MICROBIAL INSECTICIDES

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Summary

Insects, like man and other animals, are afflicted by infectious and non-infectious diseases. The realization of this is not new and had its beginnings in very early times with the development of bee-keeping and sericulture. The application of this knowledge has recently led to the development of "microbial" control, which has advanced rapidly by adopting many of the principles of biological and chemical control, to which it is closely related. This technique employs such micro-organisms as pathogenic viruses, rickettsia, nematodes, protozoa, bacteria and fungi.

INTRODUCTION

MICROBIAL INSECTICIDES are substances used to regulate insect numbers by the use of living micro-organisms and their toxic products — e.g., bacteria, fungi, viruses, rickettsia, nematodes and protozoa. Their use depends upon the fact that, under suitable environmental conditions, it is possible to induce epidemics of disease in insect populations by applying them in the same way as other insecticides are applied. A number of these microbial insecticides are now produced commercially and some of these preparations have proved highly successful in the control of certain pests. Recently their use has received an impetus because of the harmful toxic residues left on crops and in livestock by the use of some modern insecticides and the harmful effects produced by them on fish and wild life. Their great value lies in the fact that they are specific diseases to insects and are not harmful to man, animal, plants or beneficial insects such as bees and leave no harmful residues on foodstuffs when applied to crops. This aspect is becoming increasingly important.

Furthermore, insects of some species which have survived insecticides have, by a process of natural selection, produced progeny quite resistant to these insecticides. Thus there has arisen a new problem, that of resistance, which the chemical industry has met by developing new and more effective insecticides, to some of which, in turn, insects have developed a new resistance, thus perpetuating the vicious cycle.

As a result of these two problems, and some recent successes in microbial control, entomologists in various parts of the world have renewed the search for new disease organisms and the techniques by which these, and those already known, can be utilized in insect control. Some now believe that the sole use of insecticides for control constitutes "crash" tactics and that insecticides should only be used after all other avenues of control have been explored and have failed, and then used only at the minimum rate necessary to bring about economic relief, or again only used at times of great emergency as in invasions by hordes of locusts. Many others believe that both methods of control have a place in control programmes, and that a proper balance can be maintained in many cases by "integrating" microbial and insecticidal control. Others believe that the indiscriminate use of insecticides over the past decade has upset the balance of nature by the wholesale destruction of beneficial

insects such as predators and parasites, and even affected the natural distribution of higher forms of animal life such as small mammals, fish, and birds by depriving them of an essential element in their food chain, thus causing them to migrate away from the treated area, or even killing them in extreme cases. Much basic ecological study remains to be carried out on this problem.

All this has led to a rapid expansion in the study of insect pathology, the application of which is found in the study of applied insect pathology and is of paramount importance to the primary producer, to ensure the selection of the most suitable pathogen and the best method for its utilization. As yet this method of control is in its infancy and much research remains to be done.

BACTERIA

The bacteria pathogenic to insects can be divided into those which are spore formers and those which do not form spores. Many of these are known but for the present purposes of microbial control three only are outstanding. The first of these, *Bacillus thuringiensis* (see Fig. 1), is a spore-former, and produces a highly toxic crystal in the form of a proteinaceous toxin which is very lethal to a wide range of lepidopterous caterpillars. Local tests by the writer have shown that this bacillus is highly effective against cabbage white

Fig. 1: Rods of *Bacillus thuringiensis* Berl. in the body fluids of a larva of *Pieris rapae* L. (cabbage white butterfly) two days after application as a spray.

butterfly (*Pieris rapae* L.) and diamond-back moth (*Plutella maculipennis* Curt.) and that it is also effective against the larvae of Silver Y moth (*Plusia chalcites* Esper.), Olearia moth (*Agriphora coricopa* Walk.), and leafroller (*Tortrix* sp.). Commercial preparations of this bacillus enable it to be applied by conventional machines either in dust form or sprayed in the form of a wettable powder. Since the lethal effect is largely due to the toxic crystal, and that to be effective the preparation must be ingested by the caterpillar, these preparations are applied as any other stomach poison would be. Furthermore, this bacillus, when used in this way, is non-self-regenerating and repeat applications are required as is the case with any other non-residual stomach poison. Where this bacillus is effective, its use could replace the use of hazardous chemicals, and when more is known about it there is little doubt that it will become important in "integrated" or "modified" control programmes mentioned later. Extensive field experiments to test its efficacy for the control of subterranean caterpillar (*Oxycaenus* sp.) have been laid down throughout New Zealand, but results of these will not be known for some time. If successful, some amelioration from harmful DDT residues may be expected.

