THE CONTROL OF GRASS GRUB IN PASTURE USING LIQUID INSECTICIDES THROUGH SPECIAL MACHINERY

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Summary

This paper describes and discusses a new approach to the problem of controlling grass grub larvae (*Costelytra zealandica*) in pastures using liquid formulations of insecticides through special machinery; results of trials are given.

INTRODUCTION

THE prohibition of the use of DDT on pastures has made it necessary to develop alternative insecticides and explore new approaches to the techniques of grass grub control at the greatest possible speed.

In 1969 and 1970, the application of liquid formulations of insecticide on to and into the surface of soil in pastures was investigated.

For the preliminary work in 1969, a machine built by the late H. W. T. Eggers of the Department of Agriculture was used. This machine, built in 1961, was used prior to 1966 for various purposes including grass grub control (Moody, 1966). This work was not, however, extended although it was established that the application of liquid insecticidal chemicals directly to the soil was feasible.

Results from the use of relatively less persistent organophosphorus insecticides through the Eggers machine in 1969 were encouraging and an extension of the principles involved was so promising that two machines, more practical for field use, were built by the New Zealand Agricultural Engineering Institute and were used in 1970. The method of application which involves cutting the turf has been named "turf treatment". The extension of this principle, which involves direct jetting of liquid on to the pasture in a continuous stream in lines with a minimum of atomization, has been termed "jet squirt". This terminology may in due course be altered but for the purposes of this paper will be retained.

THE GENERAL PRINCIPLE

The principle involved in turf treatment is the application of a continuous stream of liquid insecticide into shallow parallel but not widely spaced cuts in turf. This results in lines of high local concentration and it is accepted that one of the factors contributing to the persistence of an insecticidal chemical is its concentration. The insecticide is also at least partly screened from direct sunlight and air movement which may reduce the rate of degradation and evaporation. Finally, by placing the insecticide just below the surface of the soil it is immediately available to those grass grubs which are active in the area and unavailable to stock and wild life. By spacing the lines of application closely (in most trials 4 in.),

the grass grubs would not have to move far before reaching an area of lethal insecticide concentration.

THE PRACTICE

Whilst the application of insecticide below the surface level of the soil would appear to be the ideal, in practice the machinery was found to be unable to provide this ideal under all conditions. In 1969, the Eggers machine failed to do more than ensure that the bulk of the chemical applied reached bare soil. This was due to the very dry conditions during the early part of the year and the extremely hard soil. On very stony soils, of course, the ideal would be hard to achieve with any machine. In 1970, there was little time fully to test and modify the new machines made by the Engineering Institute and the shoes (see Fig. 2) were worn to such an extent that again the liquid did little more than reach bare soil in a number of trials.

When in 1969 it was observed that remarkably rapid pasture responses and grass grub kill resulted from turf treatment even though the insecticide was known only to have reached bare soil, an alternative method of application was conceived. This jet squirt method did away with the disc to cut the turf and the shoe to run in the cut and applied a continuous stream of liquid to the pasture in lines 4 in. apart. This form of application in 1969, and on the type of pastures upon which the trials were done, gave as rapid response and, for practical purposes, as effective grass grub control as the turf treatment application. In 1970, however, when some of the jet squirt applications were to pastures which had a relatively dense cover of grasses and clover, the jet squirt method was less reliable; the results on the thicker swards were inferior to those where there was a considerable amount of bare soil between the pasture species.

FIG. 1: Turf treatment machine set at 6 in. spacing for trials in 1970. The machine has been modified to apply either 13 gal/acre or 1 gal/acre through separate piping.

FIG. 2: Detail of application units on turf treatment machine. A, disc. B, depth control skid. C, shoe to run in cut made by disc. D, jet for 13 gal/acre. E, subsidiary jet for 1 gal/acre.

MACHINERY

Figure 1 shows the overall arrangement. Figure 2 shows the arrangement of the discs, shoes and nozzles of the application units of the turf treatment machine used in 1970. The hypodermic needle attachment was a later modification to enable treatments to be carried out at 1 gal total liquid per acre. Twenty-five such units were mounted on two main beams and alternately staggered. Each unit was 4 in. from the adjacent one but provision was made for their adjustment to alternative spacings for trial purposes.

