THE ENTOMOLOGY OF GRASSLAND

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I feel that I must start off by explaining that the title of this address is something of a misnomer. I started off with the intention of telling you about as many of our insect pests of grassland as I could, but once I started on the grass grub it was clear I could not do this, as my time was being completely taken up with this one pest and I decided to devote the whole paper to give you an appreciation of the control position concerning grass grub today and to describe some of our plans for the future.

The grass grub, as most of you will know, has been the subject of a great deal of research in the last 10 years. And this it well deserves because it is without any doubt our most important national insect pest and it has this status because it is so widespread in our most important crop, grass. We have tried from time to time, from examination of farm losses, to -form some reliable estimate of the annual loss of production caused by this pest and it has been put as high as £30,000,000 per year. This figure, because of its magnitude and difficulty of calculating it, may not be acceptable to everyone, but even if this is halved the loss per year represents a great deal of money.

Approximately 1,200 tons of DDT were used with fertiliser on grassland last year. If you work this out at 2 lb per acre, you will find that this allows for the treatment of approximately 1,350,000 acres and it is most likely that, in terms of overseas funds earned from this treatment, it more than makes up for the whole present expenditure on the D.S.I.R.-not only the Entomology Division, which did the work, but the whole of the Department with its 24 branches. The application of other forms of DDT such as pelleted formations increases this gain still further. It seems obvious to us that much more grassland can be treated with profit and we have still a long way to go to realise the potential in increasing production in this way.

In many cases in the South Island, farming is marginal on certain classes of light country because of grass grub, and without DDT treatment farmers would find difficulty in carrying on. , In 1946 the Entomology Division began a comprehensive study of methods of control at its station in Ashburton-in the middle of the grass grub country, as it were. This location was chosen because the combination of low rainfall in summer and light land makes this insect a pest over large parts of Canterbury. We tackled the grub from several angles, chemical control and biological control being the two main approaches.

In the chemical control programme it was rapidly found that one of the then new organic insecticides, DDT, looked very promising and it was not very long before it was clear that 2 lb of DDT per acre gave a very worth-while return and that this control would remain effective over three years. It was necessary to add something to this 2 lb to give it enough bulk so that it could be spread evenly over the area to be treated. So dry-mix superphosphate came into being and there is still no form of DDT that is more acceptable for use, and so quick-acting on grass grub infestations.

Because of the finely divided nature of wettable DDT, particles are taken down fairly rapidly by rain, so that under conditions of satisfactory rain we can expect control to begin to show up in two to three weeks. However, it soon became clear that there was a great deal of unsatisfactory mixing of DDT and superphosphate. Sometimes when DDT was coloured the mix obviously contained far too much DDT and in other cases the amount was obviously too small. Because of poor mixing, efforts were made to provide a more satisfactory DDT superphosphate product, and Dr Doak and his staff at the Fertiliser Manufacturers Research Association at Otara, Auckland, produced the material known as wet mix. In this process DDT was incorporated during manufacture of the superphosphate, thus overcoming the problem of unevenness of mixing. Both wet-mix and dry-mix DDT superphosphate have been used for some years now with much success.

As a matter of fact the use of DDT has become so wide that a few years ago I began to get worried over the possible build-up of resistance to DDT in the grass grub. The chemical was being consistently used over wide areas of grassland, particularly in Canterbury, and I arranged to have a toxicologist, Professor C. C. Roan, come to us from Kansas State University, U.S.A, for the express purpose of studying the reaction of grass grubs to DDT in as many parts of New Zealand as possible. He worked out a method of applying DDT in acetone solution in the laboratory to grass grubs collected from the field. (We call this topical application.) My idea was that from this widespread study we could derive a figure of so many milligrams of DDT per unit weight of grass grubs as an expression of the LD50 in normal grass grub populations. (The expression LD50 means the dose of DDT in relation to body weight required to kill 50 per cent of the grass grub population.)

