REFERENCES

COSSONS, G. G., 1965. Private communication.

DOAK, B. W., 1962. *Ann. Rept., N.Z. Fert. Man. Res. Assn.* 1961/62: 22.

DOAK, B. W., 1963. *ibid.* 1962/63: 25.

DOAK, B. W., 1964. *ibid.* 1963/64: 25.

HAMBLYN, C. J., and DINGWALL, A. R., 1945. Earthworms. *N.Z. J. Agric.* 71: 55–58.

LEE, K. E., 1959. The earthworm fauna of New Zealand. *N.Z. D.S.I.R. Bull.* 130.

NIELSON, R. L., 1951a. Effect of soil minerals on earthworms. *N.Z. J. Agric.* 83: 433–435.

NIELSON, R. L., 1951b. Earthworms and soil fertility. *Proc. 13th Conf. N.Z. Grasslands Assn.* 158–167.

NIELSON, R. L. 1953. Earthworms (recent research work). *N.Z. J. Agric.* 86: 374.

NIELSON, R. L., 1962a. *Unpublished report to Director, Farm Advisory Division, Dept. of Agriculture.*

NIELSON, R. L., 1962b. Private communication.

NIELSON, R. L., 1964. Private communication.

NIELSON, R. L., 1965a. Presence of plant growth substances in earthworms demonstrated by paper chromatography and the Went pea test. *Nature* (in press).

NIELSON, R. L., 1965b. growth substances in earthworms. *N.Z. J. Agric. Res.* (in press).

PERROTT, D. C. F., 1964. Private communication.

RICHARDS, J. G., 1955. Earthworms (recent research work). *N.Z. J. Agric.* 91: 559.

SEARS, P. D., 1953. Pasture growth and soil fertility VII. *N.Z. J. Sci. Tech.* A35: 221–236.

SEARS, P. D., and EVANS, L. T., 1953. Pasture growth and soil fertility III. *ibid.* A35 (*Suppl.* 1): 42–52.

STOCKDILL, S. M. J., 1959. Earthworms improve pasture growth. *N.Z. J. Agric.* 98: 227–233.

WATERS, R. A. S., 1951. Earthworms and the fertility of pastures. *Proc. 13th Conf. N.Z. Grasslands Assn.* 168–175.


# EFFECTS OF GRASS GRUB INFESTATIONS ON PASTURE


P. G. FENEMORE

*Entomology Division, D.S.I.R., Nelson*


## INTRODUCTION

In considering the effects produced on pasture areas by infestations of grass grub, it is important to bear in mind certain aspects of its biology:

The insect commonly known as grass grub is the melolonthine beetle *(Costelytra zealandica)*. Other species of the same sub-family are sometimes also found in pasture, especially species of *Pyronota* (manuka beetle). The economic importance of these is however minor and this paper is concerned solely with *C. zealandica.*

The grass grub is univoltine, though there is some evidence that a certain percentage of populations at least may spend two years in the larval stage in the southernmost parts of the South Island. Adult beetles emerge in spring and live for two or three weeks. Eggs are laid in the soil and take two to three weeks to hatch. The resultant larvae pass through three instars and are actively feeding for most of the time from hatching to pupation, i.e. for about eight or nine months of the year.

In the absence of control measures, grass grub infestations tend to persist in the same place year after year, probably due to the early flight pattern of males and resultant mating of females and oviposition in the area from which they emerged.

Adult beetles will feed readily on the foliage of a wide range of plants but it is unlikely that they need to feed before they are sexually mature. Stone-fruit trees in particular may sometimes be almost stripped of foliage but any feeding by adult beetles on species of pasture plants is unimportant.

There is a wide range of feeding habits among scarabaeid larvae but *C. zealandica* feeds exclusively below ground on the roots of plants. Considerable amounts of soil are ingested and pass through the body with the plant root material.

The third instar occupies most of the larval life span and is present in the soil from about March through to September in most districts and it is usually during this period that visible damage to pastures occurs.

## EFFECTS OF INFESTATION ON PASTURE

There are at least two and possibly three distinct facets to the depredations caused by grass grub larvae in pastures. These are:

(a) direct loss caused by larval feeding on roots of pasture species.

(b) changes in pasture composition, principally weed invasion, resulting from selective feeding and/or ability of weeds to withstand attack, and

(c) possible effects on soil.

## DIRECT DAMAGE TO PASTURE SPECIES

This is the most obvious and important and therefore comprises the major section of this paper.

