Applying bacterial spores of milky spore disease, the only insect pathogen available commercially. Discovered about 1933 for control of Japanese beetle grubs

Potentialities for Microbial Control of Insects

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Do production and marketing of these living insecticides hold an opportunity for industry? Success of recent trials suggests that the future for these methods is favorable

MICROBIAL CONTROL of insects has in recent years attracted the interest of large numbers of persons concerned with the suppression of insect pests. One of a number of contributions to agriculture for which insect pathology can take credit, microbial control has stirred imagination since its introduction just before the turn of the century. Unfortunately, during this time there has been so much vacillation of appraisal, wavering of opinion, and conflict of evidence that even today there is confusion in the minds of entomologists generally as to what can be expected of microbial control methods. What of the future? Do we yet have enough knowledge to judge the potentialities of microbial control? To put it bluntly: Are the possibilities inherent in microbial control methods worth the increased effort, talent, and money that might be put into the study of the diseases of insects? Perhaps such questions as these cannot yet be satisfactorily answered, but the time does seem propitious for some "plain talk" on the subject.

Early Experience

The idea of using microorganisms to destroy noxious insects began to emerge shortly before the middle of the 19th century. In another publication the writer has traced the early development of microbial control from its beginnings up to the beginning of the 20th century. At that time the potentialities of microbial control appeared to many to be spectacularly great, even though relatively little was known of the diseases affecting insects. Near the turn of the century, the observation of natural epizootics (that is, outbreaks) of disease in insect populations dramatized the effectiveness with which disease could reduce populations of destructive insects. This led to attempts to create, artificially, similar epizootics in populations of such insects as the chinch bug, grasshoppers, scale insects, whiteflies, the European corn borer, and others. While some of these efforts seemed to be rewarded with great promise, the fact remains that none of these apparently "sure bets" paid off in the form of a thorough and reliable means of control.

The reasons for these early failures —after such enthusiastic and promising beginnings—were primarily reasons of faulty techniques, absence of adequate technical knowledge, or a misunderstanding of the numerous ecological factors involved. Unfortunately, in spite of rapid advancements in insect pathology in recent years, we are still not sufficiently informed to turn these particular failures into success.

Nevertheless, during the past decade or two advances have been made in other directions. The definite and confirmed success of milky disease bacteria as an aid in the control of the Japanese beetle stands as a testimony to the proposition that insects *can* be controlled by microorganisms pathogenic to them. More recent successful trials using viruses, bacteria, or protozoa against such insects as the European spruce sawfly, the European pine sawfly, the alfalfa caterpillar, the imported cabbageworm, the Mediterranean flour moth, and the fall webworm, are encouraging harbingers of future possibilities. In most of these and other instances, however, something appears to be throttling widespread commercial use of the pathogens concerned. If this be so, it behooves us to inquire as to where and what the bottleneck is. For example, if, as has been shown, the alfalfa caterpillar or the imported cabbageworm can be effectively controlled by the appropriate virus or by *Bacillus thuringiensis*, why aren't these microbial agents in regular use by the growers of the crops these insects attack?

To be sure the reasons may vary from case to case. Practical use of a particular pathogen against a specific insect may be thwarted by any of several factors or circumstances, or by a combination of these. As best we can, however, let us examine some of the more prominent aspects having to do with the acceptability and commercial use of insect pathogens.

Fairfax Biological Laboratory, Clinton Corners, N. Y., produces milky disease spores. A microscope and microinjector are used to inoculate the Japanese beetle grubs with spores of the disease-causing organism

Could it be that the disadvantages of microbial control methods outweigh the advantages? The final answer to this question must await more extensive use of these methods, but such a conclusion would hardly seem warranted on the basis of present knowledge.

Advantages of Microbial Control

The principal advantages of microbial control methods are:

- The harmless and nontoxic nature of insect pathogens for other forms of life; hence, the absence of toxic residues.
- The relatively high degree of specificity of most pathogens, which tends to protect beneficial insects (pollinators, parasites, and predators).
- The compatibility of many pathogens with many insecticides to the degree that the two may be used concurrently and, in some cases at least, synergistically (*i.e.,* infection may cause the insects to be more susceptible to chemical poisoning).
- The ease and inexpensiveness with which some pathogens can be produced.
- The high versatility of microbial pathogens insofar as methods of applying them are concerned. The fact that microorganisms are living agents enables man to "introduce" and "colonize" some of them which are capable of perpetuating and extending themselves in nature. In some cases the control brought about by microorganisms may be "permanent." Other pathogens may be used as sprays or dusts in the same fashion as insecticides.
- The apparent slowness by which a susceptible host develops resistance to a microbial pathogen. As yet there is no authenticated instance of an insect's acquiring a resistance (either by selection or by immunity) to an introduced pathogen or one directly applied in the field.
- The low dosages required in some instances. For example, the amount of virus produced in three or four diseased alfalfa caterpillars may be sufficient, if properly diluted, to spray an entire acre of infested alfalfa.