Trials with *B. thuringiensis* have more recently extended to the control of livestock pests. Cattle have had it added to their food ration in sufficient quantities to be passed through the body into the faeces where it has infected developing fly maggots and prevented the pupae from hatching. When added to chicken food rations in sufficient quantity to control flies in the faeces, however, it was found to reduce egg production. These, however, are only the forerunners of further experiments which will open up interesting vistas of other possible uses in the future.

Two other very important bacilli, non-spore formers, and which, unlike *B. thuringiensis*, are self-propagating, have been employed successfully along the eastern seaboard of the United States to bring the Japanese beetle (*Popillia japonica*) under control in pastures and turf. These are *Bacillus popilliae* and *B. lentimorbus*, or Milky Disease, an endemic variety of which infects grass grubs (*Costelytra zealandica*) and black beetle (*Heteronychus bonariensis*) in New Zealand. This bacillus is now also produced commercially as a dust, large quantities of which have been used in U.S.A. Laboratory tests in 1945 showed that *B. popilliae* would infect and kill the native grass grub, but further investigations on its possible field use were not carried out because of the advent of DDT. Meantime long-term experiments in U.S.A. were to show that they could be successfully employed for Japanese beetle control. This year extensive long-term field trials to test their effectiveness as a means of controlling grass grub have accordingly been laid down throughout New Zealand, but results from these will not be known for two or three years. Successful control by these bacilli would be of paramount importance, for their use may enable a great reduction, if not the complete abolition, of the use of insecticides on pastures, especially the use of DDT, or greatly modify present control programmes by the introduction of "integrated" control programmes.

Other more virulent strains of bacteria are under investigation by the United States Department of Agriculture, Beltsville (pers. comm.) and at least one strain of these may be of use against a crop pest in New Zealand. The future of these experiments could lead to the production of more highly effective and selective diseases of particular groups of insects and shows much promise. When more is known about the bacteria infecting insects, many more epidemic-producing diseases will doubtless be revealed.

FUNGI

Numbers of fungi are known to infect insects, but to date their use in applied insect pathology has been restricted because they are so dependent upon the correct environmental conditions—*e.g.*, humidity, temperature, and soil moistures—prevailing before epidemics can be started in an insect population.

One, however, is worth noticing here, namely the white muscardine fungus (*Beauveria bassiana*) known from earliest times to produce a jaundice disease in certain caterpillars. Late in 1961 this fungus was found by the writer infecting caterpillars of the subterranean caterpillar in Wellington* and it seems likely that this is one of the naturally occurring diseases restricting the numbers of this pest, at least in certain parts of the country. Like the two bacilli already discussed, commercial dusts containing large concentrations of the spores of this fungus are now being produced, and these can be distributed in the same way as the other microbial insecticides. Since the disease is now known to occur naturally in New Zealand in subterranean caterpillar, it is reasonable to suppose that, under favourable environmental conditions, mass inoculation of pastures at the right time might assist the locally occurring disease by “triggering-off” an epidemic. As the disease spreads most readily under cool moist conditions, it could be expected that, under these conditions it might prove most effective in the cool, moist districts of Otago and Southland. So, as with the bacteria already mentioned, extensive field trials with *B. bassiana* spore powder have been laid down throughout New Zealand and have been included in the long-term trials against grass grub as well as against subterranean caterpillar. It is thought that an endemic species of muscardine fungus does attack grass grub, and, if this be found true when surveys for local insect diseases have been completed, it is possible that this fungus may be of some use for the control of grass grub. Again these field trials are long-term.

VIRUSES

The most virulent diseases affecting insects, like those affecting man and his stock, are viruses, and, if means to propagate and disperse them can be found, these diseases will be most important in the control of pest species. Unfortunately, viruses do not multiply outside living tissue and so far it has not been possible to produce them commercially as microbial insecticides as in the case of the bacilli and the fungus already mentioned. Nevertheless, much intensive research is being carried out and it is only a question of time before this problem will be overcome.