The grass grub has only one generation per year and for some reason, which I am afraid I cannot adequately explain, I felt it would take the grub something like 20 years to develop appreciable resistance to DDT. This was the period it had taken' the codling moth in apple orchards in South Australia to develop resistance to DDT. It had already been suggested in certain cases where control of grass grub had been poor, that resistance had developed, but our investigations invariably showed that in most cases the difficulty could be explained by the use of faulty mixes of DDT superphosphate. It was an unsatisfactory situation anyway, and I wanted this standard reaction to DDT (or the LD50) so that we could have a measure to determine whether in fact any degree of resistance was occurring in areas where control was said to be difficult. We found that in certain areas (one near Patea) grubs definitely required more DDT to kill them. It has become pretty clear to us now that all such areas where this sort of difficulty is being experienced have a history of previous DDT treatment, but only over a period of three or four years. In one area at Riwaka in Nelson we found that in laboratory tests 100 times the normal dose of DDT would not produce a satisfactory kill. When we tried field experiments on this site we could get no kill with the normal 2 lb of DDT, either in the year of application or the next year. We could get kills with other chemicals, such as some of the organophosphates, but certainly not with DDT. This area had previous DDT treatments in 1954 or 19.55, 1959, and 1960.

It has been the experience for some time in certain areas of Rotorua pumice country that it is difficult to secure a satisfactory kill of grass grub with 2 lb of DDT per acre. One would think perhaps that in this light, relatively open soil penetration of DDT would be rapid and it would easily be well washed down by rain. Members of the Fertiliser Manufacturers' Research Association's team, however, have shown that in some of these soils DDT does not penetrate more than 3 in. This is a physical effect caused by absorption of the DDT on the soil particles, and the DDT does not penetrate deeply enough to reach the grass grub feeding on the grass roots.

During the past 12 months there has been the suggestion that the presence of protozoa in the gut of grass grubs has reduced the efficiency of DDT. In our trial at Riwaka, where we were certainly dealing with grubs that resisted DDT treatment, we found most of such -grubs were heavily infested by these protozoa. We found that a strain of grass grub in another area in Nelson that was normally susceptible to DDT was only lightly infested by protozoa. We have since found, however, grubs normally susceptible to DDT which contained heavy infestations of protozoa. We still do not know the exact answer, but we believe from the field evidence we have that protozoa are not necessarily connected with difficulty to kill with DDT. But we have yet to prove the exact relationship between these protozoa and the 'economy of the grass grub.

So we do know of several cases where grass grubs cannot be satisfactorily controlled with 2 lb DDT per acre. There seem to be various reasons, and our investigations are not yet by any means completed. But it seems fairly clear that continued use of DDT has in some instances at least brought about increasing inefficiency of this material.

Then again, physical factors in the soil have brought about inefficiency. I, for one, have been worried about how widespread factors making for inefficiency are on grassland, and this was one of the reasons why we held a conference recently in Nelson. This conference was attended by representatives of the Department of Agriculture, the Fertiliser Manufacturers' Research Association, agricultural chemical manufacturers, fertiliser manufacturers, the Dominion Laboratory, D.S.I.R., and the Entomology Division.

The Department of Agriculture gave us the comments of the field men of the Farm Advisory Division. They had been asked if DDT at the rate of 2 lb per acre was effective against grass grub. These field officers considered that if DDT is properly mixed (whether by farmers or manufacturers) and properly applied, it appeared to be as effective as ever in the control of grass grub, except in the following areas :

Auckland

(i) At Matamata, Harris Road area, Putaruru and Old Cambridge Road between Tokoroa and Hodderville.

(ii) Rotorua-Reporoa Strathmore-Broadlands and Mihi areas on the more droughty, open-textured pumice soils.

(iii) One case only in the Pukekohe-Waikato Heads hill country.

Rangitikei .

Hunterville district (Kiwitea silt loam).

Taranaki

Westmere-Wansley area, where there is some doubt about DDT giving control on the Egmont loam soils.

Nelson

(i) Riwaka and Brooklyn valleys.

(ii) An area of about 2,000 acres near Reefton.

Marlborough

The lower Wairau area.

Otago

(i) Hindon-Black Rock area.

(ii) Macraes Flat area (Wehenga soil type).

Southland

(i) Takitimu and Homestead block, Te Anau (Lands and Survey block).

(ii) An area round Gore.

Please remember, however, that in most areas by far DDT is still effective. Unless you happen to be in one of these problem areas or you know from your own experience that you do not get the results expected from DDT application, you can be confident in still using it. We are trying next grass grub season to cover as many of these problem areas as we can so that we can have more accurate information about them that will help us to work out these difficulties.