Disadvantages of Microbial Control

In apposition to these advantages of microbial control methods, the following disadvantages must be recognized:

- The necessity for careful and correct timing of the application of the pathogen with respect to the incubation period of the disease. As living agents, microorganisms usually act more slowly than do chemical poisons; therefore, they must be applied early enough to ensure that the crop will not be damaged before the insect dies. Sometimes, and with some pathogens, care must be taken to time the application with respect to proper weather conditions. However, if proper procedures are followed, difficulties need not be encountered.
- The relatively marked specificity of most pathogens sometimes narrows the spectrum of effectiveness to only one insect species in cases where several pests are involved, all of which might be destroyed by a single chemical insecticide. In some instances, however, several pathogens may be combined so as to broaden the spectrum of effectiveness.
- The necessity of maintaining the pathogen in a viable condition and at a high virulence and in a durable or resistant state until the insect is contacted. In many cases, however, techniques and procedures for accomplishing this are available.
- The difficulty of producing some pathogens either in large quantities or inexpensively, or both. Here it is to be emphasized, however, that these disadvantages usually can be overcome by research, technical improvements, and the perfection of production methods.
- The tendency of some diseases to cause the insects, or parts of the insects, to remain attached to the foliage of the host plant. This aesthetic disadvantage is particularly objectionable in the case of food crops which, when processed, may yield a product in which insect parts cannot be tolerated.
- The requirement of some pathogens, notably most fungi, for high atmospheric moisture in order to invade and infect their arthropod host. On the other hand most bacteria, viruses, and protozoa are ingested, the fluids of the insect's body providing adequate moisture for their development. Temperature may also be an important factor but, in general, conditions favorable to the host insect are favorable for the development of the pathogen.

A careful comparison of the above-listed advantages and disadvantages of microbial control in relation to other methods of control fails to reveal any inherent reason or basic principle that precludes the use of microorganisms as control agents under appropriate circumstances. In actuality each situation has to be considered on an individual basis, there being no doubt that, under certain conditions, certain pathogens offer virtually no chance of effectively controlling certain insects. On the other hand, some of the advantages of microbial control methods over other methods of control are such as to make eminently worthwhile every effort to develop and perfect microbial control methods. Nevertheless, the road ahead is not an easy one and it is beset with several difficulties.

Availability of Microbial Control Products

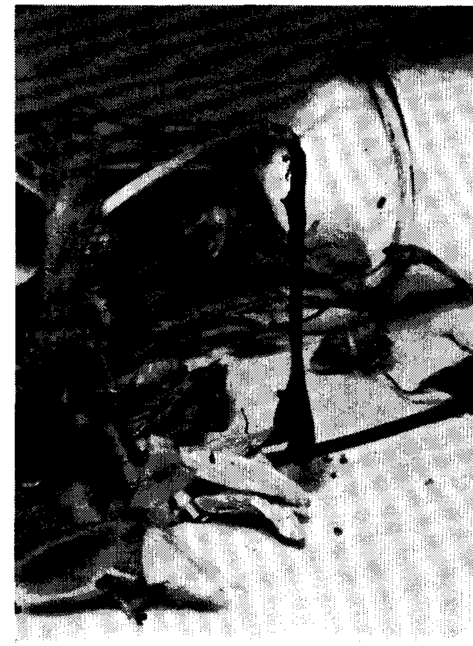
The degree to which a new product or a new method is used or well-received by farmers or growers is often referred to as the "grower acceptability" of the product or method. In the case of microbial control products and methods, however, it is not, at least as yet, so much a matter of "acceptability" as it is "availablity." Except for milky-disease spore powder, used in the control of the Japanese beetle, no insect pathogen is today commercially available for control purposes. (Prior to World War II a product known as Sporeine was manufactured in France by Laboratorie LIBEC. It consisted of bacterial spores in bentonite, and was used in the control of certain grape insects.) The truth of the matter is that although a significant number of insect pathogens are known and have been shown experimentally to the promising control agents, none of them, with the exception just mentioned, is really available in practical amounts to the growers.

