THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

VOL. 5. NO. 2.

JUNE, 1948

CODLING MOTH CONTROL EXPERIMENTS, 1945-47

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SUMMARY.

Experiments carried out in the Stanthorpe district in the 1945-47 seasons for the control of codling moth in apples are described. In these experiments DDT, benzene hexachloride and zinc fluoarsenate were tested officially for the first time in Queensland.

DDT at 0·1 per cent. concentration gave very satisfactory results when applied to the same cover spray schedule as lead arsenate. At half this strength, DDT was significantly less efficient but still superior to lead arsenate. The amount of DDT residue remaining on the fruit at harvest after the use of the higher concentration was, however, somewhat high, while the risk of increased incidence of mites, and to a lesser extent, woolly aphid, following the use of DDT, was demonstrated.

In various schedules white oil-DDT sprays effectively controlled both codling moth and red mite. However, when used alone, white oil gave indifferent control of codling moth. In addition, the depressing effect of oil on fruit size was illustrated.

Benzene hexachloride sprays at 0·013 and 0·025 per cent. concentrations of the gamma isomer had little effect on codling moth infestation.

Zinc fluoarsenate gave no better control of codling moth than lead arsenate when used at the same concentration and appeared to have no worthwhile advantages over the latter insecticide.

Hydrated lime plus zinc sulphate was shown to have a valuable "safening" effect when added to the standard lead arsenate spray, though neither material alone exhibited this property. Zinc sulphate, on the other hand, caused appreciable fruit blemishing, but it did result in improved codling moth control whether added alone or with hydrated lime to lead arsenate.

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INTRODUCTION.

During the 1945-46 and 1946-47 seasons, further experiments in the control of codling moth (*Cydia pomonella* L.) by the use of sprays were carried out in the Stanthorpe district in apples. Additional impetus was given to the investigation by the advent of the new insecticide DDT (dichloro-diphenyl-trichloroethane) and much of the work centred round the trials of this material as a cover spray.

1945-46 EXPERIMENT.

Experimental Details.

This experiment took the form of a randomized block arrangement of five treatments with five replications. Single-tree plots were employed. Two blocks of apple trees were used, one of the variety Jonathan, which is early maturing, the other of Stayman Winesap, which is a late-maturing variety. Three replications were placed in the former and two in the latter block.

All trees received the same calyx spray, namely, lead arsenate 3⅛ lb. to 100 gallons of water.

The cover spray treatments were:—

A. White oil 1⅔ gal., nicotine sulphate 1¼ pint, water 100 gal.

B. Lead arsenate 3⅛ lb., white oil 1⅔ gal., water 100 gal. for first three sprays.

White oil 1⅔ gal., water 100 gal. for subsequent sprays.

C. DDT 0·1 per cent., made up from 13·3 per cent. DDT-solvent naphtha concentrate.

D. DDT 0.1 per cent., made up from 20 per cent DDT "mayonnaise" emulsion.

E. Benzene hexachloride, 0.013 per cent. gamma isomer for first two sprays, 0.025 per cent. for subsequent sprays. Made up from 15 per cent. benzene hexachloride emulsion.

Sprays were applied on the following dates:—

Calyx spray	October 18		
Cover sprays	November 2	Variety Jonathan	Variety Stayman Winesap
	,, 22		
	December 13		
	January 2		
	,, 29		
	February 20		
	March 12		

The cover sprays were timed in accordance with spray notices issued to orchardists by the Department of Agriculture and Stock. Issue of these notices is determined by fluctuations in moth population, as recorded in traps charged with sassafras oil and located in several key orchards in the district.

Table 1.

YIELD DATA—1945–46.

Mean Percentage of Total Crop.

