INSECTICIDAL RESIDUES ON PASTURE AND FOODSTUFFS

D. L. HARRISON

Wallaceville Animal Research Station

Summary

Insecticides applied to pasture for the control of plant or soil pests leave residues on plant tissue, the magnitude of which depend primarily on the rate of application and formulation. Subsequent depletion of residues is governed by many factors including plant movement, rainfall, general weathering effects, and dilution by the bulk of new plant growth. Sufficient withholding periods for stock must be observed following the application of insecticides to grazing pastures to ensure that residues in derived meat and dairy produce are kept below legal tolerance levels. The results of trials on this subject carried out during the last three years are presented and discussed.

INTRODUCTION

PASTURE is the major food item of the New Zealand sheep, beef animal and dairy cow and foodstuffs derived from animal tissue comprise a large proportion of human diet in this country. It is well established that when pasture contaminated with insecticide (especially a chlorinated hydrocarbon) is ingested by stock, some of the insecticide will survive the processes of digestion and accumulate in the body fat appearing eventually as a residue in the fat portions of meat and dairy produce. From the nature of this pasture/animal/foodstuff complex it is clear that such an insecticide residue in food is merely the end result of a process beginning with the insect pest on the pasture. Insecticide residues in food serve no useful purpose and may in fact present a possible health hazard. For this reason health authorities have set permissible limits or tolerances for these chemicals in food — tolerances which must be met if the food is to be acceptable on New Zealand and overseas markets.

There are few pasture pests which cannot be controlled effectively and economically with the array of agricultural chemicals presently available in this country. The tolerance levels for residues of these toxicants that will be acceptable on toxicological grounds is also known. The use of insecticides on grazing pasture must, therefore, be a compromise between effective pest control on the one hand and consumer safety on the other, the link between the two being the time interval between application of the insecticide and the introduction of stock to the treated forage. This review covers some of the residue studies with dieldrin and DDT which have been carried out by Wallaceville Animal Research Station during the past three years. With the analytical methods used in this work the lower limits of quantitative detection of dieldrin and DDT were 0.1 p.p.m and 0.5 p.p.m., respectively. For practical purposes, figures of the above order were considered to meet the requirement of a nil tolerance.

DIELDRIN

Four trials, in which dairy pasture was sprayed with 4 oz of dieldrin per acre applied as a diluted 15% dieldrin emulsion, were carried out at Dargaville during January to April, 1959.

TRIAL 1

A 7.3 acre area of 3 in.-long pasture was sprayed and grazed continuously for the ensuing 56 days by a group of five cows. Tables

1 and 2 show the results of dieldrin analyses of pasture samples taken at random from the whole area and of butterfat made up at intervals from pooled milk from the five cows.

TABLE 1: DIELDRIN ON PASTURE

<i>Days after Spraying</i>	<i>Dieldrin (p.p.m. on dry matter basis)</i>			
-1				0.35
0				29.5
2				15.3
4				14.1
7				9.4
14				10.4
21				4.2
28				1.1
56				0.4

Rainfall: 0 to 2 days — 1.55 in.; 0 to 56 days — 7.29 in.

TABLE 2: DIELDRIN IN BUTTERFAT

<i>Days after Spraying</i>	<i>Dieldrin (p.p.m. on bulked butterfat of 5 cows)</i>			
-1				0
3				21
7				17
14				11
21				8.5
28				6.6
56				2.4

A further four fresh cows were put on this area 56 days after spraying and grazed for one week. The bulked butterfat gave the following results:

Pre-grazing control 0.6 p.p.m.
56 to 63 days (7 days grazing) 0.7 p.p.m.

The control in this latter experiment contained dieldrin but the difference figure of 0.1 p.p.m. shows that there was negligible uptake of dieldrin from the pasture after 56 days.

TRIAL 2

A 6.2 acre area of 2 to 3 in.-long pasture was sprayed, fenced off into quarters and left for one week. Four groups of five cows were then admitted to the ungrazed quarters successively 1, 2, 3 and 4 weeks after spraying. Each group grazed the area for one week after which pooled butterfat samples were analysed for dieldrin content. The results are given in Table 3.