Then what about residues in farm produce? The insecticides we use to kill insects are generally also harmful to other forms of animal life in varying degrees. It is only natural that we do not want to take in with our food anything that is going to be harmful to us, To prevent -this happening there is a vigilant organisation in New Zealand as well as in overseas countries where insecticides are used. The Department of Health is the responsible body here. How is testing done? Mostly by trial on laboratory animals such as white rats. What is the safe dose of these materials can easily be determined in, say, a white rat's diet and also what is the toxic dose. This dose is related to the body weight of the animal tested. The reference standard for different chemicals is generally called the LD50, which in ordinary terms is the amount required to kill 50 per cent of the population. From these are fixed the amounts allowable in human food. They are of the order of 1/100 of the minimal dose toxic to the test animal. On this basis the allowable amount of DDT in human food has been fixed at 5 parts per million parts of food. We can rest assured that food containing this or less will be harmless to us.

The residues in farm products, of course, come from the chemicals placed on the grass for grass grub or other insect pest control. Every farmer should be conversant with the conditions of correct application of insecticide materials and the precautions to be observed in their use. We advise that applications should be made only to dry, short pastures; stock must not be in the fields at the time of application, and they must be kept out for certain periods (withholding periods). These vary according to the class of stock to be held in such paddocks, for example, whether dairy cows or sheep. Precautions should be taken to prevent drift of insecticide on to other areas, either neighbours' farms or other parts of your own farm where stock are grazing. It is obvious that if you were to treat your whole farm in the season you could easily run into difficulties with residues and for this reason a farmer is not allowed to treat more than one-third of his property.

I cannot emphasise too much how important it is to observe these precautions carefully. As most people know we are experiencing certain difficulties in our overseas trade in such commodities as meat. Certain countries that offer profitable markets for us have stringent laws governing the amount of insecticide residue allowable in such meat. I am afraid that (usually because of careless application by some farmers) we are becoming alarmed over the frequency with which residues are found that exceed the accepted tolerance of 5 parts per million. A careless few are spoiling things for the great majority.

The other obvious cause of excess contamination is drift. Unfortunately there have been instances of farmers having excess contamination 'of products who have not used insecticide; it has come from a neighbour. To stop this sort of thing it will be necessary to ensure that the formulations used will not drift. This means using pellets.

It is interesting to consider the seriousness of the residues left on grass by various formulations. The residues left decrease as one goes down the following list:

Sprays (emulsion or wettable powders)
Dry-mix DDT superphosphate
Wet-mix DDT superphosphate
Granulated DDT superphosphate
Prills mixed with Superphosphate
Prills

The amount of residue left on grass from granulated forms is about 1/10 of that left by dry or wet-mix DDT superphosphate; and sprays leave still more. It is therefore clearly obvious that if granulated or pelleted forms containing DDT are used, risks of contamination are much less. Since the prevention of harmful chemical residues is a completely governing factor in the application of insecticides to grassland, isn't it rather obvious that we should aim at trying to make the application of such forms quite practicable? There are certain difficulties in the way at the moment: Price, and the fact that pelleted or granulated forms have been shown in our tests to be slower acting on the grubs, because they take longer to get down to the soil region where the grubs are working. Granulated forms, for example, act much more slowly than does dry-mix DDT superphosphate. But I feel that the future for use of insecticides on grassland lies in the improvement of pelleted formulations.

Well, if DDT is proving so troublesome are there not some other insecticides that are as effective and much safer from the residue point of view? We are continually looking for such a material. The class of chemicals known as the organophosphates, into which diazinon, gusathion, malathion and delnav all fall, do not leave harmful residues in farm products; they break down very rapidly, so that nothing harmful is left in, say, 48 hours or less. It has been found that cows can be fed diazinon with their feed and no trace of it appears in the milk at the next milking. This is a severe test.

We have tried representatives of the organophosphates such as diazinon, gusathion, folidol, malathion, dipterex, parathion, and many more, and we have also tried representative carbamates, such as sevin and zectran, and also chlorinated hydrocarbons other than DDT (such as heptachlor, telodrin, methoxychlor, and chlordane) .

We first tried diazinon and gusathion on the DDT-tolerant grass grub population at Riwaka, where 2 lb of DDT per acre did not work, Diazinon and gusathion were used at 4 lb and 2 lb per acre in this preliminary work. We took special pains to get this material down into the infested pasture so that it would come into contact with grass grubs as quickly as possible and therefore we used diazinon as a wettable powder and gusathion as an emulsion, and after application they were well watered in.

The plots were examined 10 weeks after treatment both by counting grubs in the soil and by observation of the type of grass growth on the plots. It was quite clear that whereas we had no response with DDT, diazinon and gusathion had given good kills and the growth of grass on the diazinon plot was the best. In the following generation, too, it was clear that the effect from even the 2 lb of diazinon was still showing, but we are not sure whether the original kill was so thorough that there were no beetles left to infest these plots the following year or whether the diazinon persisted to the second year. We haven't enough information on the habits of grass grub beetles yet to allow us to decide.

