ECONOMICS OF PASTURE INSECT CONTROL

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THE effect of technical advances on farm production is manifest in two ways: first, what could be termed the "offensive" effect — *i.e.*, efforts to improve productivity by the development of higher-yielding varieties, labour-saving machinery, more efficient fertilizers and so on — and, second, contributions of a "defensive" nature (Lewis, 1962) concerned with maintaining existing levels of productivity against the natural causes tending towards their reduction. Advances in the second field are usually less dramatic but it would be uncomfortable to contemplate the fate of some New Zealand industries if it were not for the intervention of the agricultural scientist in his protective role.

Measures of the contribution of improved technology to agricultural productivity largely overlook the contribution of the scientist in the defensive field; the more successful farmers are in eradicating pests and diseases, the more difficult it is to assess their effects*. The costs of plant and animal protection on the farm are usually swallowed in some imprecise accounting term and lie buried forever.

It is clear that, although pasture insect control undoubtedly contributes to national production, it does so in a defensive way.

SOME PREVIOUS PAPERS

The major contributions to the economics of pest control originate from the United Kingdom and the United States. The various attempts, at the national level, to estimate aggregate crop losses in various countries are summarized by Ordish (1955):

Country	Loss attributed to Pests and Diseases
United States	 13.5–19% (10 crops) — value \$200,000 m.
Switzerland	 25–30% (2 crops, vines, fruit and vegetables)
Holland	 10% — all crops
Germany	 15% — several crops
Britain	 £88 m. — negating 2 m. acres of crop land

At the farm or crop level, Ordish developed a simple extension of a cost/potential benefit ratio for evaluation of crop protection measures. Hillebrandt (1959) has constructed a model based on a theoretical dosage-response curve, showing, for various doses of pesticide, the yield of the crop which is attributable to the application of the pesticide. The model was extended to consider different levels of infestation, and uncertainty (Hillebrandt, 1960). The only New Zealand publication on the economics of insect pests appears to be that of Flay and Garret (1942), which analyses the costs of grass-grub (*Costelytrum zealandica*) infestation on medium land in Canterbury. These costs were expressed largely as reduced crop,

* These effects are probably both unmeasurable and immeasurable. Ironically, one would hope that the desire to assess even part of this contribution is continually frustrated, since this would require a widely destructive epidemic — *e.g.*, an outbreak of foot-and-mouth disease or of some pest totally immune to treatment.

meat and wool production, and the costs of additional re-sowing of pastures as a result of grass-grub infestation. At this time, the possibility of economic control on a farm scale appeared “remote”, and the adjustment of farm management policy provided the most promising method of minimizing the financial loss of grass-grub infestation.

In the last two decades, the chemical control of pasture insects has been facilitated by widespread availability of DDT as a relatively cheap insecticide. In more recent years, with the legislative control of the use of DDT, and the emergence of alternative, and more expensive, chemical control measures, it has become highly desirable for an integrated and co-ordinated approach to the economics of control of pasture insect pests.

THE MEANING OF ECONOMICS

The development of any discipline or field of study is inevitably accompanied by the adoption of a terminology which is often meaningful only to those whom it serves. Different disciplines often impart quite different meanings to the same term. The word “economic” is one such term, which appears to have three distinct meanings:

- (1) To the applied scientist, the term frequently means “involving or promising to involve financial gain or loss — *i.e.*, a pest becomes “economic” when it attacks, or might attack a plant or animal grown for financial reasons.
- (2) To many, “economic” is synonymous with “profitable” — *i.e.*, an economic proposition is one on which a profit is possible.
- (3) To an economist the term refers to a set of theoretical principles and their application. Economic criteria applied to given technical situations imply a search for, not merely a profitable solution, but the “most profitable”, or optimum solution. Often such an aim is unattainable, in which case that which appears to be the “best” is chosen.

In the remainder of this paper, the application of economic criteria aims at determining some optimum policy or treatment — *i.e.*, an attempt will be made to derive the best, or most profitable course of action in a given set of circumstances.

It will become obvious that the derivation of the most desirable course of action involves two steps:

- (1) The collection of adequate technical information in a form suitable for economic evaluation.
- (2) The application of economic criteria to these data.