TABLE 3: DIELDRIN IN BUTTERFAT

<i>Days after Spraying</i>	<i>Dieldrin (p.p.m. on butterfat of groups of 5 cows)</i>			
-1				0
7 to 14				28
14 to 21				6.0
21 to 28				3.1
28 to 35				1.6

Trial 1 showed that the level of dieldrin on sprayed pasture which was being grazed continuously by cows reached approximately 1 p.p.m. after one month and was of the order of the pre-trial control pasture level after two months. The level of dieldrin in the butterfat of cows grazed continuously after spraying reached a maximum in the first three days. After one month the level was

6.6 p.p.m. and after two months 2.4 p.p.m. Extrapolation of the results in Table 2 indicated that the butterfat would not be free from dieldrin in less than four months from the time of spraying. There would be negligible uptake of insecticide from the pasture after two months so that the dieldrin appearing in the butterfat after this period would be derived from insecticide stored in the body fat during the first few weeks following spraying.

It is clear from Table 3 that one month is too soon to return cows to sprayed pasture and it is estimated by extrapolation of these results that cows should not be returned to sprayed pasture sooner than two months after treatment to prevent dieldrin contamination of butterfat. These conclusions were confirmed in two more similar trials carried out during the same period. It should be noted that rainfall was high during these trials and pasture growth in this North Auckland area from January to April was extremely rapid.

The following year dieldrin was used on the same farm in the forms of dieldrin-superphosphate (two trials) and 5% dieldrin prills applied at the rate of 4 oz of insecticide to the acre. Cows commenced grazing immediately after topdressing in Trials 1 to 3 and after one week in Trial 2. A grazing pattern similar to that described for Trial 2 above was followed using 12 groups of four cows. The residue levels in butterfat obtained are shown in Table 4.

TABLE 4: DIELDRLIN IN BUTTERFAT

<i>Grazing Period after Treatment (days)</i>	<i>Dieldrin (p.p.m.)</i>		
	<i>Trial 1 (Dust)</i>	<i>Trial 2 (Dust)</i>	<i>Trial 3 (Prills)</i>
1 to 8	3.4		1.2
8 to 15	3.0	2.9	1.1
15 to 22	1.4	1.1	0.7
22 to 29	0.5	0.6	0.6
29 to 36		0.5	

The pre-trial butterfat controls had an apparent dieldrin content of 0.12 p.p.m.; total rainfall during the trial was 8.49 in.

The results indicate that dieldrin contamination on these pastures during the first week (as reflected in butterfat levels) were much greater from dieldrin dust (Trial 1) than from dieldrin prills (Trial 3), but residues were similar from all treatments by the 4th week after treatment. A withholding period for dairy cows of at least six weeks would be necessary for both dieldrin prills and dusts to avoid detectable residues in butterfat. Rainfall and pasture growth rate were again extremely high and it is considered that the period for withholding stock would have to be longer than six weeks if dust or prill treatments were followed by relatively dry conditions with minimum plant growth. Follow-up work at Wallaceville based on pasture analyses from replicated plot treatments with dieldrin-superphosphate dust and dieldrin emulsion sprays showed that, while residues from spraying were higher initially by 56% than from dusting, the residues at 28 and 42 days were similar from both spray and dust formulations. It was not until eight weeks after insecticide treatment that the pasture residues returned to the pre-trial control level of 0.15 p.p.m. on the dry-matter basis.

DDT

The magnitude and persistence of DDT residues on pasture were studied by applying this insecticide to 1/40 acre ungrazed plots in the forms of an oil-based emulsion spray, wet-mix DDT-superphosphate and dry-mix DDT-superphosphate. Treatments were applied

to short dry pasture at the nominal rate of 2 lb (all rates given in lb of p.p. isomer per acre), and values in Table 5 are mean residue figures from triplicated plots.