Pneumatic wheels were provided to trail the machine when not in operation and these were lifted off the ground during application. The discs were pressed into the turf by the weight of ballast carried as water in two 44 gal drums mounted on the machine.

Some independent movement of each of the application units was required to take up inequalities of the ground surface and this was achieved by mounting the discs on a length of 3 in. $\times$ $\frac{1}{4}$ in. spring steel.

Water-diluted insecticide was supplied to the jets by auxiliary motor at 30 lb/sq. in. and the rate of application in practice was 13 gal/acre at $3\frac{1}{2}$ mph.

JET SQUIRT MACHINE

This machine is of very simple construction and consists of a rigid boom upon which a series of nozzles are mounted at 4 in. intervals. Each nozzle includes an orifice plate or some form of metering outlet which is capable of jetting liquid as a solid stream with minimum of atomization. By mounting this boom on skids so that the jets travel an inch or two above the pasture, the object of applying the liquid in lines with the

FIG. 3: Turf treatment trial, 1970. Pasture pulling is shown on the central untreated plot. High rainfall has masked grass grub damage.

minimum of lateral dispersion is achieved. Trials were carried out using 13 gal/acre at 30 lb/sq. in.

METHODS

The 1969 trials were conducted in the South Island only on a variety of soils including many that were extremely stony. Application was by modified Eggers machine and by a jet squirt device in strips 4 ft wide and ranging in length between 30 and 60 yd. A strip of similar width was left untreated between each pair of treated strips (Fig. 3). As treatment proceeded, the strips were defined by a dribble application of paraquat at the edges. Each treatment was replicated according to the space available.

Except where grass grub infestations were apparently even over the whole trial site, sampling was selective and confined to those patches which, on superficial examination, would have been expected to be supporting high grass grub populations. Samples (7 in. square spade holes approximately 5 in. in depth) were taken about 18 in. from and on either side of the paraquat marking lines: thus each pair, one from the treated and one from the untreated strip, were comparable. A minimum of 9 such pairs were taken from every treatment.

In 1970, two turf treatment machines built by the New Zealand Agricultural Engineering Institute were used, one in the North Island and one in the South. The Eggers machine was also used in the North Island. A jet squirt apparatus capable of adjustment to spacings greater than 4 in. was used in the South Island but in the North Island trials using this technique were confined to 4 in. spacing using the turf treatment machine with the discs and shoes lifted out of the ground.

DISCUSSION AND RESULTS

GENERAL

The trials in 1969 were carried out to test a novel application technique using relatively short-lived insecticides. There was no prior knowledge of the likely efficiency of the technique. The results both in visible pasture response and grass grub kill were so promising that the 1970 trials were conducted mainly to test whether the technique was reliable under a wide variety of conditions and to determine its practicability on a field scale. Thus no investigations in depth have yet been carried out. Normally the advancement of a technique from its first conception to practical application is spread over a number of years; and many of the questions raised as progress is made are answered before the technique is adopted for field use. In this case, there are a great many questions which cannot yet be answered; however, attempts have been made to ensure that no important hazards or difficulties will arise. It can be seen, therefore, that this paper is presented with some apologies but its early publication has been dictated by the urgency of the grass grub problem in New Zealand and the results recorded relate to the South Island trials only.

GRASS GRUB CONTROL

Turf treatment

Table 1 indicates that there can be seasonal differences in the effects of the less persistent insecticides. In this case it is believed that the differences can be accounted for by the effects of differences in rainfall during the early part (particularly in March) of the grass grub season in 1969 compared with 1970. Table 3 shows that relatively little rain fell in March 1969 compared with the same month of 1970; although these figures relate to one recording station, observations at the time indicate that the pattern was more or less the same throughout the areas in which the trials were conducted.

In 1969, some trials were laid down on sites which were noted as being moist. Table 1 shows that diazinon, parathion-methyl and parathion were less effective when applied as turf treatments to these sites. In 1970 most sites were noted as being moist.