In New Zealand, as in most other countries, there is ample evidence that both the applied scientist and the economist have avoided interdisciplinary consultation in potentially rewarding areas. Often the applied scientist has neglected to provide suitable technical data for economic analysis. The economist has neglected to process the information which is available, for the guidance of farmers and extension workers. The field of pasture insect pests is no exception. The legacy of the situation in this field appears to be that farmers are sure that pasture insect pests should be controlled, but unsure of the most profitable approach to the problem.

THE ECONOMIC APPROACH

There is clearly a need to establish, at this early stage, the specific objective of the economic analysis. Several alternative objectives should be considered:

- (1) Which is the most effective way to treat pasture insect pests? — a purely technical problem.
- (2) Which is the cheapest way? — a cost-minimizing problem.
- (3) Which is the most profitable policy of treatment?

This paper suggests that the third alternative is the appropriate objective for economic evaluation of the array of choices which face farmers in the control of pasture insect pests. Treatment of pasture pests is evaluated in a profitability study which matches costs of a treatment policy against the returns which accrue as a result of the treatment.

The costs associated with a pasture insect control programme will be both the costs associated with purchase and application of the insecticide, and the value of production foregone by delaying pasture treatment. Similarly, the returns associated with such a programme will be the value of production loss avoided by treatment; and possibly the value of production increase as a result of higher stocking rates, following narrower "safety margins" in farm stocking policies.

ECONOMIC MODEL

The type of economic model developed below is applicable to those pasture insect pests which exhibit an infestation cycle—*i.e.*, infestation occurs, and if control measures are not taken, it increases in intensity at a certain rate as time passes, until some natural regulatory factor inhibits growth and eventually causes a population decline. The infestation cycle is repetitive. The present state of knowledge of the population dynamics of pasture insect pests suggests that grass-grub exhibits these characteristics; it has been used as an example to develop the analysis.

The construction of an economic model involves the adoption of certain simplifying assumptions. These may be relaxed from time to time to approach a more realistic situation. Initial assumptions are:

- (1) A medium cropping soil in Canterbury, with normal pastures established, on an average fat-lamb farm.
- (2) Normal climatic influences.
- (3) That prices and costs are given and constant.
- (4) Initially zero grass-grub infestation.
- (5) That grub counts provide an accurate index of infestation.
- (6) Pastures are assumed to be fully stocked—*i.e.*, any decrease in pasture growth will decrease production.

The initial situation will be:

Stocking rate: 6 ewes per acre.

Production per ewe equivalent: 1.2 lambs @ 45s. (\$4.50); 10.5 lb ewe wool @ 38d./lb (32c).

Costs per ewe: \$2.80.

Net value of production: \$35.76 per acre.

THE GRASS-GRUB

Publications detailing the life-cycle and destructive habits of the grass-grub are well known; no technical details need be recounted here, except those which influence the type of economic analysis to be employed.

The life-cycle of the grass-grub can be summarized briefly. Adults emerge from early or mid-November to early December and eggs are produced during the same period. The first of three larval instars lasts from early December to late January; only small or insignificant amounts of damage are thought to occur during this stage. The second instar is completed during March or April and the third lasts through winter, entering a pre-pupal, non-feeding stage about July. Pupation begins during the September-October period. The most severe damage occurs during the second and third instar.

At present, control measures are limited to killing the larvae or grubs. Traditionally, chemical control is attempted fairly early in the larval stage to minimize the damage later in the larval stage. Slower acting chemicals may be applied as early as spring. It should be added here that it appears impossible to eradicate the grass-grub completely and permanently from a particular location.

It seems clear that, because of the nature of the life-cycle of the grass-grub, and the restrictions imposed by control techniques, the main economic question is not ultimately one of determining the optimum month of treatment; rather it will be a question of the optimum treatment pattern within the restriction that control measures are rational only at a definite stage of the annual cycle. The perennial nature of grass-grub infestation suggests that the behaviour of the population through time is the appropriate parameter on which to base economic evaluation of control measures. Evidence suggests that, if no control measures are taken in any year, grass-grub infestation patches would contain numbers of grubs as shown by the "normal growth pattern" in Fig. 1.

Figure 1 was derived from data supplied by J. M. Kelsey. Larval counts were made in each year after pastures were sown down in 67 mid-Canterbury paddocks. The graph was drawn from mean infestation in each year, and therefore illustrates the "average" rate of population growth, reaching a maximum of 10.93 larvae per spade square in the sixth year, and falling to 5.5 larvae per spade square in the seventh year. At this stage data were not available on the behaviour of the grub population in subsequent years.