Variety.	Treatment.	No. of Fruit.	Harvested Fruit.							Windfalls.			Total "Moth."
			Total.	Sound.	Reject.					Total.	"Moth."	Others.	
					Total.	"Moth."			Others.				
						Total.	"Wormy."	"Stung."					
Jonathan	A. White oil—nicotine sulphate	2,101	93·8	90·2	3·6	3·3	2·5	0·8	0·3	6·3	1·2	5·1	4·5
	B. Lead arsenate—white oil, replaced by white oil	2,236	95·6	92·1	3·5	3·1	2·0	1·1	0·4	4·3	0·6	3·7	3·7
	C. DDT 0·1 per cent. (solvent naphtha) ..	1,540	95·2	87·3	7·9	2·9	1·2	1·6	5·0	4·8	0·1	4·7	3·0
	D. DDT 0·1 per cent. (" mayonnaise ") ..	2,117	88·9	84·0	4·9	4·1	3·7	0·3	0·8	11·1	1·3	9·8	5·4
	E. Gamma benzene hexachloride 0·013 and 0·025 per cent.	1,802	90·4	70·5	19·9	17·7	13·9	3·8	2·2	9·5	3·9	5·6	21·6
Stayman Winesap	A. White oil—nicotine sulphate	1,366	75·8	63·4	12·4	7·3	0·5	6·8	5·1	24·1	3·8	20·3	11·1
	B. Lead arsenate—white oil, replaced by white oil	1,285	50·3	43·2	7·1	3·8	0·2	3·6	3·3	49·7	5·0	44·7	8·8
	C. DDT 0·1 per cent. (solvent naphtha) ..	1,197	56·0	50·7	5·3	1·2	0·1	1·1	4·1	44·0	3·8	40·2	5·0
	D. DDT 0·1 per cent. (" mayonnaise ") ..	1,307	51·4	49·3	2·1	1·8	..	1·8	0·3	48·6	3·6	45·0	5·4
	E. Gamma benzene hexachloride 0·013 and 0·025 per cent.	1,296	67·9	43·7	24·2	16·6	6·3	10·3	7·6	32·1	24·6	7·5	41·2
Jonathan plus Stayman Winesap	A. White oil—nicotine sulphate	3,467	86·6	79·6	7·0	4·8	1·7	3·1	2·2	13·3	2·2	11·1	7·0
	B. Lead arsenate—white oil, replaced by white oil	3,521	79·2	74·3	4·9	3·4	1·4	2·0	1·5	20·9	2·2	18·7	5·6
	C. DDT 0·1 per cent. (solvent naphtha) ..	2,737	78·0	71·3	6·7	2·1	0·7	1·4	4·6	22·0	1·7	20·3	3·8
	D. DDT 0·1 per cent. (" mayonnaise ") ..	3,424	74·6	70·8	3·8	3·2	2·3	0·9	0·6	25·4	2·2	23·2	5·4
	E. Gamma benzene hexachloride 0·013 and 0·025 per cent.	3,098	81·0	59·3	21·7	17·2	10·7	6·5	4·4	19·0	12·6	6·4	29·8

The Jonathan fruit were harvested between January 30 and February 1 and the Winesaps on March 26 and 27. Windfalls in both cases were collected and examined at intervals after January 1.

Results.

Results of the experiment were assessed by examining the total crop of fruit—that is, the harvested crop plus the windfalls—but it should be noted that in the tabulations of data none of the windfall fruit is included in the category "sound." Fruits were classified according to whether larvae had survived after penetrating the skin (thus giving rise to a "wormy" apple) or whether the attack had been abortive (giving the so-called "blind stings"). "Wormy" apples were further classified according to the point of larval entry, that is, through the calyx or elsewhere on the fruit. Fruit showing any degree of codling moth attack was classified as such; no allowance was made for what may be termed "inconsequential stings." Fruit in each category were both weighed and counted; but, because the two sets of figures were closely parallel, only data relating to numbers are considered here.

The data are summarized in Table 1.

Table 2 shows a summary of the analysis of the data for percentage of sound fruit based on the total crop.

Table 2.

MEAN PERCENTAGE OF SOUND FRUIT (1945–46).
(Based on Total Crop.)

Summary—Table of Means.

Variety.	Treatment.	Equivalent Percentage.	Significantly Exceeds.	
			At 1 per cent. Level.	At 5 per cent. Level.
Jonathan plus Stayman Winesap	A. White oil—nicotine sulphate..	81·5	E	C, D
	B. Lead arsenate—white oil, replaced by white oil	76·9	E	
	C. DDT 0·1 per cent. (solvent naphtha)	75·0	E	
	D. DDT 0·1 per cent. ("mayonnaise")	73·3	E	
	E. Gamma benzene hexachloride 0·013 and 0·025 per cent.	60·4	..	

Analyses were carried out in terms of a transformed variate given by $p = 100 \sin^2\phi$, where p = percentage. The table of means shows the equivalent percentages.

Analysis of the figures for moth infestation in the total crop gave results substantially the same as those shown in Table 2.

In no case were there any significant differential effects of spray treatment between the two apple varieties.

With regard to the type of moth attack, no significant differences could be detected except in the case of benzene hexachloride where a markedly higher proportion of the total infested apples was "wormy." This result was only to be expected in the light of the poor degree of control given by this material.