It is believed that the known deleterious effects of soil micro-flora in moist soils on some organophosphorus insecticides, together with their relatively rapid degradation in moist soils (in the absence of micro-flora) compared with dry soils (Lichtenstein and Schultz, 1964), would in part account for the rather better effects of the 1969 treatments compared with similar treatments in 1970.

Loss of insecticidal effect in 1970 could have been accentuated by some lateral dispersion by rainfall (see Table 3) which could lead to a dilution of the insecticide to below the necessary lethal concentration.

Kill of grass grubs must be due to their movement into areas of lethal insecticide concentration. Under moist conditions it is possible that the movement of grubs is reduced because of the more abundant feed provided by good pasture root growth, thus further reducing the efficiency of treatments.

Jet Squirt Applications

Table 2 shows a trend toward variability between seasons for this form of treatment also. These results may be due to the same causes as

TABLE 1: RESULTS OF TURF TREATMENT TRIALS, 1969 AND 1970

Year	Treatment (lb)	Mean No. Grass Grubs per sq. ft — all trials		Range of Effectiveness as % Control per Trial
		Treated	Control	
1969	fensulfothion 2	3.8	32.7	98, 96, 94, 94, 94*, 92 90*, 88, 83†, 83*, 82, 72*
1970	fensulfothion 2	2.3	25.2	97, 97, 96, 94, 92, 88, 86, 85, 82
1969	fensulfothion 1	3.9	30.6	96, 92, 91, 72
1970	fensulfothion 1	4.4	29.0	95, 90, 87, 86, 84, 84, 81, 81, 69
1969	diazinon 2	8.1	35.6	98, 97, 92, 92*, 90, 88, 76, 75, 63*, 62*, 52†, 48*
1970	diazinon 2	7.1	27.5	87, 82, 81, 80, 79, 76, 76, 76, 73, 69, 64, 61, 60
1969	parathion-methyl 2	10.2	32.1	98, 85, 69, 66, 46*, 44*
1970	parathion-methyl 3	17.1	28.9	87, 85, 58, 48, 45, 41, 36, 34, 32, 30, 11, 0
1969	parathion 2	9.3	30.7	90, 88, 81, 62, 50*, 45*
1969	lindane 2	12.9	34.5	94, 84, 80, 73, 70*, 62*, 57*, 56, 55*, 46, 45†
1969	"Mocap" 2	5.1	45.8	92†, 91, 85
1970	"Mocap" 2	7.4	27.5	94, 84, 76, 76, 65, 63, 55
1969	"Mocap" 4	0.0	32.4	One trial only.
1969	"Dowco 179" 2	5.2	30.8	80, 68
1970	"Dowco 179" 2	3.0	29.3	90. One trial only assessed to date.
1969	phoxim 2	15.5	31.7	84, 84*, 75, 68, 68, 60, 51*, 40*, 0*

*Soil moist at time of treatment.

†43 points rain fell 2 days after treatment.

TABLE 2: RESULTS OF JET SQUIRT TRIALS IN 1969 AND 1970

Year	Treatment (lb)	Mean No. Grass Grubs per sq. ft — all trials		Range of Effectiveness as % Control per Trial
		Treated	Control	
1969	fensulfothion 2	4.4	29.2	95, 93, 92, 85*, 78, 65*
1970	fensulfothion 2	2.7	17.5	85 — one trial only
1969	fensulfothion 1	5.2	32.7	94, 91, 86, 84, 67*
1970	fensulfothion 1	6.2	25.5	76 — one trial only
1969	diazinon 2	8.1	30.7	94, 93, 91, 78, 68*, 6*
1970	diazinon 2	10.3	33.6	86, 79, 75, 49, 42
1969	parathion-methyl 2	19.8	35.1	82, 52, 44*, 36*, 35
1970	parathion-methyl 3	26.0	37.3	54, 41, 23, 0
1969	parathion 2	22.3	39.4	68, 27, 19*
1969	"Dowco 179" 2	12.5	42.2	88, 72, 45
1969	phoxim 2	15.7	32.8	86, 85, 59, 46, 27*
1969	"Mocap" 2	4.6	43.8	94, 83
1970	"Mocap" 2	8.4	53.1	89, 87, 76

*Soil moist at time of treatment.

have been given for the variability of the turf treatments. There is, however, another important factor: in 1969 treatments were mostly to paddocks which were largely bare due to drought and hard grazing; in 1970, however, paddocks were in much better condition with a far greater cover of grasses, clovers and flat weeds. These prevented much of the applied liquids from reaching the soil and deposits on foliage would not only fail to reach the grass grubs because of their resistance to weathering, but would also have been subject to rapid physical degradation by light.