PASTURE DAMAGE

The assessment of grass-grub damage to pasture is a technical problem which will not be discussed here. However, it is extremely important that acceptable measures be available if economic evaluation is to be even approximately correct.

Figure 2 illustrates the results obtained by Kelsey, using different methods of estimating grass-grub damage. It is difficult to define the relationship between these two measures, especially since the leaf length values are a mean of measurements taken from 72 "good" pastures throughout New Zealand, where the farmer had complained of a lack of grazing hours, and the surface cover figures represent means of measurements taken from the 67 "average" pasture samples. The graph showing the loss of surface cover on the "average" pastures was the basis of further calculations.

Fig. 1: Assumed normal growth pattern of grass-grub population. (Data from Kelsey, pers. comm.)

Fig. 2: Two measures of grass-grub damage to pastures. (Data from Kelsey, pers. comm.)

PRODUCTION LOSSES

In order to estimate production losses due to grass-grub infestation, the assumption was made that, on "fully-stocked" pastures, losses in production were directly proportionate to pasture damage as reflected in the loss of surface cover. This assumption implies that, as production losses occur, they are linearly correlated with the percentage of pasture which is not covered with the species initially sown down. Of necessity, the indefinable grazing value of the weeds and other grasses which may have become established has been omitted.

If the normal growth pattern shown in Fig. 1 can be accepted as representative, and the pasture damage associated with various rates of infestation, as represented by loss of surface cover shown in Fig. 2 are acceptable, production losses can be approximated by interpolation. These are shown on a per acre basis in Fig. 3 for the seven-year period following pasture sowing.

Production losses will be higher on those paddocks which are "fully stocked". Obviously, paddocks which are under-stocked will provide a safety margin of pasture which may be destroyed before actual production losses occur. The extent of these safety margins and the consequent reduction in production losses are also shown in Fig. 3 for various degrees of under-stocking.

CONTROL MEASURES

In assessing the cost of control measures, the cost of the active ingredient only was considered. Costs of application were omitted because of the diversity of application techniques — *e.g.*, application may be by

Fig. 3: Annual loss in production from grass-grub infestation.

contract, with fertilizer, and so on. All calculations were made on the basis of 2 lb of active ingredient per acre. The costs per acre for the five pesticides included in the study were:

Trichlorphon	....	40 lb of 5% mix at 1/7 lb	= 63/4	(\$6.33)
Diazinon	....	40 lb of 5% mix at 2/- lb	= 80/-	(\$8.00)
Lindane	....	10 lb of 20% mix at 5/- lb	= 50/-	(\$5.00)
DDT prills	....	10 lb of 20% mix at 1/10 lb	= 18/4	(\$1.83)
DDT granulated	....	2 lb at 7/3 lb	= 14/6	(\$1.45)

In the case of granulated DDT superphosphate, the cost of the active ingredient was obtained by averaging figures for two available mixes, after subtracting the cost of the normal superphosphate at current prices.

For each of these preparations, further calculations were based on the following initial and residual effects, assuming 100% grass-grub mortality rate following efficient application by conventional methods.

Preparation	Mortality Rate	
	First Year of Application	Residual Effect
Trichlorphon	100%	Nil
Diazinon	100%	Nil
Lindane	100%	100% second year — subsequently nil
DDT prills	Nil	100% second and third years — subsequently nil
DDT granulated	Nil	100% second and third years — subsequently nil

Since permanent extermination of a grass-grub population is apparently unlikely, the effect of the application of an insecticide will be to delay, rather than halt, the development of the normal growth pattern. The

actual delay will depend on the mortality pattern of the insecticide and its residual effect—*e.g.*, the application of trichlorphon in any year reduces the larval population to zero in that year, but it will have increased to 2.35 per spade square by the following year. On the other hand, no effect has budgeted for DDT in the first year; allowance has been made for reduction of the grass-grub population in the second year and delay of the normal growth pattern for a further year.