1946-47 EXPERIMENT.

Experimental Details.

This experiment consisted of six randomized blocks, each of 12 single-tree plots, located in an area of Granny Smith apples.

All the trees received the same calyx spray of lead arsenate made up as follows:—

Lead arsenate (powder)	3 lb.
Hydrated lime	1½ lb.
White oil	2½ pints.
Water	100 gal.

The cover spray treatments were:—

A. Lead arsenate 3 lb., white oil 2½ pints, water 100 gal.

B. Lead arsenate 3 lb., hydrated lime 1½ lb., white oil 2½ pints, water 100 gal.

C. Lead arsenate 3 lb., zinc sulphate 1 lb., white oil 2½ pints, water 100 gal.

D. Lead arsenate 3 lb., hydrated lime 2 lb., zinc sulphate 1 lb., white oil 2½ pints, water 100 gal.

E. Zinc fluoarsenate 3 lb., white oil 2½ pints, water 100 gal.

F. DDT 0.1 per cent.

G. DDT 0.05 per cent.

H. DDT 0.05 per cent., white oil 1 per cent.

I. DDT 0.1 per cent., replaced by white oil 1 gal., water 60 gal. for the fifth and subsequent cover sprays.

J. DDT 0.1 per cent., alternating with white oil 1 gal., water 60 gal.

K. White oil 1 gal., water 60 gal.

L. Control, untreated.

The DDT sprays were prepared from a 20 per cent. "mayonnaise" emulsion. The strength of lead arsenate in the calyx and the various cover sprays was practically the same as that used in the previous season's experiment, though the actual formulations were somewhat different.

The sprays were applied on the following dates:—

Calyx spray	October 14 to 18.
Cover sprays	October 28.
	November 6
	November 26
	December 17-18.
	January 3
	January 27
	February 17
	March 11

Table 3.

YIELD DATA—1946–47.

Mean Percentage of Total Crop.

Treatment.	No. of Fruit.	Harvested Fruit.						Windfalls.			Total "Moth."
		Total.	Sound.	Reject.				Total.	"Moth."	Others.	
				Total.	"Moth."		Others.				
					Total.	"Wormy."	"Stung."				
A. Lead arsenate	2,624	80·3	36·6	43·7	42·8	9·3	33·5	0·9	19·7	13·6	6·1	56·4
B. Lead arsenate—hydrated lime	2,183	82·3	38·2	44·1	42·9	9·0	33·9	1·2	17·7	11·8	5·9	54·7
C. Lead arsenate—zinc sulphate	2,641	86·7	53·9	32·8	32·2	5·1	27·1	0·6	13·4	7·1	6·3	39·3
D. Lead arsenate—hydrated lime—zinc sulphate	2,891	87·1	57·8	29·3	28·9	5·3	23·6	0·4	12·9	6·2	6·7	35·1
E. Zinc fluoarsenate	2,347	72·2	35·1	37·1	36·7	17·5	19·2	0·4	27·8	23·2	4·6	59·9
F. DDT 0·1 per cent... ..	2,689	90·9	81·5	9·4	7·1	0·3	6·8	2·3	9·1	1·2	7·9	8·3
G. DDT 0·05 per cent. ..	2,553	86·8	66·5	20·3	18·6	2·3	16·3	1·7	13·2	6·3	6·9	24·9
H. DDT 0·05 per cent., plus white oil 1–100	1,925	89·2	69·4	19·8	17·4	1·1	16·3	2·4	10·8	2·9	7·9	20·3
I. DDT 0·1 per cent., replaced by white oil 1–60	3,084	90·7	73·3	17·4	17·1	7·1	10·0	0·3	9·3	4·0	5·3	21·1
J. DDT 0·1 per cent., alternating with white oil 1–60	2,407	88·6	72·2	16·4	14·8	2·3	12·5	1·6	11·4	4·7	6·7	19·5
K. White oil 1–60	2,026	61·6	33·5	28·1	27·8	22·8	5·0	0·3	38·4	33·2	5·2	61·0
L. Control, untreated ..	2,385	42·9	6·7	36·2	36·1	33·1	3·0	0·1	57·1	55·5	1·6	91·6

As in the previous experiment the cover sprays were timed in accordance with Departmental spray notices, but on two occasions wet weather prevented strict adherence to this schedule. The spray applied on January 27 was due between January 21 and 24 and that applied on February 17 between February 11 and 14. Mechanical troubles with spray machinery delayed until the following day the completion of the spraying started on December 17.