EFFECTS ON SOIL FERTILITY AND BENEFICIAL ORGANISMS

That long-term deleterious effects on soil might result from the broadcast application of broad-spectrum organophosphorus insecticides has been

TABLE 3: RAINFALL IN MARCH 1969 COMPARED WITH RAINFALL IN MARCH 1970 — LINCOLN COLLEGE RECORDS

March 1969	Rainfall (points)	March 1970	Rainfall (points)
5	2	1	12
6	1	6	16
20	14	7	3
21	32	13	5
29	8	14	156
		15	14
		16	94
		19	1
		20	37
		21	40
		22	7
		24	4
		26	3
		31	23
Total	57	Total	415

TABLE 4: WORM COUNTS

(In 1969 total numbers from twenty 1 in. cores to 6 in. depth, all worms or portions thereof counted as whole worms. In 1970 mean of five 7 in. spade squares. Sampled 4 months after treatment.)

Treatment (lb)	1969		1970	
	Site 1	Site 2	Site 1	Site 2
fensulfothion 2	28	16	15	11
fensulfothion 1	35	14	16	9
diazinon 2	22	13	15	7
parathion-methyl 2	30	13	14*	9*
parathion 2	27	15		
"Mocap" 2	27	14		8
"Dowco 179" 2	29	15		
phoxim 2	21	12		
lindane 2	25	10		
Control	30	15	17	11

*Treatment at 3 lb.

TABLE 5: NEMATODE COUNTS

(Total numbers of free-living nematodes from five 1 in. cores taken to 2 in. depth extracted by modified Baermann funnel technique.)

Site/Treatment	No. of Nematodes/Sample					Totals
	1	2	3	4	5	
Untreated lawn	432	280	256	338	228	1,534
Paddock under cultivation	1	5	5	3	7	21
fensulfothion plot 2 lb	262	398	125	656	452	1,893
Control plot	101	232	164	192	324	1,013
"Mocap" plot 2 lb	155	543	175	206	106	1,185
Control plot	172	269	250	186	307	1,184

TABLE 6: ANALYSES OF DIAZINON IN SOIL

(In ppm at various times, distances and depths from an application line after turf treatment using diazinon 2 lb. Rainfall between sampling dates is also shown.)

Days After Treatment	Rain before Subsequent Sample (points)	Distance from Treatment line (in.)	ppm at Depth of Sample		
			0-1 in.	1-2 in.	2-3 in.
0	67	0	10.1	0.2	0.1
		1/2	0.1	0.1	ND
		1	ND	ND	ND
8	94*	0	14.5	0.1	ND
		1/2	0.9	T	NT
		1	0.1	ND	T
21	114	0	3.1	ND	ND
		1/2	2.4	ND	ND
		1	0.3	ND	ND
34	154	0	1.2	ND	ND
		1/2	0.5	ND	ND
		1	ND	ND	ND
56		0	1.4	0.1	ND
		1/2	0.5	0.1	ND
		1	ND	ND	ND

ND — Diazinon not detectable.

T — Trace, 0.01 to 0.1 ppm.

* — Site also sprinkler irrigated during this period.

Note: Application lines were 4 in. apart: no diazinon was detected from one inch from the application line to the centre point between the lines except for a trace at 8 days after treatment.

of concern to many workers; work on this aspect must be extended over a long period. The results to date, however, indicate that some of the problems are unlikely to arise because of the topical form of application. The preliminary worm (Table 4) and nematode (Table 5) counts and observation of worm populations during the grass grub assessments show no drastic reduction in populations after treatment. In addition, the analyses of soil from treated plots (Table 6) show that contamination is so localized that there is an abundant reservoir of untreated soil from which beneficial organisms may spread when the insecticidal or other effects of the chemical have dissipated. The effects of an annual treatment to the same area cannot be gauged at this stage but, if the chemical is persistent or extremely effective, annual retreatment is unlikely to be required, whilst if the chemical is not persistent it seems that a balance in favour of the beneficial organisms is likely to be maintained.