Control of grass-grub will similarly achieve benefits, not by permanent pest population reduction, but by interrupting and delaying the normal growth pattern—*i.e.*, potential damage is postponed. The amount of damage which occurs will depend on the stage at which the normal growth pattern is interrupted. Continued annual treatments would successfully delay the beginning of the cycle; biennial treatments would allow the first year of the cycle to occur every second year, and so on. It seems logical that the main question in economic evaluation of grass-grub control (or other pests exhibiting population cycles) should be to determine at which point—if any—on the normal growth pattern it is most desirable for the cycle to be repeatedly terminated. This is a question of evaluation of several strategies—representing the application of control measures at different intervals of time. Therefore this paper considers, for each preparation previously mentioned, six strategies:

1. Annual treatment of pastures
2. Treatment of pastures every two years
3. Treatment of pastures every three years
4. Treatment of pastures every four years
5. Treatment of pastures every five years
6. Treatment of pastures every six years

From another point of view, the problem can be seen as determining the level of grub population at which it is most profitable to begin control measures.

The “returns” to control measures are expressed in this paper as the cash value of the difference between the decrease in production which would have occurred if no control measures were applied, and the decrease which would occur if a particular control strategy was followed. It is essentially comparing production “with” and “without” control measures. Since the returns accrue from delaying the normal growth pattern, and this can be continued indefinitely, calculations covered an arbitrarily limited period of fifteen years.

Although grass-grub control measures, as outlined above, involve time as an essential variable, discounting techniques were not employed. The costs and “revenues” generated by the different strategies occur in cycles of varying frequency and amplitude. The problem is one of comparing steady states of different strategies of pest control, where one year is no more important than another. In this situation, discounting techniques are inappropriate, and could produce perverse results. Profitability figures derived here should not be used for comparison of expenditure on grass-grub control with avenues of farm investment which do not exhibit a cyclical pattern of revenue flows.

RESULTS

In the following, R represents the returns to control measures in the form of production loss avoided, and C represents the cost of the control programme. Results are expressed in terms of two criteria:

$R-C$: the absolute surplus or profit per acre per year, of the control strategy. A positive value of $R-C$ indicates a profit.

R/C : the revenue generated from the investment of each dollar spent in control measures in each strategy.

CONTINUING PASTURES

$R-C$ and R/C values as estimated for the various control strategies on continuing pastures, with different pesticides, are shown in Table 1. The upper figure in each pair is the $R-C$ value and the lower, bracketed figure is the R/C ratio.

TABLE 1: VALUES OF $R-C$ AND R/C FOR GRASS-GRUB CONTROL STRATEGIES WITH DIFFERENT PESTICIDES—CONTINUING PASTURE

Control Strategy	Pesticide				
	Trichlorophon	Diazinon	Lindane	DDT Prills	DDT Granulated
FULLY-STOCKED PASTURE					
1		19.17 (4.02)	17.50 (3.18)	20.50 (5.10)	22.56 (13.33)
2		14.36 (5.25)	13.47 (4.15)	22.82 (9.56)	23.41 (24.98)
3		10.10 (5.79)	9.54 (4.57)	18.29 (11.97)	19.34 (32.71)
4		7.44 (5.41)	9.00 (4.28)	15.08 (12.31)	15.95 (33.64)
5		4.71 (4.72)	4.37 (3.73)	10.80 (11.80)	12.23 (34.43)
6		4.70 (4.70)	4.36 (3.72)	10.37 (11.37)	11.00 (31.07)
10% UNDER-STOCKED					
1		15.59 (3.46)	13.92 (2.74)	16.92 (4.38)	19.92 (11.50)
2		10.78 (4.19)	9.89 (3.32)	19.25 (8.22)	20.07 (21.57)
3		8.90 (5.22)	8.35 (4.13)	15.90 (10.54)	16.96 (28.80)
4		6.50 (4.85)	6.06 (3.84)	15.35 (12.52)	14.38 (29.72)
5		3.99 (4.15)	3.65 (3.29)	9.37 (10.37)	10.80 (30.52)
6		3.76 (3.97)	3.43 (3.14)	8.70 (9.70)	10.04 (29.54)

TABLE 1—Contd.

