly uniform in size and vigour. Weather conditions subsequent to planting were favourable, resulting in a good stand, and the crop made satisfactory progress throughout, with harvesting commencing in the middle of February.

At the time of planting, the seedlings were virtually free of leaf-miner but infestation developed later to a point where, a little over one month after planting, 80 per cent. of the plants in untreated plots were infested. In the middle of January moths were observed to be again active in the crop and fresh mining was in evidence at the third sampling which commenced on February 2.

Design and Layout.

The experimental design involved a split-plot arrangement with three absolute replications. The main-plots were set out as randomized blocks and the four main-plot treatments comprised the two insecticide levels and the two

† Supplied by Imperial Chemical Industries of Australia and New Zealand Ltd. as a mayonnaise emulsion (E.F. 488M) containing 1·95 per cent. of the gamma isomer of benzene hexachloride together with 7·9 per cent. of the less active isomers—alpha, beta and delta—in an aromatic solvent, and as an impregnated dust with pyrophyllite as the diluent.

‡ The original concentrations were intended as 0·02 per cent. for sprays and 0·2 per cent. for dusts, based on a gamma benzene hexachloride content of 10 per cent. for the crude product (D 919) used in the preparation of sprays and dusts. It has since been established that the gamma isomer content of the crude product was 13 per cent. and adjustments have been made accordingly.

durations of treatment factorially arranged. The main-plots were subdivided into six sub-plots each, including the five insecticidal treatments and the control, these being randomized within the main-plots. Sub-plots were 12 feet (3 rows) wide and 90 feet long, with plants spaced 2 feet apart in the rows. Six sub-plots end to end, and separated by buffer strips 12 feet wide, constituted a main-plot, while four adjacent main-plots formed a complete block, of which there were three in this experiment.

Insecticide Applications and Treatment Modifications.

Details of insecticide applications are given below:—

Application.	Date of Application.	Number of Days since Previous Application.
First	Nov. 26–29	..
Second	Dec. 10	11–14
Third	Dec. 21	11
Fourth	Jan. 5–6	15–16
Fifth	Jan. 19	13–14

The initial applications were made each day immediately after planting and were thus spread over the four consecutive planting days. The third application was made under rather bad weather conditions owing to several showers of rain falling during the day. The fourth and fifth applications were limited to the long-term schedule plots as provided in the original design of the experiment.

Observations prior to the fourth application revealed pronounced phytocidal effects of the "Gammexane" treatments. Consequently, all but the low level of "Gammexane" dust were discontinued and a low level "Gammexane" dust substituted for the high level "Gammexane" spray and dust, and a low level D.D.T. dust for the low level "Gammexane" spray. Prior to the fifth application it was noted that all "Gammexane"-treated plots were showing severe damage by leaf-miner and leaf-eating species, such as *Heliothis armigera* Hbn., *Plusia chalcites* Esp., *Prodenia litura F.*, and Tettigoniidae, and it was decided to replace all of the original "Gammexane" treatments with corresponding levels and forms of D.D.T. so as to avoid undue crop losses.

The first treatments were applied with small hand atomizers and dusters; for subsequent applications knapsack sprayers and bellows type dusters were used. Throughout the experiment separate machines were reserved for use with D.D.T. and "Gammexane." Rates of application ranged from 24 to 36 gallons per acre for sprays and 12 to 48 pounds per acre for dusts, depending mainly on the size of the plants.

PHYTOCIDAL EFFECTS.

Reference has already been made to earlier phytocidal tests with D.D.T. wherein it was found that concentrations within the limits of those employed in this investigation were for all practical purposes innocuous. In this trial there was no evidence of any phytocidal effect with D.D.T. treatments.

The phytocidal effect of "Gammexane" sprays and dusts was most pronounced and was accentuated at the higher concentrations. There was a marked stunting of the plants with inhibition of terminal growth resulting in prolific sucker development, sometimes giving a "rosetted" appearance. Leaves were malformed and reduced in size, the development of one half of the lamina frequently being retarded or even inhibited. Accompanying these symptoms there was distinct coarsening of the leaf and roughening of the surface, accompanied by mottling. The general appearance of affected plants was reminiscent of extreme "frenching."