Watering in of this formulation is hardly a practical way for the farmer to apply diazinon, so the next year we applied diazinon in granulated form in Nelson and Canterbury areas. Again we secured control, but results were a bit erratic, depending on rainfall. Where rainfall is plentiful and the material is quickly washed in, it appears that good control can be expected, but where rainfall is light the chemical deteriorates before it can reach the level where the grass grubs are working. We are also trying the effect of lower rates of diazinon and generally carrying forward our work with this material, but we have not reached a stage yet where we can recommend it for farm use. One of the very big drawbacks is the cost of treatment, which for 2 lb per acre is something like £8 to £9, which of course is prohibitive. Gusathion is somewhat cheaper, but not within the bounds of practical economics.

If, say, diazinon proved generally satisfactory as a grass grub controller, large usage might, I presume, bring the price down, but several critics dispute this; I do not see how it can be used on a large scale until the price is considerably lowered. Unfortunately, this may well prove to be an insuperable difficulty with this class of chemical.

As examples of other chlorinated hydrocarbons I want to mention heptachlor and telodrin. Straight away, I want to say that both these materials seem to be better soil insecticides against grass grubs than DDT. They kill better at equivalent dosages and both have remained effective for the two years we have had them under test, but they are still chlorinated hydrocarbons and persist in the fat of the animal body so that we are very liable to have our residue trouble still. Heptachlor is considerably more toxic than is DDT (about three times) and our only hope when we compare it with DDT is that we can use it at lower dosages than for DDT. Price again comes in, as heptachlor costs about four times as much as DDT. I think we are almost satisfied about the efficiency of heptachlor as a grub killer at, say, 1 lb per acre, but the thing that is stopping us from recommending it is the unknown degree of the residue problem from its use.

Telodrin, it appears, from the tests we have done, may be satisfactory at ½ lb to 1 lb per acre. In laboratory tests we have found it effective at less than ½ lb per acre, but such low concentrations have failed in field tests. It is considerably more toxic than is heptachlor and there is particular uncertainty at the moment about its practicability because of this. Price has not been discussed with us as far as I know, because development and application of the chemical under conditions in New Zealand have not got that far.

In summing up control of grass grub by chemicals we can say definitely that nothing yet in sight can compete with DDT in safety and economics. Unfortunately we have the danger of residues, and something will have to be done about that I think. Earlier, I outlined the possibilities of pelleted or granulated formulations. As far as I can see from the price angle alone DDT is likely to be with us for grass grub control for quite a time yet. We are suspicious that wholesale resistance to DDT by grass grub might appear. If this happens of course, its useful period of grass grub control will be over, but this is by no means the situation at present.

I would ask farmers very seriously to do their utmost to observe the proper precautions in applying DDT; your local agriculture instructor will be only too pleased to help you with this. If you can all do this, it will help us considerably to increase farm production in New Zealand.

There is only one other aspect I want to touch on. We are not only relying on chemical control for grass grub, but have made a start to explore the possibilities of biological control. We started on this years ago when our grass grub station was established at Ashburton, but success with DDT threw out of gear all our other ideas. However, because of residue problems (and with resistance problems showing up on the horizon) we are continuing with our efforts in biological control.

The grass grub is a native insect and we have encountered some dozen or so natural enemies over the years, but nothing that really controls it. The fact that it is a native will suggest to most people that it is going to be particularly difficult to graft an exotic parasite or predator on to a native insect. However, there is nothing to show that this is not a reasonable task to attempt. As a matter of fact I am going to quote two examples where this has been done and in this part of the world-in Fiji.

About 1925 a moth, ***Levuana iridescens,*** thought to be a native, was causing a great deal of damage to the coconut palm and grave fears were held for the future of the copra industry. There were no known parasites of this ***Levuana*** species. In a determined effort to do something about control, the authorities decided to import a parasite *Ptychomyia remota* from Malaya. This insect was a parasite of another moth species ***(Artona catoxantha)*** which is in a different sub-family from ***Levuana,*** though the larvae or caterpillars are very similar. The upshot was complete control of the ***Levuana*** pest. Within three months of liberation at the original liberation site in Suva the pest was completely exterminated in that area, In six months this remarkable insect had spread over the other infested parts of Fiji, with wonderful results in controlling the *Levuana* pest. In a year or two the pest was almost wiped out of the colony.