TABLE 5: DDT ON PASTURE
(Figures are p.p.m. on dry matter basis)

<i>Days after Treatment</i>	<i>Spray Area</i>	<i>Wet-mix Dust Area</i>	<i>Dry-mix Dust Area</i>
1	2,440	490	767
4	1,352	107	182
8	695	52.5	72.5
14	316	31.8	38.3
21	—	13.0	12.8
28	82	7.5	8.3
42	26	2.1	3.0

Of the three forms of DDT, residues from spray treatment were the highest and most persistent. Compared with wet-mix DDT-superphosphate the pasture contamination from spraying was 5 times greater after one day, 12 times greater after 42 days, and approximately 8 times greater over the whole trial period. Subsequent analysis of the DDT dusts showed that the wet-mix fertilizer (1.8% pp-DDT, equivalent to 2 lb) contained only 72% of the DDT in the dry-mix formulation (2.5% pp-DDT, equivalent to 2.8 lb). On the reasonable assumption that it would be valid to reduce the dry-mix residue values to 72% of those shown in Table 5 for equal initial rates of fertilizer application, there was essentially no difference in the residue levels and persistence of DDT for wet-mix and dry-mix formulations.

No rain was recorded before the one-day samplings but between the 1- and 4-day samplings the rainfall was 0.99 in., mostly light persistent rain with occasional heavy showers. It is clear from the analytical results that approximately 1 in. of continuous rain soon after topdressing does not remove the DDT from pasture as has sometimes been supposed. Over the six weeks of the trial, the total rainfall was 4.56 in. and the average pasture length on uncut areas was about 12 in. when the trial ended.

These two factors, together with unmeasurable effects such as dislodgement of deposits by wind, volatilization of insecticide, breakdown through ultraviolet light, etc., all contribute to the reduction of residues in the field. From 1 to 4 days the DDT applied as dusts was depleted by 76 to 78%, whereas the loss of spray residue was only 45%. After 14 days between 87 and 95% of the one-day deposits had been lost from all treatments and the subsequent rates of depletion were similar and gradual.

A logical explanation for these results is that, in the first few days after topdressing and before appreciable plant growth had occurred, residue loss would be largely mechanical through the action of wind and rain with dust particles being more easily removed from the plant surfaces than oil-based emulsion deposits. Insecticide remaining on pasture after a week or two is probably firmly adherent to or dissolved in the cuticular waxes, and, whatever the subsequent rainfall and plant movement, residue loss would be mainly the result of dilution by fresh plant growth. For this reason, a "time for pasture growth" factor or withholding period must be observed when pastures are treated with chemically stable and therefore persistent insecticides. It is also apparent that the residue-diluting effect of plant growth will be more pronounced on short than on long pasture and this underlines the necessity for grazing down pasture as short as possible before applying insecticides.

In a recent trial at Stratford, dairy pastures were treated with DDT-superphosphate (wet-mix) and 10% DDT prills (a pelleted formulation) and residues were determined on pasture and in the butterfat of cows which were allowed to graze for one week at various intervals after topdressing.

TABLE 6: DDT ON PASTURE
(p.p.m. on dry matter)

<i>Days after Topdressing</i>	<i>Prill Area</i>	<i>Superphosphate Area</i>	<i>Rainfall between Samplings (in.)</i>
7	10.2	56.8	6.09
14	5.0	25.3	0.26
21	1.3	10.3	4.44
28	1.0	8.1	0.05

The apparent DDT content of control pasture was 0.9 p.p.m.

TABLE 7: DDT IN BUTTERFAT
(Mean residue levels for separate groups of three animals)

<i>Grazing Time after Topdressing (days)</i>	<i>Prill Area</i>	<i>Superphosphate Area</i>
7 to 14	4.1	23.5
14 to 21	3.3	11.0
21 to 28	1.1	5.0
28 to 35	0.5	1.6

The DDT in pre-trial butterfat controls for the 8 groups of cows used ranged from 0.3 to 0.8 p.p.m. with an average value of 0.5 p.p.m.

This trial showed conclusively that DDT contamination of both pasture and animal fat was considerably less when the insecticide was used in the prill or pelleted form. The residues from prills expressed as percentages of the corresponding residues from DDT-superphosphate were:

Pasture: At 7 days	.....	.....	.....	.....	.....	18%
Overall	.....	.....	.....	.....	.....	17%
Butterfat: At 7 days	.....	.....	.....	.....	.....	17%
Overall	.....	.....	.....	.....	.....	22%

From the data in Tables 6 and 7 it was established that negligible contamination of butterfat would result from grazing dairy cows on pasture on which the DDT level had reached approximately 1.3 p.p.m. on a dry-matter basis.

