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CONTROL OF PASTURE INSECTS IN NEW ZEALAND

R. J. B. POWER

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

The control of noxious elements in the pasture insect complex has, with the rapid growth of world human population, assumed an often dangerous urgency. New Zealand, because of its great dependence on grassland farming, is less able than many countries to tolerate competition between insect and sheep or cow for available pasture. In our attempt to synthesise, largely from climax forest, a community favouring domestic livestock, we have compounded an environment eminently suited to two indigenous insects, the grass grub (*Costelytra zealandica* (White)) and the porina caterpillar (***Wiseana*** spp.). It is axiomatic that the degree of stability of a community is proportional to its complexity: In the highly simplified environment of our exotic pastures, diversity has been reduced to a point where the population density of component species oscillates and where, when one or more of these component species is in conflict with our intentions, it becomes a pest.

I shall attempt to broadly review the extent of our knowledge and our ignorance of the biology and ecology of *C. zealandica*; for the deficiencies apparent in our study of this species are basic to an understanding of the other pasture pests with which we must contend.

BIOLOGICAL ASPECTS

C. zealandica is a small melolonthid beetle with a one year life cycle. It overwinters as a larva and apart from brief evening flights as an adult, passes the whole of its life in the superficial soil layer. The emergence of adults begins about mid-October, reaches its peak in November and lasts in all about eight weeks. Adults may, however, be present as early as September or as late as May (Miller 1921). The sexes are equal in number with the male emerging earlier in the year and earlier in the evening than the female (Kelsey 1951). The adult lives for about three weeks (Fenemore 1966). Transformation from pupa to adult takes place some time before primary emergence. The factors governing oviposition require explanation: A number of seeming contradictions in the literature suggest that at least two distinct patterns are involved. On the one hand, mating takes place on the soil surface immediately after primary emergence followed by return to the soil of the gravid female without feeding or flight. Soil covering, or the lack of it, may not be important in this instance. On the other hand when flight is induced by conditions of light, air, low humidity, moderately high ambient temperature and, perhaps, failure to mate on emergence, there appears to be definite rejection of bare ground for oviposition (Kelsey 1951, 1957a; Miller 1945). These differences in behaviour may well depend on the physiological age of the female. Oviposition takes place one to two weeks after mating and eggs are laid in the top seven inches of soil, the depth chosen being dependent on soil moisture (Kelsey 1951). The beetles lay about fifty large eggs in clusters of varying number. These need moisture for development. Eggs hatch two to three weeks after laying. The larvae begin to feed immediately on plant roots and make use of organic matter in the soil which is ingested while feeding. All three larval instars move actively both horizontally and vertically through the top soil but neither the extent nor rate of this movement is known. Feeding ceases about July when, as a fat fully-fed grub, the last instar larva burrows down a few inches and builds an oval cell in which pupation takes place. Pupae are typically present in September and October.

PHYSICAL REQUIREMENTS

Given (1966), writing of *C. zealandica*, gives its range as "throughout the country from sea level to over 4,000 feet, in rainfall from 14 inches to over 100 inches per annum, through most soil types and associated with most plant communities except dense forest". Under dry conditions larvae cease feeding for a time and conserve moisture by encapsulating in the soil some distance below the surface. Given (1952) notes that "low temperatures may drive larvae down to some depth, but they are not infrequently found within an inch of the surface, actively feeding when the soil is frozen around them". *C. zealandica* reaches its greatest numerical density, however, in intensively managed exotic pasture and inflicts the greatest economic damage where pasture vigour is reduced by other factors.

STATUS

Elliott (1963) remarks that "apart from major variations governed by climate and weather, there are variations within districts, between paddocks and between different parts of the same paddock, such that grubs from small areas a few yards apart are frequently quite homogeneous within the batch but with each batch clearly distinguishable from its neighbours". The species *zealandica* appears to be genetically unstable. The range of variability both in morphological and physiological characteristics between populations of larvae and of adults is comparatively great. Given (1966) considers that active speciation is in progress. This factor more than any other accounts, in my view, for the apparent versatility and adaptability of the grass grub.

CONTROL

Control of a versatile and ubiquitous species like *C. zealandica* may be defined as the reduction of pasture damage attributable to the pest to a level at which it makes grassland farming profitable. This level will vary with place and time and will depend on a multitude of factors such as local environmental resistance to grass grub, inherent pasture vigour and land use pattern. With intensive land use approaching the absolute potential of production, tolerance limits for competition between crop and pest become even narrower and pest control must approach the point of eradication.

All pasture pest control disciplines, be they chemical, biological or agronomic, have a vital ecological content. Lack of general appreciation of this fact has led, not surprisingly, to abuse of the means of control available to us and to a multiplication of the factors which must now be taken into account in any control programme.

Chemical control

Chemical control of grass grub has not proved to be the panacea of our hopes. Predictably, insecticide-resistant strains of *C. zealandica* have appeared and the problem of toxic residues in farm produce is causing us concern. Characteristically the emphasis still seems to be on refining the chemistry and mechanics of formulation and application rather than on assessment of the total effect of a chemical on the soil biota. We know next to nothing of the effect of insecticides on non-target organisms in the soil or of the extent to which we are influencing soil metabolism by disturbing natural interaction between populations of soil micro-organisms. Leaving aside economic considerations for the moment, we must admit that chemicals have thus far been a crude tool in inept hands.