Grass grub larvae in all three instars have effective chewing mouthparts including prominent powerful mandibles. In pasture the larvae must subsist largely on fibrous rooting systems but they are equally at home on more solid, bulky roots and will for instance completely consume slivers of carrot pushed into soil.

The range of plants on which they will feed is very wide indeed, but little is known of their preferences within the desirable pasture species. In general terms however, it is clear that pastures improved for stock also provide improved conditions for the multiplication of grass grubs. Dense infestations are very rarely found under poor native-type pasture. The factors responsible for these differences in population levels may be well worth investigation.

Various figures have been put forward from time to time as estimates of the financial loss per annum caused by grass grub in pastures and some workers have ventured to suggest how much loss of growth may be caused by different levels of infestation.

Such estimates may have some validity when made by persons with years of field experience but unless reliable factual experimental data are published it is not possible to assess the worth of such estimates.

There are unfortunately very little of such data available for grass grub at present. Some obtained during the course of chemical control studies are presented below, but even in the absence of practical results some facts may be brought out by theoretical considerations.

In an infested area the numbers of third instar grass grubs may be as high as 100 or more per square foot, but the general average in pastures showing prominent damage would be nearer 30 per square foot. For ten infested areas sampled in 1962 and 1963 the mean overall population was 28.3 grubs per square foot with a range from 15 to 48 for different sites.

The weight of a full-grown third instar larva is about 150 milligrams. On the basis of 30 larvae per square foot this is 4321 lbs. of biomass per acre, i.e. equivalent to four or five sheep. And this weight of grass grubs is an annual "crop" which is produced each year almost from zero. I am not aware of any data which would enable one to compare the efficiency of conversion of food intake in relation to body weight by grass grubs and sheep but with this degree of infestation it seems likely that at least as much plant material is consumed below ground by grubs as above ground by stock.

Distribution of grass grubs within an area is anything but uniform and the coefficient of variation of numbers within samples taken on a regular grid pattern may be as high as 100 per cent. This has an important bearing on any field work in which the effect of different population levels is being investigated.

### *Relationship between grub numbers and pasture growth*

For any economic pest there are two important critical levels of infestation: that at which detectable damage occurs to the crop and that at which it is economically worthwhile to treat.

The level of infestation of a pest which just causes detectable crop loss will of course vary with soil fertility, weather, crop variety, etc. The economic level from the point of view of expenditure on control measures will also vary, principally in relation to the cost and effectiveness of particular treatment procedures and the value of the crop.

It is however obviously very desirable to obtain a good estimate of these critical levels and this may perhaps best be done by determining the relationship between degree of infestation and crop loss over a range of environmental conditions.

For very few pests indeed is useful information of this sort available. Some is being obtained from field trials designed primarily to compare the effectiveness of various insecticides in controlling grass grub. It often happens in such trials that a range of effects is produced in reducing numbers of grubs present. If one or more treatments produce 100 per cent control of grubs in addition to intermediate effects this is particularly useful. Some measure of pasture growth on the various treatments can then be made for correlation with numbers of grubs present.

The following example is taken from a trial laid down in May 1962. This comprised twelve treatments which, in terms of grubs present, gave a range of effectiveness in 1963 from 0 to 100 per cent.

TABLE 1.

*Counts of larvae, April 1963*

| Treatment number | True mean sq. ft. | Transformed mean/plot total $(X)^{\frac{1}{2}}$ | Transformed mean/plot total $(X+1)^{\frac{1}{2}}$ |
|---|---|---|---|
| 12 | 0.00 | — | — |
| 8 | 0.66 | — | 1.23 |
| 7 | 1.44 | — | 1.43 |
| 10 | 4.50 | — | 1.84 |
| 9 | 7.44 | 2.07 | |
| 11 | 16.89 | 3.60 | |
| 6 | 17.79 | 3.54 | |
| 5 | 21.90 | 4.36 | |
| 4 | 25.32 | 4.50 | |
| 3 | 28.11 | 4.92 | |
| 2 | 31.11 | 4.84 | |
| 1 | 32.43 | 5.43 | |

SE ± 0.64 ± 0.17
d.05 1.81
d.01 2.41

*Visual assessment of pasture growth, June 1963.*

| Treatment number | Score for growth |
|---|---|
| 12 | 3.83 |
| 8 | 3.50 |
| 7 | 3.33 |
| 10 | 3.17 |
| 9 | 2.97 |
| 11 | 2.57 |
| 4 | 2.20 |
| 6 | 2.17 |
| 5 | 2.07 |
| 2 | 1.97 |
| 3 | 1.57 |
| 1 | 1.50 |