CONCLUSIONS

Several conclusions of a general nature may be drawn from the results of the foregoing trials and these are discussed in the following sections.

FORMULATION

For a given rate of application the degree of contamination of pasture and the fat of grazing animals depends primarily on the physical form of the insecticide, for the tendency to leave residues decreased in the order emulsion sprays > superphosphate dusts > prills. Stock withholding periods will also decrease in the same order. From the viewpoint of residues in foodstuffs, therefore, the tendency must be towards pelleted formulations for persistent insecticides and the main use for sprays will be for insecticides of the organo-phosphate type with short residual life in the field.

RAINFALL, PLANT GROWTH AND WITHHOLDING PERIODS

It is probable that rain assists in removing the bulk of the initial insecticide contamination from pasture soon after treatment and subsequently assists in promoting new pasture growth which has the residue-diluting effect already described. Soil fertility,

pasture species, and ground temperature are examples of other factors which must also play a part in residue reduction. It is virtually impossible to set one withholding period for the year-round use of a persistent insecticide on pasture by which it could be guaranteed that a fixed tolerance for animal produce would never be exceeded in any part of the country. Considerably more data are required on residues resulting from the use of insecticides on pastures under a variety of climatic conditions.

SAFE PASTURE

In this context insecticide-treated pasture will be safe to graze when the residue remaining on pasture does not result in residues in derived food in excess of an acceptable tolerance. Thus, from the Stratford trial, dairy cows should not be allowed to graze until the pasture DDT-level has fallen to approximately 1.3 p.p.m. in order to avoid residues in butterfat. The safe DDT-level for meat-producing animals will be higher than that for dairy cows as in New Zealand the tolerance for DDT in meat fat is 5 p.p.m. In the particular case of dieldrin, there is a nil tolerance for both meat fat and dairy produce. The dieldrin trials indicated that cows should not be returned to dieldrin-treated pasture until the dieldrin level was of the order of the pre-trial control value.

It is probable that insecticides will be detectable in the daily milk so long as there is any insecticide in the fat depots of the animal. A nil tolerance in dairy produce means that lactating cows must be virtually free from insecticide contamination at all times. Further work is being carried out on these aspects of residues.

INSECTICIDE DRIFT

Although outside the scope of the trials covered in this review the problem of insecticide drift to neighbouring farms or on to other parts of the same farm during the spreading of DDT-superphosphate dusts is one which could have serious consequences, particularly in a dairying area. It can be calculated that one gram only of DDT on an area of one acre of 3 in. pasture will result in an average residue of about 1.5 p.p.m. — approximately the level considered safe for dairy pastures. Even in moderate wind conditions it would be difficult with ground appliances to guarantee that no more than this quantity of insecticide drifted on to an adjacent area and the problem would obviously be accentuated by aerial application. A farmer may have a third of his property topdressed from the air with DDT and observe the withholding period recommended for the acceptability of his own farm produce while his neighbour, whose cows were grazing on the other side of the fence during topdressing, could be penalized for producing insecticide-contaminated milk. This situation is unfair to both parties concerned, and, if it can be corrected by the use of a DDT formulation which eliminates drift altogether, then the use of this form of DDT must be encouraged.

It is apparent from this review that there are many problems associated with the use of insecticides on pastures in relation to the grazing animal that still need to be studied. In this regard the setting of food tolerances in New Zealand without the comprehensive but necessary background data on agricultural usage is the exact reverse of the procedure which has been followed in the U.S.A. Food tolerances in both countries are similar and similar recommendations for insecticide use may apply equally well in many cases. Pasture, however, is in a special category in that it is the staple diet of grazing animals. It is essential therefore that an endeavour should be made to find the most effective and safest means of using insecticides against pasture pests under New Zealand's particular conditions of pasture production and farm management.