Windfalls were collected and examined at intervals after January 1 and the crop was harvested on April 8-10.

Results.

Results relating to codling moth control were assessed on practically the same lines as in the previous experiment. The total crop was examined, that is, harvested fruit plus windfalls. Fruit were classified as "wormy" or "stung," according to whether the larvae had penetrated beyond the skin or whether the attack had been abortive, but no attempt was made to classify the "wormy" fruit on the point of larval entry. Fruit in each category was counted only. As in the previous season's experiment no allowance was made for "inconsequential stings" and none of the windfall fruit was included in the category "sound."

The data obtained are summarized in Table 3.

Table 4 gives a summary of the analysis of the data for percentage of sound fruit based on the total crop.

Table 4.

MEAN PERCENTAGE OF SOUND FRUIT (1946–47).

(Based on Total Crop.)

Summary—Table of Means.

Treatment.	Equivalent Percentage.	Significantly Exceeds—	
		At 1 per cent. Level.	At 5 per cent. Level.
F. DDT 0·1 per cent.	81·0	G, D, C, B, A, K, E, L	J, H, G, D, C, B, A, K, E, L
I. DDT 0·1 per cent., replaced by white oil 1–60	73·1	D, C, B, A, K, E, L	D, C, B, A, K, E, L
J. DDT 0·1 per cent., alternating with white oil 1–60	70·5	C, B, A, K, E, L	D, C, B, A, K, E, L
H. DDT 0·05 per cent., plus white oil 1–100	70·2	C, B, A, K, E, L	D, C, B, A, K, E, L
G. DDT 0·05 per cent.	67·2	C, B, A, K, E, L	C, B, A, K, E, L
D. Lead arsenate—hydrated lime—zinc sulphate	57·8	B, A, K, E, L	B, A, K, E, L
C. Lead arsenate—zinc sulphate ..	53·4	B, A, K, E, L	B, A, K, E, L
B. Lead arsenate—hydrated lime ..	38·0	L	L
A. Lead arsenate	37·3	L	L
K. White oil 1–60	35·0	L	L
E. Zinc fluoarsenate	34·9	L	L
L. Control, untreated	6·0	..	..

Analyses were carried out in terms of a transformed variate given by $p = 100 \sin^2\phi$, where p = percentage. The table of means shows the equivalent percentages.

Similar analyses for the data relating to percentage of moth infestation in the total crop (fruit plus windfalls) and for the percentage of "wormy" apples in the harvested crop reveal essentially the same order of significant differences as shown in Table 4. Some slight variations from this order are to be expected from the data presented in Table 3. So far as moth infestation in the total crop is concerned, 0.1 per cent. DDT shows out even more favourably than in Table 4, and similarly, 0.05 per cent. DDT plus white oil is seen to greater advantage in respect of percentage of "wormy" apples in the harvested crop. On the other hand, in the latter analysis, 0.1 per cent. DDT replaced by white oil recedes so far down the scale that it is significantly better than only white oil alone and the untreated controls.

DISCUSSION.

Codling Moth Control.

Codling moth infestation in 1945-46 was of average intensity, but in the next year infestation throughout the Granite Belt was severe, the season being regarded as one of the worst for a number of years. Reference to Table 3 shows that on unsprayed trees in 1946-47 only 6.7 per cent. of the crop was sound. Of the rejected fruit only 0.1 per cent. was unsound for reasons other than codling moth infestation. This factor of variable pest incidence from season to season may have been responsible for the rather different performances of similar treatments in the two experiments under review. Interference by weather conditions with the spraying programme of 1946-47 may also have had some influence. No such interference occurred in 1945-46.

The discussion which follows relates, of course, only to the use of the various treatments as cover sprays, the calyx spray treatment being constant for all trees in each experiment.

DDT.

The 1945-46 experiments with this material were promising, the total infestation being of the order of 5.0 per cent., but the two mixtures tried at the 0.1 per cent. strength did not prove superior to white oil—nicotine sulphate. No constant difference was revealed between "mayonnaise" emulsion and solvent naphtha formulations. In this experiment no indication was given of the outstanding control which was to be demonstrated by the 0.1 per cent. spray under the severe testing conditions of 1946-47. In this second year not only was the total number of fruit attacked small (8.3 per cent.), but the proportion of "wormy" apples harvested was extremely low (0.3 per cent.). These facts are illustrated in Table 3.