SE ± 0.25
d.05 0.70
d.01 0.93
Correlation coefficient
Score for growth-larval numbers = 0.967

*Weights of green herbage from mown sample strips, June 1963.*

| Treatment number | Mean Wt. in grs. |
|---|---|
| 12 | 467 |
| 9 | 458 |
| 10 | 430 |
| 11 | 370 |
| 7 | 364 |
| 8 | 330 |
| 6 | 323 |
| 4 | 311 |
| 3 | 277 |
| 1 | 268 |
| 2 | 247 |
| 5 | 225 |

SE ± 38
d.05 106
d.01 141
Correlation coefficient
wt. of herbage-larval numbers = 0.781

In June 1963, after the area had been closed to stock for some time, pasture growth was assessed visually by three observers independently scoring each plot on a scale of 0-5 for height and density. Sample strips of one mower width were also cut from each plot and weights of green herbage recorded. Results of these assessments are also presented in Table 1.

There was a very high negative correlation between numbers of larvae present and visual scoring, but the degree of correlation was slightly less with mown weight.

The data in Table 1 may be presented graphically by plotting larval counts against the measure of pasture growth. This has been done in Figure 1 for the counts of larvae and the visual scoring for growth. The points obtained seem to indicate a straightforward linear regression. If the values for visual scores significantly different from the highest scoring plots (those with no grubs) are marked on this graph it can be seen that approximately six groubs per square foot produced visual changes that were significantly different at the 5 per cent. level from plots with no grubs. A difference significant at the 1 per cent. level exists between the score for a pasture with 9 grubs per square foot and an uninfested pasture.