Biological control

Biological control, properly defined, embraces the whole field of manipulation of our biotic environment to our advantage and to the detriment of objectionable species. This manipulation presupposes a thorough knowledge on the part of the operator of intraspecific, interspecific and intercommunity interactions and the natural mortality factors governing population growth at all points in the life history of the pest species, from place to place and from one season to another. Most important of all, the operator must have a knowledge of the biology of all the species involved. Our thinking, or at least our action in this field to date, has fallen far short of this ideal and has consisted largely of *ad hoc* operations with introduced parasites, predators or pathogens which, as Pottinger (1967) remarks, present odds as long as those of selecting a winner at a race meeting.

The primitive habitat of *C. zealandica* was tussock grassland near forest. Kelsey (1957b) records larvae of this species from native tussock grassland up to 4500 ft. Given (1945) records a number of tachinid parasites of indigenous melolonthid larvae which he found to occur, without exception, in populations in native grassland associated with forest. Prior to the settlement of this country, grass grub populations were held in check by parasites such as these and probably also by the predatory native birds. The incursion of grass grub into open improved pasture has, because of the inability of its natural enemies to follow it, produced the high populations with which we now contend. To achieve effective biological control of *C. zealandica* we are faced with manipulating the artificial medium in which we culture it; and as this medium is unique there seems to me to be little hope of importing a ready-made inimical factor from outside.

A number of density dependent mortality factors notably cannibalism, limited disease epizootics and avian predation tend to distract attention from the fundamental importance of density independent influences in population dynamics. Our remedy is surely to step up environmental resistance to grass grub at the point in its development where mortality factors already exact the greatest toll. Again, the crying need for ecological information is apparent.

Control through land management

The agronomic approach offers many possibilities, if not for the control of pasture pests, at least for reduction of their serious economic consequences. There exists a wealth of suggestive but largely uncritical observation on the effect of various extrinsic factors on pasture production in the face of attack by pests.

The proper qualitative and quantitative evaluation of these from an ecological standpoint is most desirable, as the control of a specific pest is often accomplished more efficiently and cheaply by control of its environment than by direct attack on the organism itself. All aspects of farm practice from the timing of cultivation, cropping and rest, through the effects of stocking rate, sward composition and inherent resistance to attack of pasture species, to the avoidance of toxic residues by stall feeding animals on food produced with the protection of insecticides, require investigation. There will, of course, be many problems along the way. Lucerne, for example, once established, is very resistant to damage by grass grub and black beetle but is a favoured food plant of white-fringed weevil and thus may be contraindicated as a fodder crop in areas where it and grass grub occur together. Climatic and edaphic factors will complicate the situation from place to place as will aspect and catenary effects on the individual farm.

Other possibilities of control

Traps, attractants and repellants for *C. zealandica* do not look promising but have yet to be thoroughly explored. Unusual physical methods such as the use of an electrical field, ultra-sound or irradiation of the soil deserve assessment.

Release of sterile males into a breeding population is a control technique which is most effective at low population density. It could be a useful tool as and when we are able to reduce overall densities of grass grub by other means.

Hormones which regulate growth and metamorphosis may yet be used as specific, residue-free insecticides.

The conservation technique, by which parasite and host are brought together by creating habitat conditions suited to the parasite within the new environment occupied by the host, has yet to be attempted.

CONCLUSION

All that has gone before points inescapably to the necessity for concerted and long-term professional research into the ecology of our pasture pests. Almost all control effort over the past forty years has been based on deduction and has failed to produce a tangible effect on the abundance of grass grub. A more fundamental approach to our pasture pest problem is needed. Control should be a unified concept based on a management plan for each major pest species and embracing workers in all scientific disciplines bearing upon it.

Governments may be forced by events to legislate for the complete destruction of pests over large areas using whatever means are at hand. Beirne (1967) forsees that, as human needs increasingly outweigh intellectual, aesthetic and sentimental considerations, we may well reach a point where there is a demand for the elimination of all living organisms, other than those producing food and fibre, from areas of intensive production.

It is vital that we be in a position to assess, before the event, the ecological implications of any proposed method of control. It is equally important that we be able to advise on the least dangerous course of action.

REFERENCES

BEIRNE, B. P., 1967. Biological control and its potential. *World Rev. Pest Control* 6: 7–20.

ELLIOTT, R., 1963. Toxicological aspects of grass grub control. *Proc. Grass Grub Conference, Nelson.*

FENEMORE, P. G., 1966. Effects of grass grub infestations on pasture. *Proc. N.Z. Ecol. Soc.* 13: 75–78.

GIVEN, B. B., 1945. Tachinid parasites attacking melolonthid larvae in New Zealand. *Trans. Roy. Soc. N.Z.* 75: 321–323.

GIVEN, B. B., 1952. A revision of the Melolonthinae of New Zealand. Pt. 1, The adult beetles. *N.Z. Dept. Sci. Industr. Res. Bull.* 102.

GIVEN, B. B., 1966. The genus *Costelytra* Given (Melolonthinae: Coleoptera) including descriptions of four new species. *N.Z. J. Sci.* 9: 373–390.

KELSEY, J. M., 1951. Grass grub and grass caterpillar control. *N.Z. J. Agric.* 83: 113–22, 195–200.

KELSEY, J. M., 1957a. Oviposition preference by *Costelytra zealandica* (White). *N.Z. J. Sci. Tech.* 38A: 634–637.

KELSEY, J. M., 1957b. Insects attacking tussock. *N.Z. J. Sci. Tech.* 38A: 638–643.

MILLER, D., 1921. Life history of the New Zealand grass grub. *N.Z. J. Agric.* 23: 199–203.

MILLER, D., 1945. The grass grub problem. *N.Z. J. Agric.* 70: 51–55.

POTTINGER, R. P., 1967. An ecological approach to the study of insects. *N.Z. Agric. Sci.* 1(12): 8–15.