20% UNDER-STOCKED						
1	....	....	12.01 (2.91)	10.34 (2.30)	13.34 (3.67)	15.88 (9.68)
2	....	....	10.54 (4.12)	16.32 (3.26)	15.68 (6.88)	16.74 (18.15)
3	....	....	7.71 (4.65)	7.15 (3.68)	13.48 (9.09)	14.57 (24.89)
4	....	....	5.55 (4.29)	5.10 (3.39)	11.26 (9.45)	12.10 (25.82)
5	....	....	3.27 (3.59)	2.94 (2.84)	7.9 (8.94)	9.37 (26.60)
6	....	....	3.26 (3.58)	2.93 (2.83)	7.5 (8.51)	8.14 (23.25)
30% UNDER-STOCKED						
1	....	....	8.44 (2.33)	6.77 (1.85)	9.77 (2.95)	12.55 (7.86)
2	....	....	8.64 (3.56)	7.74 (2.82)	12.10 (5.54)	13.40 (14.73)
3	....	....	6.52 (4.09)	5.97 (3.24)	11.13 (7.68)	12.19 (20.99)
4	....	....	4.60 (3.72)	4.15 (2.95)	9.36 (8.02)	10.21 (21.91)
5	....	....	2.56 (3.02)	2.23 (2.40)	6.51 (7.51)	7.94 (22.70)
6	....	....	2.55 (3.01)	2.22 (2.38)	6.08 (7.08)	6.72 (19.35)
40% UNDER-STOCKED						
1	....	....	4.86 (1.77)	3.19 (1.40)	6.19 (2.24)	9.21 (6.03)
2	....	....	6.73 (2.30)	5.84 (2.37)	8.52 (4.20)	10.06 (11.31)
3	....	....	5.32 (3.52)	4.77 (2.79)	8.75 (6.25)	9.81 (17.08)
4	....	....	3.64 (3.15)	3.19 (2.50)	7.45 (6.59)	8.30 (18.00)
5	....	....	1.84 (2.46)	1.51 (1.94)	5.08 (6.08)	6.51 (18.79)
6	....	....	1.83 (2.45)	1.50 (1.94)	4.65 (5.65)	5.28 (15.44)

NOTES:

- (a) *R-C* values are given in \$ per acre and are shown as the upper, unbracketed figure in each pair.
- (b) *R/C* values are the lower and bracketed figures.
- (c) Control strategies 1 to 6 are:
 Control strategy 1—annual treatment
 Control strategy 2—treatment every 2 yr
 Control strategy 3—treatment every 3 yr
 Control strategy 4—treatment every 4 yr
 Control strategy 5—treatment every 5 yr
 Control strategy 6—treatment every 6 yr
- (d) Values calculated on a 15-year period.

Fig. 4: Profit per acre of different control strategies using diazinon—10% understocked.

Interpretation of Table 1 will be facilitated by a graphical example. Figure 4 illustrates the relationship between $R-C$ and R/C for different control strategies, using diazinon on a pasture which is 10% understocked. The horizontal axis measures the intensity of expenditure on grass-grub control, or the average expenditure per year on an acre of pasture. The various control strategies can also be positioned on this axis—e.g., Strategy 1 requires the expenditure of \$8.00 per year, Strategy 2 requires \$4.00 per year, and so on. The $R-C$ estimates are graphed as a total profit curve which shows first “increasing” and later “decreasing” returns to expenditure. The R/C estimates in Table 1 measure returns per dollar spent on grass-grub control; similarly $(R/C)-1$ or $(R-C)/C$ will show profits per dollar spent. There is obviously a parallel relationship between R/C and $(R/C)-1$, which is graphed in Fig. 4 as average profit per dollar spent. The curves shown in Fig. 4 are, of course, linear approximations to the “actual” curves; the indivisible nature of the analysis precludes more accurate calculation. However, it was possible to calculate an approximation to marginal or additional profit per dollar spent on grass-grub control. This is shown in Fig. 4 centred on the mid-points of each linear portion of the curve.

Figure 4 demonstrates the high profitability of the lower levels of expenditure on pesticides; as expenditure increases, the profitability of further expenditure decreases. Average profit per dollar spent is a maximum in this example under Strategy 3—i.e., at about \$2.67 per year. Operation below this point is unwise, or in the terms of the economist, irrational, because it is possible to increase the average return to *each* dollar by spending more. It is possible then to define a minimum level for wise use of pesticides for grass-grub control—i.e., where the average profit per dollar spent is a maximum, and this is indicated in Table 1 as the highest R/C ratio in any column.