MACHINERY PERFORMANCE

In general terms, the turf treatment machine constructed by the N.Z. Agricultural Engineering Institute performed well and no problems arose when it was used on pastures which had not been severely damaged by grass grubs. When a mat of loose turf was present as a result of grass grub attack, problems arose with the clogging of the discs with turf and some sites were impossible to treat.

Whilst it is obviously preferable to treat pastures before they are severely damaged by grass grub, if treatments are often to be done on pastures with a loose surface some modification of the machinery is required. No modifications to overcome this problem have been made, but initially it is expected that the removal of the depth skids (see Fig. 2) will be an improvement. Depth of cut could be controlled by the outside ground wheels which could be set to run close to the surface of the pasture and operate as depth control wheels if necessary. The amount of ballast carried should also be adjusted to give the necessary turf cut according to the pasture and soil condition.

The jet squirt apparatus is so easy to construct that the design seems to be a matter of preference and cost.

HAZARDS

The use of any toxic compound poses a risk to the user and appropriate protective clothing must always be worn. Both turf treatment and jet squirt applications are virtually drift-free and one of the hazards from the use of liquid insecticides is largely eliminated. Work in progress indicates that treatment with 1 gal of total liquid per acre is feasible in which case the handling of the concentrate will be reduced to a minimum: chemicals could be supplied ready for use and containers would be merely "plugged in" prior to treatment.

Some chemicals, applied as granules, have over recent years killed many birds. It is believed that turf treatment by placing the chemicals on, or even just below the soil surface, over which there is an insulating mat of grass and clover, would reduce if not eliminate any risk to wild life. It is believed that, if the jet squirt technique were used with the more toxic chemicals on pasture, there would be a hazard to wild life.

SUMMARY AND CONCLUSIONS

The turf treatment and jet squirt trials conducted in 1970 were designed to determine the validity or otherwise of the very promising results obtained by these methods of application in 1969. At the same time, an attempt has been made to determine the practicability and possible hazards of these methods of application for field use.

It has been fortunate that climatic conditions, particularly the pattern of rainfall over the two seasons, has been so dissimilar. It is believed on this account that the following conclusions are valid for the future.

The insecticide fensulfothion at both 1 and 2 lb (all rates in active ingredient per acre) applied through a turf treatment machine has been consistently effective over both seasons. If machinery can be devised to apply a ready-to-use formulation at a very low volume per acre, hazards to applicators may be reduced. On the basis of limited data it seems that the hazards to wild life and beneficial organisms are less when the chemical is applied directly to the soil in discrete lines than as broadcast granules. It is not possible yet to draw any conclusions regarding the use of the jet squirt technique using fensulfothion on pasture since hazards to stock and wild life are still to be evaluated.

The insecticide diazinon applied at 2 lb performed well under the drier conditions in 1969 but was less effective in 1970. On the basis of trial results in the past (Raaijen, 1969; Rastrick and Mason, 1966) using granules, turf treatment is at least as effective as the broadcasting of granules even in a wet season, whilst in a dry one the results from this form of treatment will be more reliable. When applied by the jet squirt technique, diazinon will perform well when paddocks are bared and in the relative absence of rain. When, however, pastures are well grassed and when at the same time there is ample rain, the application of granules may be preferable.

"Mocap", on the limited data available, appears to be promising but more information is required on its limitations and performance.

Parathion in both years and with both methods of application has given results which are so variable that, if its toxicity is taken into account, it cannot be compared favourably with the insecticides already mentioned.

Some other chemicals show promise.

Both the turf treatment and jet squirt machines are essentially very simple: no serious difficulties arose from the use of the machines constructed for these trials and there appears to be no reason why they could not easily be constructed and used commercially.

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