Reduction of the DDT concentration to 0.06 per cent. significantly impaired the efficiency of the spray, 24.9 per cent. of the total crop being attacked, but even at this strength DDT sprays were significantly superior (at the 5 per cent. level of significance) to all lead arsenate formulations in the 1946-47 series. The proportion of "wormy" fruit harvested was again small

(2.3 per cent.) and the decrease in efficiency is largely reflected in the higher percentage of "stung" fruit (16.3 per cent. as compared with 6.8 per cent. with the higher concentration). This indicates that more larvae survived long enough to commence feeding than with the higher concentration, but obviously survival of many of them was only temporary.

The inclusion of 1 per cent. white oil in the 0.05 per cent. DDT spray had no effect on codling moth control.

The replacement of the 0.1 per cent. DDT by a white oil spray after the end of December—that is, for the fifth and subsequent cover sprays—resulted in a decrease in efficiency to the same level as that of 0.05 per cent. DDT, but it is noticeable that the proportion of "wormy" apples harvested (7.1 per cent.) was significantly greater than with the latter spray. Alternation of 0.1 per cent. DDT and white oil in successive cover sprays, starting with DDT, resulted in four applications of each spray being made and again there was a reduction in efficiency approximately to the level of the 0.05 per cent. DDT, though in this case no undue proportion of "wormy" apples was recorded. The difference in the results from these two DDT—white oil schedules is thought to be due, for the most part, to the comparatively ineffective control exercised over second generation larvae by the oil spray.

When the DDT treatments were applied up to the end of the season, particularly with 0.1 per cent. concentration, a high proportion of the "stung" fruit was blemished only to an inconsequential degree. This was in marked contrast to the arsenical treatments, where many of the "blind stings" were really severe blemishes. It is assumed that, of the codling moth larvae which survived the contact action of DDT long enough to start feeding, many succumbed very shortly afterwards, resulting in little more than a superficial break in the skin of the fruit. Thus the efficiency of DDT, particularly at the 0.1 per cent. level, is considered, in actual fact, to be appreciably greater than is indicated in the tables.

Lead Arsenate.

Because of an excessively heavy residue accumulation from the lead arsenate—white oil spray in the 1945-46 experiment, its use was discontinued after three applications and the white oil spray substituted. The control exercised by this combination schedule was of the same order as that given by white oil—nicotine sulphate (7.0 per cent. infestation).

In 1946-47, the more orthodox lead arsenate spray with oil added at spreader proportions (lead arsenate 3 lb., white oil 2½ pints, water 100 gal.) gave surprisingly poor control, 56.4 per cent. of the total crop being infested. This result may be merely related to the severe moth incidence during the season. On the other hand, torrential rain, which would have had the effect of removing arsenical deposits on the fruit, may have been more directly responsible for the ineffectiveness of the spray, especially if coincident with protracted moth emergence and egg-laying in the second generation.

The improvement in moth control brought about by the addition to the lead arsenate spray of zinc sulphate, either alone or in conjunction with hydrated lime, when the percentage infestation was reduced to 39.3 and 35.1 respectively, is worthy of note. There is no indication that hydrated lime alone in the quantities used had any influence on codling moth control. The zinc salt may have improved the spreading properties of the spray, which are rather poor, especially on the waxy fruit surface.

Zinc Fluoarsenate.

In the 1946-47 experiment, this material was tried for the first time in Queensland. At the same concentration as lead arsenate, it was about as efficient as lead arsenate alone or lead arsenate—hydrated lime, 59.9 per cent. of the total crop being infested; it was inferior to the lead arsenate—zinc sulphate combinations. A relatively high proportion of "wormy" apples was harvested (17.5 per cent. as compared with 9.3 per cent. with lead arsenate alone). This may have been due to poor adhesion, especially under rainy conditions, which perhaps could be improved by the addition of a sticker. Zinc fluoarsenate mixes with water rather more readily than lead arsenate, and in the proportions used had superior spreading properties to the comparable lead arsenate formulation.

White Oil.

White oil, at the full summer strength of 1 gallon to 60 gallons of water, was included in the 1946-47 experiment to provide some comparative data in relation to the combined DDT and white oil schedules. As with lead arsenate, the degree of control obtained was surprisingly low, only 39.0 per cent. of the total crop escaping attack. As oil acts only as an ovicide, it is postulated that the timing of spray applications in relation to oviposition was poor as a result of weather interference with spraying schedules and/or of prolonged egg-laying periods. It should also be noted that the majority of the infested apples harvested were "wormy" (22.8 per cent. out of a total of 27.8 per cent. attacked), a result quite in accord with expectations.