Similarly, a point of optimum operation can be determined. This will be the point where total profit, or $R-C$, is a maximum, and incidentally where the marginal profit is zero. This point is not reached in Fig. 4,

but is shown in the columns in Table 1 as the highest $R-C$ value. More frequent application than indicated by this point is again irrational, since higher profit could be achieved by reducing expenditure on insecticides. On economic criteria, Table 1 should be interpreted thus:

- (1) The minimum level of use of an insecticide to control grass-grub should be that strategy which shows the highest R/C ratio.
- (2) If working capital is available, strategies involving more frequent treatment should be carried out. If working capital is limited, the strategy should be adopted which involves the most frequent treatment (subject to (3)) which can be financed.
- (3) If working capital permits, the strategy showing the highest $R-C$ value should be followed.

The minimum and optimum control strategies based on these criteria are summarized in Table 2.

The first point which emerges is the obvious profitability of control measures for grass-grub. On the fully stocked pasture, the optimum treatment policy is that strategy which maintains the presence of an active insecticide on the pasture every year. The frequency of application should ideally be dictated only by the time lapse between application and the toxic effect, and the residual effect of the pesticide used — *e.g.*, lindane and DDT need to be applied each second year. In other words, at current costs, and within the restrictions imposed by the model, treatment policies which minimize damage, and therefore production losses, are optimal.

The same remarks apply to a pasture which is 10% understocked. Lower infestation levels still cause enough loss in production to warrant maintaining grass-grub levels at a minimum. As the degree of understocking increases and production losses due to any level of infestation are smaller, the optimum for the more expensive pesticides, lindane, trichlorophon and diazinon, moves to a strategy involving less frequent treatment. In no case, however, does the optimum treatment strategy allow more than one year to elapse without the presence of an active grub-control ingredient. In all stocking rate situations, as might well be expected, DDT in either form should be applied every two years.

Table 1 demonstrates the well-known economic advantages of DDT. In all cases both $R-C$ and R/C are more attractive for DDT than for other preparations, confirming the conventional view that, if possible, and effective (*i.e.*, absence of an immune grass-grub population), DDT should be used. If, for some reason, DDT may not be used, the $R-C$ estimates show that the order of preference would appear to be the descending order of cost per year of toxicity — *i.e.*, lindane, trichlorophon, and finally diazinon.

In virtually all cases, the minimum level of operation suggested allows no more than two years to elapse without the presence of an active ingredient of some pesticide on the pasture. If working capital is available, this should be reduced to one year or preferably none. From another point of view, pesticides should be applied at least when grass-grub counts reach 4.25 per spade square, preferably when the count is lower, and ideally it should be maintained close to zero.

The main point arising from this analysis is, however, the high profits which can accrue from grass-grub control, particularly at higher stocking rates.*

* It must be assumed that stocking rate policies are formulated by the farmer independently of, and not because of the grass-grub problem.

TABLE 2: MINIMUM AND OPTIMUM CONTROL STRATEGIES BASED ON ECONOMIC CRITERIA —
CONTINUING PASTURES

Stock Concentration	Critical Point	Trichlorophon	Diazinon	Lindane	DDT Prills	DDT Granulated
Fully stocked	...	3	3	4	5	4-5
	Minimum	1	1	2	2	2
10% under- stocked	...	3	3	4	5	5
	Minimum	1	1	2	2	2
20% under- stocked	...	3	3	4	5	5
	Minimum	1	2	2	2	2
30% under- stocked	...	3	3	4	5	5
	Minimum	2	2	2	2	2
40% under- stocked	...	3	3	4	5	5
	Minimum	2	2	3	2	2

TABLE 3: MINIMUM AND OPTIMUM CONTROL STRATEGIES BASED ON ECONOMIC CRITERIA—
SHORT-TERM PASTURES

Stock Concentration	Critical Point	Trichlorophon			Diazinon			Lindane Pasture Life in Years			DDT Pills			DDT Granulated		
		3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Fully stocked	...	3	2	3	3	2	3	3	4	5	3	4	5	3	4	5
	Minimum	1	1	1	1	1	1	2	2	2	3	2	2	3	2	2
10% under- stocked	...	3	2	3	3	2	3	3	4	5	3	4	5	3	4	5
	Minimum	1	1	1	1	1	1	2	2	2	3	2	2	3	2	2
20% under- stocked	...	3	2	3	3	2	3	3	4	5	3	4	5	3	4	5
	Minimum	1	1	1	1	1	1	2	2	3	3	2	2	3	2	2
30% under- stocked	...	3	2	3	3	2	3	3	4	5	3	4	5	3	4	5
	Minimum	2	2	2	2	2	2	2	2	2	3	2	2	3	2	2
40% under- stocked	...	3	2	3	3	2	3	3	4	5	3	4	5	3	4	5
	Minimum	2	2	2	2	2	2	3	2	3	3	2	2	3	2	2