SAMPLING TECHNIQUE AND ASSESSMENT OF RESULTS.

Assessment of leaf-miner infestation for the purposes of the experiment was based on samples of 30 plants per sub-plot, the data being reduced to a "per plant" basis. To reduce errors due to wind drift of insecticides the two outer rows of each plot were regarded as guard rows and the sampling was taken from the inner row only. The first sampling was carried out over the period January 4-6; that is, at the time of the fourth insecticide application and thus about six weeks after the initial treatment. Two further samplings were made at approximately fortnightly intervals, on January 18-20 and on February 2-3. The same method of progression through the plots was followed at each sampling so that, except where occasional plant losses had occurred between samplings, the same plants were examined on each occasion.

Two methods of assessment were followed, namely, (*a*) a count of leaves mined and (*b*) a count, or more correctly an estimate, of the number of mines present. The former constitutes a rather severe criterion in that it takes no account of the degree of infestation in each leaf. The latter is considered to give a better estimate of larval population and severity of leaf damage but is subject to some limitations. In heavy infestations it may happen that a large mine would contain several larvae. On the other hand, a single larva may occasionally produce more than one mine when forced to vacate the original mine through accidental circumstances, such as death of the leaf in which it is feeding.

DISCUSSION OF RESULTS.

Table 1 sets out in a summarized form the data relevant to the main effects of the treatments. In view of the modifications introduced into the "Gammexane" schedule the data from these plots were omitted from the analyses except in the case of insecticide comparisons at the first sampling. For completeness and as indicative of trends the data from the first sampling are retained to show the relative merits of D.D.T. and "Gammexane" as insecticides for tobacco leaf-miner control.

Table 1.

LEAF-MINER INFESTATION (EXPRESSED AS MEANS PER PLANT).

Treatment.	Leaves Mined.			Number of Mines.		
	1st Sampling Approx. 6 Weeks after Planting.	2nd Sampling Approx. 8 Weeks after Planting.	3rd Sampling Approx. 10 Weeks after Planting.	1st Sampling Approx. 6 Weeks after Planting.	2nd Sampling Approx. 8 Weeks after Planting.	3rd Sampling Approx. 10 Weeks after Planting.
Control	1·867	2·078	3·044	3·162	4·976	7·106
3 Applications	..	0·029	0·921	..	0·038	1·389
5 Applications	..	0·007	0·134	..	0·007	0·178
Low Level	0·015	0·027	0·622	0·021	0·032	0·960
High Level	0·000	0·009	0·434	0·000	0·013	0·607
Differences for Significance 5% ..	0·063	0·031	0·363	0·068	0·043	0·648
Differences for Significance 1% ..	0·091	0·042	0·550	0·091	0·059	0·982
D.D.T. S/N* Spray ..	0·000	0·005	0·543	0·000	0·005	0·803
D.D.T. M/E.† Spray ..	0·000	0·002	0·242	0·000	0·002	0·334
D.D.T. Dust	0·022	0·046	0·798	0·032	0·060	1·213
Gammexane M/E.†Spray	0·188	..	..	0·257	..	..
Gammexane Dust ..	0·429	..	..	0·588	..	..
Differences for Significance 5% ..	0·076	0·038	0·149	0·108	0·053	0·299
Differences for Significance 1% ..	0·102	0·051	0·206	0·144	0·072	0·405

* S/N = solvent naphtha—" Wetsit " emulsion.

† M/E. = mayonnaise emulsion.

The effect of duration of treatment can be seen by reference to the data from the second and third samplings. It is evident that three applications of D.D.T. sprays and dusts at approximately fortnightly intervals from transplanting did not afford adequate protection during the whole of the post-treatment period. The absence of differences of any magnitude at the second sampling, made four weeks after the third application, indicates that the residual effect of these insecticides persists for approximately this period, but the fact that there was a slight increase in infestation at this time points to one month as the upper limit of persistency. From this evidence it may be inferred that the fifth application, in view of the approach of harvesting, was probably superfluous.