White Oil—Nicotine Sulphate.

This spray, used only in the first experiment, is one of well-proven good performance and the results obtained on this occasion were the normal expectation judging from trials in previous years. The total infestation was 7.0 per cent.

Benzene Hexachloride.

The first trial of this new insecticide on deciduous fruit took place when it was included in the 1945-46 experiment. The poor results are clearly shown in Table 1, where the total infestation is shown to have been 29.8 per cent. This occurred despite an increase in concentration of the gamma isomer from 0.013 per cent. to 0.025 per cent. in the third and subsequent cover sprays.

Effect of Treatments on Other Pests.

Woolly Aphid (*Eriosoma lanigerum* Hausm).

In the 1945-46 experiments there was a sharp build-up in the woolly aphid population of all trees treated with DDT. This effect was, however, most pronounced on the Winesap trees which received seven spray applications; it resulted in premature leaf fall and, on some trees, death of approximately one foot of all leader growth. Although this increase in aphids is generally supposed to be due to the suppression of parasite activity (chiefly *Aphelinus mali* Hald.) it was noted that at all times many parasitized aphids could be found. Parasite activity was, therefore, not actually inhibited. In the following season (1946-47), the aphid population on these trees, which did not receive any further DDT applications, receded to the normal insignificant proportions.

In 1946-47 an observable build-up did take place on DDT-treated trees but, except on one tree (which was sprayed with 0.05 per cent. DDT throughout), the ultimate population attained was still negligibly small. It is suggested that this result, unexpected after the earlier experience at Stanthorpe and the reported occurrences elsewhere, was due more to seasonal effects on the aphid than to any variation in the role of DDT in relation to either the pest or its parasites. The season was one of abnormal drought up to about mid-January and of unduly heavy rain thereafter. The earlier drought period is thought to have been prejudicial to aphid increase. Support is lent to this hypothesis by the observation that, in the 1945-46 experiment, when seasonal conditions were more normal, a noticeable increase had occurred by mid-December, that is, only six weeks after the first DDT application.

Mites (*Bryobia praetiosa* Koch and *Tetranychus* sp.).

In both experiments mite populations reached a high level on all trees receiving DDT alone, and also benzene hexachloride, though the increase was not so pronounced in the latter case. No difference could be detected between the two DDT concentrations used in 1946-47.

White oil added to 0.05 per cent. DDT and white oil alternating with 0.1 per cent. DDT appeared to counteract completely the tendency of mite populations to increase following DDT application. The substitution of oil for DDT after the end of December did not, however, have this effect, for the amount of leaf "stippling" due to mites was little less than with DDT alone when used throughout the season. This observation suggests that mite activity is greatest in the spring and that any influence of DDT on mite populations is manifested mostly during this period.

Fruit Fly (*Strumeta tryoni* Froggatt).

Fruit fly attack generally was not severe in either season, and, though all fruit were examined for fly "stings," no satisfactory data on the effect of cover spray treatment on fruit fly incidence were collected.

Other Treatment Effects.

Tree Vigour.

Though none of the experimental trees was actually showing symptoms of zinc deficiency, some beneficial effect on tree vigour was anticipated from those sprays containing zinc, because of the general tendency to this disorder in the district. However, this expectation was not realized except in the case of the lead arsenate-hydrated lime-zinc sulphate spray. Trees treated with this spray were, at the end of the season, clearly distinguishable from all others in the experiment, due, apparently, to their being somewhat more densely foliaged, with the leaves a little bigger and a deeper green in colour, though actual measurements to substantiate these observations were not made.

Foliage Injury.

The foliage "burn" which normally follows the use of lead arsenate sprays on apples was very much in evidence in these two experiments. In 1945-46 the effect was most pronounced on the Jonathan trees, which are recognized to be particularly susceptible to this form of injury. In 1946-47 the Granny Smiths, considered to be somewhat more tolerant to arsenical sprays, ultimately developed severe burn, though it was not apparent to any extent until after the wet, humid weather of February.

In an attempt to reduce foliage injury the various modifications of the lead arsenate spray mixture had been introduced into the 1946-47 experimental programme. Hydrated lime, rather commonly used in the Granite Belt as a "safener" with lead arsenate, had no effect under the conditions of the experiment. Zinc sulphate accentuated the injury, trees sprayed with lead arsenate-zinc sulphate being rated the most severely "burnt" of all. However, when both hydrated lime and zinc sulphate were added to the lead arsenate sprays, a considerable improvement was effected, the amount of injury suffered by the trees being negligible.