The same thing has happened in Fiji with another coconut pest, a leaf-mining beetle. This native beetle has been well controlled by introducing an exotic natural enemy.

We have good hopes that it may be possible to find a parasite on a similar species in some part of the world that may control our grass grub. I feel that if we do not investigate this possibility, we will be lacking in our duty as scientists. If we are successful, we will do away at once with problems of resistance and harmful residue of chemicals in food and the cost of control will be immeasurably reduced. So we have reinstituted a campaign of looking for possible natural enemies overseas. At present the Commonwealth Institute of Biological Control is looking for them in South America. We are sending them annually about £1,000 for this search and we are almost on the point of receiving material from them.

We are also interested in the possibilities of using biological control agents such as bacteria, viruses, protozoa, nematodes, or parasitic worms and fungi, and we have at our laboratory at present a Fulbright scholar from the University of California, Professor Hall, who we hope can help us, as he is an expert in this field. The Department of Agriculture is also cooperating and has made a number of investigations with materials it has imported.

I hope I have been able to give you some appreciation of the state of control of grass grub today and of our plans for carrying on this work. When we discovered DDT as a remedy for grass grub, many people thought trouble from the pest was over; this was a reasonable attitude, but I think you will be able to see how wrong it has proved to be.

DISCUSSION

Q. (McKenzie): Could Dr Cottier say how long an application of DDT will give protection against *Porina* attack?

A. Our Mr J. M. Kelsey maintains that in Canterbury DDT will probably protect against subterannean grass caterpillar for three successive years. However, in Otago and Southland and some areas in the north farmers claim that protection is secured only for one year, i.e., the year of application. We are concerned about this and are making arrangements to investigate control in these areas.

Q. (McKenzie): If the *Porina* caterpillar is killed by eating poisoned grass, how can effective control be obtained with pelleted forms?

A. Pelleted forms are definitely slower in effect than are dry and wet mix DDT superphosphate, because of the much lower amounts of DDT left as residue on grass foliage. Residues left on grass by pelleted forms are 1/10th that left by dry and wet mix DDT superphosphate. Residues are causing difficulties in our farm products and in order to protect our export trade, it is desirable to restrict the application of DDT to pelleted forms. We will have to suffer the consequence that immediate control will be slower-but this will depend on climate and with good rainfall results might be quicker than in dry climates. We have not carried out enough experimental work on this but results people get with pelleted forms indicate this. We are working to find an alternative means of controlling *Porina*; also we may have to get back to baits. Where control is obtained over a series of years good control can definitely be anticipated in the second and third years after applying pelleted forms.

Q. Would starlings eating grass grubs on areas treated with DDT be affected?

A. Yes, it is possible that starlings may be killed in this way, but I would hasten to add that we ourselves have not seen any appreciable number of dead bodies lying about treated areas. I have heard reports now and again on this happening but from our experience we feel that the cause might be from something else. From overseas experience I should think the feeding of such grubs to nestling birds might have serious consequences. This is the most likely way DDT could be serious to starlings. Although we are constantly on the lookout for 'cases of harm by DDT to starlings and other birds, we have not seen any convincing evidence in New Zealand, but I would like to see some work done to try and assess the effects on nestlings.

Q. (C. P. Whatman): Would Dr Cottier comment on the placing of DDT directly into the soil in order to leave no residue on the pasture?

A. The placing of DDT directly into the soil in this way would solve our residue problems. It would be of particular interest in grass grub control. No really serious effort has been made to develop machinery for doing this satisfactorily in grassland, but I think this will be worth investigating. The ploughing up of pasture and the application of DDT on fallow ground, say, once every three years could be an answer to the grass grub problem, but then the present method of grassland farming does not permit this; if we were to do this it would mean changing our whole method of farming. Also it does not seem to me feasible to use this method in hill country.

Q. (A. Pantall): Will there be a supply of DDT fertiliser this autumn? Is anything being done to reduce the cost of prills, which represents a considerable added expense to the farmers?

A. I am afraid I cannot answer this at present. I hope there will be pelleted forms of DDT-superphosphate available, but the necessary costly machinery to produce this is possessed by only a few fertiliser works. This will be over to the fertiliser companies.

I do not know of anything being done to reduce the cost of prills for farmers. I presume large usage will automatically reduce the price, and manufacturers will help farmers as much as possible. It is unfortunate, but in order to protect our overseas markets, farmers will in the immediate future find the cost of DDT treatment higher.