On the above grounds it would appear that fortnightly intervals between treatments, as adopted in this experiment, were unnecessarily short. There is, however, the question of coverage of new growth to be considered. This assumes particular importance with a crop such as tobacco, in which the surface area of the foliage increases rapidly during the earlier stages of growth. For this reason monthly applications might in practice prove too infrequent to ensure adequate protection under all conditions.

When the data for "Gammexane" treatments at the first sampling were included in the estimates of main-plot effects, a significant difference between the two levels occurred, due to the marked significant difference between the higher and lower concentrations of "Gammexane," as shown in Table 2.

Table 2.

LEAF-MINER INFESTATION AT FIRST SAMPLING EXPRESSED AS MEANS PER PLANT.

Treatment.	Leaves Mined.		Number of Mines.	
	Low Level.	High Level.	Low Level.	High Level.
D.D.T. S/N Spray	0·000	0·000	0·000	0·000
D.D.T. M/E Spray	0·000	0·000	0·000	0·000
D.D.T. Dust	0·045	0·000	0·063	0·000
Gammexane M/E Spray	0·243	0·133	0·357	0·157
Gammexane Dust	0·688	0·190	0·943	0·233
Mean	0·191	0·065	0·273	0·078

The first sampling showed that "Gammexane" exercised a considerable degree of control over the leaf-miner but that it was obviously inferior to D.D.T. at the concentrations used. Thereafter any strict comparison between the two insecticides was rendered impossible by virtue of the treatment modifications which were introduced. In any case the phytocidal effect of the "Gammexane" sprays and dusts would preclude their use on tobacco, at least in the forms used in this experiment.

D.D.T. was outstandingly superior to the controls. The data on types and forms of insecticides set out in Table 1 are means of long and short term treatments. Table 3 sets out the data relevant to D.D.T. in the series of long duration only, from which it is possible to compare sprays and dusts without any masking effect from the less adequate short term treatments.

Table 3.

LEAF-MINER INFESTATION WITH 5 D.D.T. APPLICATIONS EXPRESSED AS MEANS PER PLANT.

Form in which D.D.T. Applied.	Leaves Mined.			Number of Mines.		
	1st Sampling.	2nd Sampling.	3rd Sampling.	1st Sampling.	2nd Sampling.	3rd Sampling.
S/N Spray	0·000	0·000	0·020	0·000	0·000	0·020
M/E Spray	0·000	0·000	0·017	0·000	0·000	0·017
Dust	0·022	0·020	0·367	0·032	0·020	0·498
Differences for Significance 5%	0·107	0·054	0·211	0·153	0·075	0·410
Differences for Significance 1%	0·144	0·072	0·291	0·204	0·102	0·566

From Table 3 it is clear that there is no significant difference between the two types of spray, but there is a consistent difference in favour of sprays as against the dust, this difference being significant at the third sampling. In comparing the efficacy of sprays and dusts one must not lose sight of the fact that they are applied by different types of machine, variations in the efficiency of which might well lead to slightly different results. Another point is that by the time of the fourth and fifth applications the crop had made considerable growth and treatments were for several reasons concentrated on the upper portions of the plants. It is practically certain that leaf-miner larvae in the lower leaves would not have come within the sphere of influence of the fifth insecticidal application; thus the difference in favour of the sprays may be related to a more pronounced residual effect of the latter as compared with the dust.

CONCLUSIONS.

The results of this investigation make it clear that a high degree of control of the leaf-miner in tobacco may be obtained by the routine application of D.D.T. sprays or dusts in the field. The evidence points to concentrations of 0·1 per cent. of the para para isomer of dichloro-diphenyl-trichloroethane for sprays and 1·0 per cent. for dusts as being adequate for this purpose. Protection should be afforded by an application of D.D.T. either immediately before or immediately after the seedlings are transplanted, to be followed by two or three further treatments at intervals of two weeks or a little more. The initial application could be most cheaply and effectively applied to the seed-beds prior to planting out. Treatment along these lines can be expected to control the pest when relatively high populations occur in crops subject to reasonably favourable growing conditions.

In this experiment, the seedlings were virtually free from leaf-miner when transplanted. The pest can, however, be a source of considerable injury in the seed-beds and it may be inferred from the investigation outlined above that applications of a D.D.T. spray or dust if and when necessary will control the pest in the seed-bed also.

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