SHORT-TERM PASTURES

Pastures are often established as an element of a rotational pattern of farming. In this case it is necessary to consider the profitability of grass-grub control measures over much shorter periods than the fifteen-year span considered for the continuing pasture. Consequently the economic evaluation was extended to consider 3-year, 4-year and 5-year pastures. Results are not detailed, but are summarized in Table 3. The same stocking rate variations were considered.

Although short-term pastures would be affected by only the first portion of the normal growth pattern, it is profitable to apply control measures. Further, a similar pattern emerges in optimum treatment patterns for short-term pastures to that for continuing pastures. The optimum strategy for the more heavily-stocked pastures is that which ensures the presence of some active ingredient on the pasture in each year; the particular strategies are dictated by the lapse between application and the toxic effect, and the residual effect of the preparation. Only on relatively under-stocked pastures do less frequent applications become more profitable.

As might be expected, the minimum strategies which were economically rational were, in most cases, treatment in the first year only. Only with the preparations with a shorter toxicity effect could it be suggested that this is not the case—*e.g.*, the appropriate minimum strategy with trichlorophen in the 5-year pasture is Strategy 3, and similar slight differences show for diazinon.

Profit per acre figures from grass-grub control for short-term pastures are generally not impressive, ranging from \$2.90 to \$3.90 per acre for optimum strategies on fully stocked pastures, and from \$0.48 to \$1.45 for optimum strategies where pastures are 40% under-stocked. Although this analysis does not permit comparisons, it may well be that other more profitable uses exist for farm working capital.

SUMMARY AND CONCLUSIONS

Given the following:

- (1) A medium-cropping soil in Canterbury,
- (2) A pasture capable of carrying six ewes per acre,
- (3) A grass-grub population which varies over time as shown in Fig. 1, which results in loss of surface cover as shown in Fig. 2, and which causes production losses as shown in Fig. 3,
- (4) Insecticides with costs, mortality rates and residual effects as previously outlined.

then are wise minimum treatment pattern, and the optimum treatment pattern have been calculated. This latter would normally be one which maintains the grass-grub population at as low a level as possible, provided stocking rates are fairly high.

This rather simple model has been restricted in completeness by the information available. Ideally, an economic evaluation of pesticides at the farm level could be studied in a simulation model including:

- (1) The normal pest growth pattern for the particular soil type.
- (2) The effect of application of the different pesticides at various critical months of the year.
- (3) The toxic effect of a wider range of chemical concentrations of pesticides than conventionally used in experiments.

Data on (2) and (3) appear to be quite limited.

The conclusion reached in this paper that frequent pasture treatment for grass-grub control is desirable implies that the farmer should be prepared to allocate working capital on a regular basis to prevent the growth of the grass-grub population above a minimal level. Before recommendations along these lines can be made to farmers on an individual or even an area basis, the fundamental assumptions of this paper should be examined closely. It is felt that the following deserve closer attention:

- (1) The variation in the normal growth pattern between soil types, climatic conditions, and farming patterns.
- (2) The trends in the normal growth pattern over long periods of, say, twenty years.
- (3) The factors which affect the growth of a pest population from one year to the next—*e.g.*, it may be possible to make projections of likely populations one or two years ahead, depending on the prevailing conditions.
- (4) The variation in efficiency of application between farmers, and between methods of application.
- (5) The introduction of official standards to specify the mortality rate and residual effect of different preparations under different conditions.
- (6) The development of more suitable measurement techniques to express the relationship between:
 - (a) Pest populations and pasture loss.
 - (b) Pasture loss and potential production loss.
 This would involve grazing experiments to determine the ultimate relationship between the pasture pest and the grazing animal.
- (7) The relationship between stocking policies and the probability of pasture infestation. It is possible that farmers are reluctant to take full advantage of the stock-carrying potential of their farm because of the possibility of heavy pasture infestation.

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(The author wishes to state that, since this paper is intended as an illustrative example of economic evaluation, the conclusions reached are not appropriate for commercial comparisons.)