Some remarkable success has been achieved in Canada by the aerial distribution of a polyhedral virus of sawflies attacking the forests, and to a lesser extent alfalfa caterpillar has been controlled similarly by ground spraying in a limited zone in California. Virus diseases of armyworm are known to occur in New Zealand, another infects an endemic moth which sporadically attacks forest trees, while the virus disease of cabbage white butterfly has a very important effect in controlling population numbers in crops like rape and choumoellier in the autumn. Late last year a nuclear polyhedral virus was found for the first time by the writer attacking caterpillars of subterranean caterpillar in the Wellington district† but its importance in controlling population numbers is unknown. It may be quite considerable.

* Identification by Prof. E. A. Steinhaus, University of California.

† Identification by Dr Y. Tanada, University of California.

While the use of viruses, perhaps, holds out most promise in the future, for the time being they are of only restricted value. The time will come, however, when they will take their rightful place alongside other methods of microbial control.

NEMATODES

Nematodes are found parasitizing all groups of animals and plants, and insects are no exception to these. The best known is one which was found parasitizing the larvae of Japanese beetle in New Jersey, U.S.A., and is named *Neoaplectana glaseri*. It exerts considerable influence in the control of this pest in the United States, and was introduced into New Zealand in an attempt to control grass grub. Australia is at present testing it for the possible control of curl grubs.

More recently, however, research has revealed a most interesting nematode parasite of codling moth larvae which is designated DD.136. The interesting feature peculiar to this nematode is that it is the vector of a bacterium which it injects into the host insect with its needle-sharp mouth-parts. The bacterium then multiplies within the insect which it kills, and the nematode in turn then feeds on the bacteria. Research on this combination of nematode and bacterium is proceeding, and, when more is known about it, it might be found of some use for the control of pests in this country.

RIKETTSIA AND PROTOZOA

Both of these groups of parasites attack insects, and, although much research is being carried out on them, so far they are of little significance in artificially induced microbial control. The results of further research, however, may lead to their practical use for this purpose.

"INTEGRATED" OR "MODIFIED" PROGRAMMES

The idea of integrating chemical and biological control of pests is not new in applied entomology, but added impetus has been given to it by the secondary problems associated with the use of new, widely toxic, synthetic organic insecticides. In an integrated programme, applied biological control is supplemented by appropriate chemical control procedures. The latter are thus reduced in frequency and intensity because the average level of pest abundance is first reduced by the former. Thus the two control methods complement each other, but, because the full potentialities of biological control have not been exploited, the potentialities of integrated controls have hardly been touched. A further contributing factor retarding the expansion of this method is that complex programmes of this type require trained and experienced entomologists for their full implementation and for this reason the adoption of integrated control will probably be a slow process.

Nevertheless, progress is being made in this field which can be expected to play an increasingly important role in pest control programmes of the future. Over the past nine or ten years it has been successfully employed by Pickett and his colleagues for the control of orchard pests in Nova Scotia apple orchards, resulting in satisfactory control, larger crops, and better quality fruit.

It has also been employed as a method of control of purple scale by strip treatment in orange groves in California. Of a large number of possibilities considered, periodic strip treatment offered the most practical approach. The most fundamental consideration in this method is that the periods between treatments be long enough so

that natural enemies from untreated areas have a chance to effectively re-colonize the treated strip after the pests again start to increase.

The application of this technique to broad acres is most difficult, but, as residue problems become more and more acute, and as research on integrated programmes advances, techniques to overcome these difficulties will be found. At present consideration is being given in New Zealand to the method or methods of formulation which will enable some of the microbial insecticides already mentioned being formulated with current synthetic organic insecticides in such a way as to enable their dispersal on broad acres by conventional machinery. If such formulations can be successfully developed, then the belief with which this paper opened up, that both microbial and insecticidal control have a place in control programmes and so maintain a proper balance without unduly upsetting the ecosystem, comes within the bounds of possibility, and opens up the possibility of developing practical control programmes which may be employed on large areas such as on pastures. Such a project is both exciting and a challenge and points the way in which future research should be directed.

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