Zinc fluoarsenate completely failed to live up to its overseas reputation; foliage injury was quite as severe as that caused by lead arsenate alone.

With DDT slight leaf "burn" was suspected on odd trees from the use of the solvent naptha formulation in the 1945-46 experiment. No phytotoxic effects whatever were observed in either experiment with "mayonnaise" emulsion formulations. In 1946-47 the contrast, from this point of view, between trees treated with DDT alone and all others was pronounced.

The inclusion of 1 per cent. white oil in the 0.05 per cent. DDT in the second experiment resulted in slight injury to some trees only, an effect almost certainly attributable to the oil component of the mixture and not to any incompatibility between the components of the combined spray. Injury of the same order occurred with the other two schedules involving DDT and white oil. In the case of white oil alone somewhat more severe "burn" was experienced. The degree of injury was presumably related to some extent to the actual oil "load" received by the trees. It was further noted that oil "burn" became evident earlier in the season than arsenical "burn."

White oil-nicotine sulphate, in 1945-46, also caused slight leaf "burn," no doubt again due to the oil component of the mixture. Very slight injury resulted from the use of benzene hexachloride in 1945-46.

Fruit Injury.

Fruit blemishes, taking the form of greyish scars not unlike some forms of mechanical injury, resulted from the use of lead arsenate plus zinc sulphate. Whatever the cause of this injury, it was completely eliminated by the addition of hydrated lime to the combined spray.

Fruit Size.

Table 5 gives the mean weight of 50 fruit based on a random sample of 50 fruit from each tree in the 1946-47 experiment, together with a summary of the statistical analysis.

Table 5.

MEAN WEIGHT OF 50 FRUIT (1946–47).

Treatment.	Mean Weight. (Lb.).	Significantly Exceeds—	
		At 1 per cent. Level.	At 5 per cent. Level.
D. Lead arsenate—hydrated lime—zinc sulphate	19·58	K, I, C	J, E, K, I, C
A. Lead arsenate	19·50	K, I, C	J, E, K, I, C
B. Lead arsenate—hydrated lime ..	19·38	K, I, C	E, K, I, C
G. DDT 0·05 per cent.	19·17	I, C	K, I, C
H. DDT 0·05 per cent., plus white oil 1–100	19·00	I, C	I, C
F. DDT 0·1 per cent.	18·67	C	I, C
L. Control, untreated	18·25		
J. DDT 0·1 per cent., alternating with white oil 1–60	17·71		
E. Zinc fluoarsenate	17·67		
K. White oil 1–60	17·12		
I. DDT 0·1 per cent., replaced by white oil 1–60	16·46		
C. Lead arsenate—zinc sulphate ..	16·42		

These figures show clearly that white oil, at least at the higher concentration of 1 in 60, had a depressing effect on fruit size. This effect appears to have been exercised late in the season, since the treatment—DDT replaced by white oil after the end of December—was as injurious in this respect as white oil alone throughout the season. Lead arsenate-zinc sulphate also reduced fruit size, a result presumably related in this case to the fruit injury referred to earlier. That this reduction was not due to foliage "burn" is shown by the good size attained by fruit on trees sprayed with lead arsenate alone. The position of zinc fluoarsenate in the table should be noted. Obviously this spray did nothing to improve fruit size.

The figures in Table 5 confirm visual observations made during the season, with the exception that fruit from the lead arsenate-hydrated lime-zinc sulphate combination was expected to show out to greater advantage. It is suggested that there may have been an increase in size accompanied by a decrease in density; if this were the case, a careful grading for size would have been necessary to reveal the differences clearly.

Fruit Colour.

Benzene hexachloride in the 1945-46 experiment delayed the development of the red colour in Winesaps, with the result that the fruit, when mature, had a distinct yellowish tinge quite foreign to the variety.

An early impression in the 1946-47 experiment that DDT was promoting the development of "blush" on the Granny Smith fruit was not substantiated by a careful tree-by-tree check just prior to harvesting. However, "blush" appeared to be slightly more prominent on those fruit without a visible spray residue, whether untreated controls or DDT-or oil-sprayed, than on those carrying a whitish residue, such as resulted from the various arsenical treatments.

Fruit Quality.