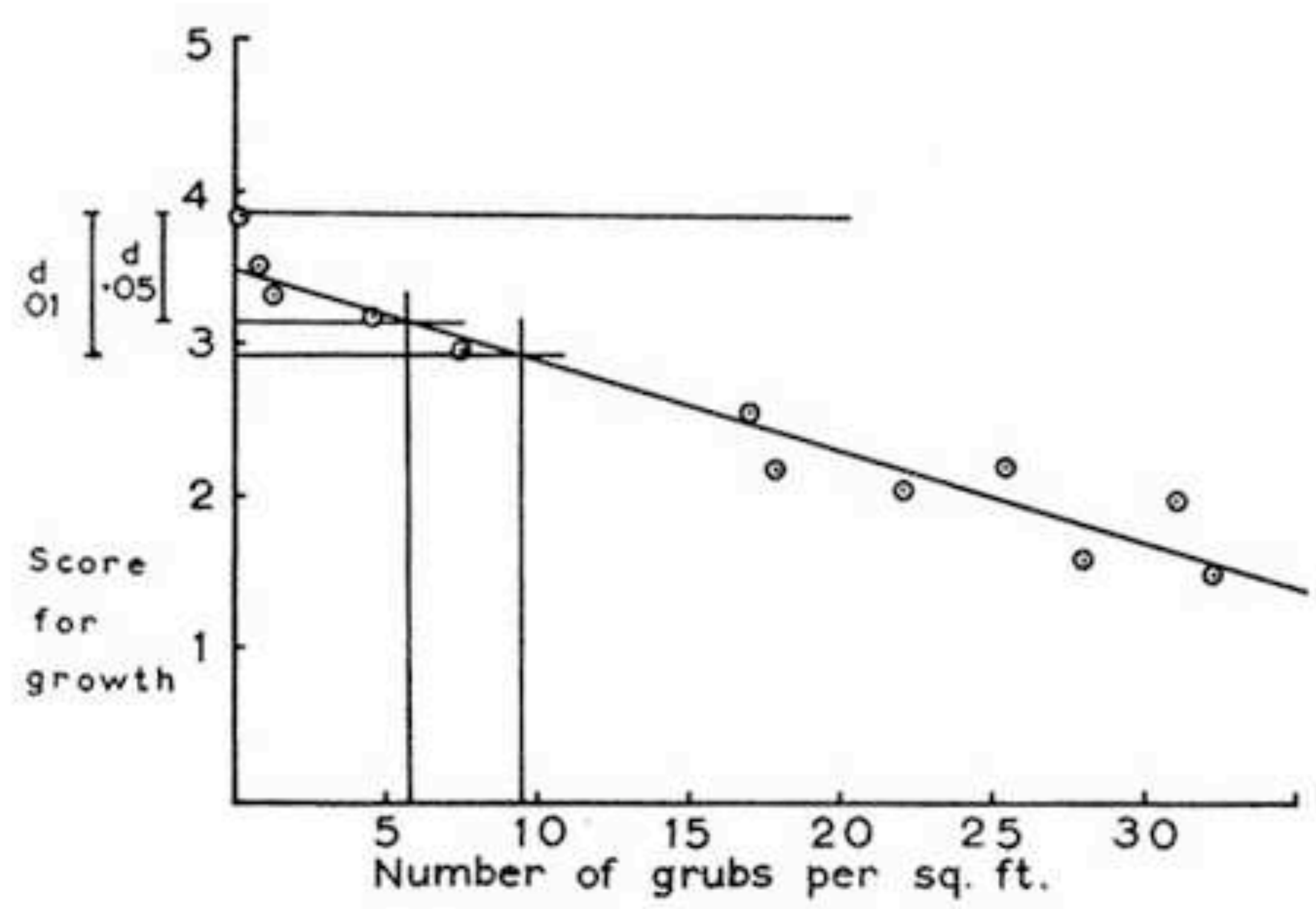


FIGURE 1. *Regression of score for growth on number of grubs. (Riwaka 1963)*

Many more data of this type relating pasture yield to grub levels are needed and when this is sufficiently detailed it may be possible to formulate some sort of regression equation for grub numbers against yield. This sort of data has been accumulated for a limited number of agricultural pests in Great Britain and in spite of variations which must obviously occur with season and site, provides a valuable basis for the economic planning of control measures.

The picture with grass grub in pasture will however certainly be more complicated because we are concerned not with an annual crop which has a definite discrete harvest but with comparatively continual production over a long period. Also with an annual crop the numbers of a pest can be related without difficulty to a definite stage of crop growth. With grass grub it is necessary to relate numbers to a particular time of year and the proportion of different instars present, in order to take into account the natural decline in numbers from early 1st instar to maturity.

Besides its important bearing on the economics of insecticide usage, the provision of an adequate picture relating grub numbers to pasture yield is of great interest when considering other methods of controlling insects, such as biological control involving the use of parasites and predators.

### CHANGE IN PASTURE COMPOSITION

From general observation it is apparent that pasture subject to grass grub attack is opened up, enabling weed seedlings to establish. There must be either some selectivity in feeding on the part of the grubs or possibly some weed species can tolerate feeding effects more than pasture species.

In a trial laid down in 1962 the mean amount of ground covered by weeds was 8 per cent. with a heavy overall grass grub population. Two years later the coverage of weeds on plots effectively treated to reduce the grub population had fallen to 4 per cent or less, whereas on plots with ineffective treatments it had risen to 20 per cent.

Some observations suggest that white clover may be affected more than grasses in mixed swards. It is not known whether a feeding preference by the insects, or varying ability to withstand attack is involved. There are almost certainly differences between grasses in response to feeding by grass grubs. Vigorous rooting grasses such as cocksfoot seem to be able to continue growing despite high grass grub numbers but much closer investigation of this aspect is needed.

One difficulty of utilizing plants tolerant to grass grub attack as opposed to plants which grubs find less palatable is that numbers of grubs may be able to rise to higher levels in the former than in normal pastures so that the problem could in the long run be aggravated.

### POSSIBLE EFFECTS ON SOIL

Grass grub larvae feeding in pasture undoubtedly ingest and pass through their bodies comparatively large volumes of soil, though this has never been measured. Such soil is very finely broken down and, where heavy grass grub infestations have persisted for several years, there may be considerable loss of crumb structure. In such cases it is quite possible that plant growth is indirectly adversely affected in addition to the direct feeding of larvae.

## CONCLUSION

The need for reliable data relating levels of grass grub infestations to pasture growth has been stressed. One way of approaching the problem is to work with naturally occuring populations in different areas and relate them to pasture production, but it seems preferable to compare plots on the same site with different population levels of grubs. Different levels in numbers of grubs may be produced in plots by the use of insecticides.

This approach is open to the criticism that chemical treatments may affect pasture growth in ways other than their direct effect on the target species. Such criticism may be valid but treatment by insecticides seems unlikely to lead to substantially incorrect conclusions because of the close correlation that exists between the numbers of grass grub larvae and symptoms of damage on the one hand and the lack of effect on pasture growth by most insecticides in the absence of known damaging species on the other.