Fruit quality is somewhat difficult to define and, while the fruit is still on the tree, judgment is influenced to some extent by the visible spray residue. Thus, all the fruit not carrying an arsenical residue had a bright, shining skin and a pleasing general appearance. However, the size differences discussed earlier (see Table 5) were obvious in some cases; hence, of the fruit free from visible residue, that treated with DDT or DDT plus white oil was adjudged the best. Amongst the arsenical-treated fruit, that receiving the lead arsenate-lime-zinc sulphate combination was obviously of outstanding quality, though carrying the heaviest residue. The small, blemished fruit of the lead arsenate-zinc sulphate treatment were the least attractive of all.

DDT Residues.

An examination of DDT residues on the fruit was made at the conclusion of the 1946-47 experiment. Four fruits were taken at the time of harvesting from each experimental tree treated with DDT and an analysis of the residues made by standard alcoholic potash hydrolysis. The results are shown in Table 6.

Table 6.

DDT Residue (1946–47).

Treatment.	Residue (Parts per Million).
F. DDT 0·1 per cent.	17·0
G. DDT 0·05 per cent.	3·4
H. DDT 0·05 per cent., plus white oil 1–100	10·4
I. DDT 0·1 per cent., replaced by white oil 1–60	7·7
J. DDT 0·1 per cent., alternating with white oil 1–60	7·0

As the last spray was applied a month before harvesting and a further week passed before the chemical examination was made, this analysis represents the residues after a lapse of five weeks from the last spray application. With a tentative DDT tolerance of 7 parts per million, these figures warrant careful consideration. There is some evidence to suggest that white oil increased the persistency of DDT residues.

CONCLUSIONS.

1. From the results of two season's experiments it is concluded that, under Queensland conditions, DDT at a concentration of 0·1 per cent. is an efficient cover spray in the codling moth control programme and that its superiority over other materials is likely to be most marked in seasons of severe moth incidence. Provided the problem of residues on the fruit is satisfactorily resolved, the insecticide must play an important part in codling moth control in Queensland. The "mayonnaise" type of emulsion apparently had no phytotoxic effect on apples.

2. Since reduction in the DDT strength to 0·05 per cent. lowers the efficiency of the spray appreciably and probably does nothing to mitigate the ill-effects of the material which result in an increased incidence of some pests other than codling moth, such a procedure is not justified unless for the reason of reducing spray residue on the fruit.

3. It is now evident that an upthrust in woolly aphid population is not inevitable following the use of DDT, but the risk is there and the need to apply counter-measures must be kept in mind. On the other hand, the probability of mite increase is apparently greater. There is thus a need for effective supplementary control measures for both of these pests. White oil is not a promising material for this purpose whether mixed with DDT or otherwise included in the control schedules. The adverse effect on fruit size and, to a lesser extent, the risk of some leaf "burn," not to mention the possibility of cumulative ill-effects from season to season, are sufficient grounds for discarding white oil, except as a spreader, from the codling moth spray programme. As white oil alone has also been shown to give only indifferent codling moth control under some conditions, its inclusion in any control schedule with DDT is liable to reduce the over-all efficiency of the cover spray programme.

4. As DDT is very likely to supersede lead arsenate as a cover spray, investigations on "safeners" for the latter are perhaps of only academic interest. However, if this section of the problem comes in for further enquiry at any time, the findings of the 1946-47 experiment will be of interest. Grave doubts were thrown on the alleged "safening" effect of hydrated lime alone, and zinc sulphate alone also appeared to have no "safening" properties, but a mixture of hydrated lime and zinc sulphate holds considerable promise. Further investigation of such a combined spray may be worth while, particularly in view of the possible "tonic" effect on the trees. An appreciable improvement in codling moth control can be expected as a result of the addition of zinc sulphate.

5. Zinc fluoarsenate is unlikely to play any part at present in the codling moth control programme in Queensland. Even if DDT were not available, zinc fluoarsenate could be expected to displace lead arsenate only if it were cheaper or more readily available. Any advantages it may have are not sufficiently obvious to impress farmers. In the more important fields of codling moth control and foliage injury, it would not appear to be superior to lead arsenate.

6. As benzene hexachloride exerts little, if any, control over codling moth when used as a cover spray at concentrations of 0·013 and 0·025 per cent., it can probably be dismissed from further consideration.

ACKNOWLEDGEMENTS.

Mr. J. W. Stringer, Applethorpe, kindly made available the trees for each experiment. Several officers of the Entomology Section and of the Horticulture Branch assisted in the planning and performance of the experiments. Mr. J. Foran, Chemist in the Department's Chemical Laboratory, made the analysis of DDT residues. Mr. P. B. McGovern, Departmental Biometrician, has been responsible for the statistical examination of data. For all this assistance, grateful acknowledgement is made.