Our own laboratory regularly receives inquiries from growers and agriculturists as to where they might obtain a supply of bacterial spores or viruses with which to treat their crops. Being primarily a research organization our laboratory is not in a position to provide such products beyond the amounts required for experimental purposes. In some instances, in this country and abroad, governmental agencies are in a position to provide at least limited amounts of the required pathogens. However, in this country at least, rarely could this be done on a scale comparable to the present availability of insecticides. This, of course, leads to the question: "Why aren't microbial control products available commercially to the grower?"

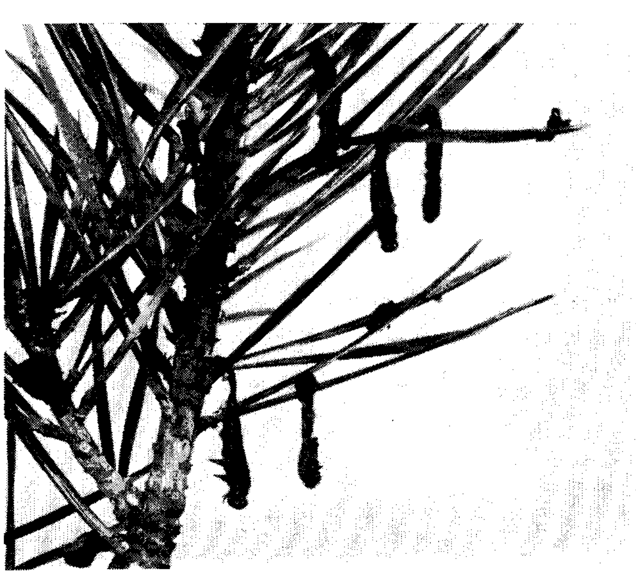
The Role of Industry

In the first place, there appears to be a hesitancy on the part of industry to take the necessary risks involved in the manufacture and sale of microbial control products. Part of this hesitancy appears to be caused by the uncertainty as to just which branch of industry is in the best position to manufacture the products, and which can best distribute them. There appears to be a belief on the part of some representatives of industry that either of two alternatives might best succeed. Either the insecticide industry could both manufacture and distribute the products, or the products could be manufactured by biological houses or fermentation companies and be distributed by insecticide concerns. To be sure, there are other alternatives. Undoubtedly it is the kind of problem that solves itself. depending on the country and social order concerned and upon the intrinsic nature of the products themselves.

Those commercial concerns that have looked—albeit gingerly—into the matter have also been somewhat apprehensive about methods of mass-producing the pathogens. The production of bacteria and fungi does not offer quite the difficulties that does the production of viruses, protozoa, and nematodes. Many of the former can be grown on artificial media, and the amounts produced are in proportion to the amounts of media that can be handled. Some interested individuals envision production facilities of the type used to produce antibiotics; others see possibilities of adopting production methods similar to those used in the fermentation industry.



Alfalfa caterpillar dead of polyhedrosis virus used in sprays



Life-size photograph of European pine sawfly larvae killed by virus sprayed on the pine needles

In the case of insect viruses and most protozoa, artificial media are of little avail. These agents require living tissues in which to develop. This does not mean, however, that mass production methods are out of the question. There appear to be several methods of approaching the problem: In the first place, some insect viruses may be gathered from the field in rather large numbers together with their diseased hosts. Tbus, in a few hours one man can gather for processing enough diseased alfalfa caterpillars to provide virus in amounts adequate to treat hundreds of acres of infested alfalfa. On the other hand, certain other viruses (such as those affecting certain forest insects) are more difficult, impractical, or virtually impossible to collect in this fashion. Similar variations pertain to viruses, or protozoa, that can be produced by rearing insects in insectaries in large numbers and then infecting them with the appropriate pathogen.

The advent of tissue cultures in the production of mammalian viruses suggests the use of similar techniques in the case of insect viruses, and possibly protozoa. Indeed, one insect virus, that of silkworm jaundice, has already been grown experimentally in tissue culture. Unfortunately, very little has been accomplished in the way of culturing insect tissues, and virtually nothing has been done to adapt insect tissue culture to mass production methods. These developments must precede any realization of the mass production of insect viruses and protozoa by tissue culture methods. Then, too, it should be remembered that susceptible insects themselves (a naturally provided tissue culture) can often be reared inexpensively in large numbers, a fact that would make present tissue culture methods almost prohibitive on a comparative cost basis. Nevertheless, in view of the rate at which tissue culture methods are being perfected, one cannot preclude the possibility of their eventual applicability for the mass production of certain insect pathogens.

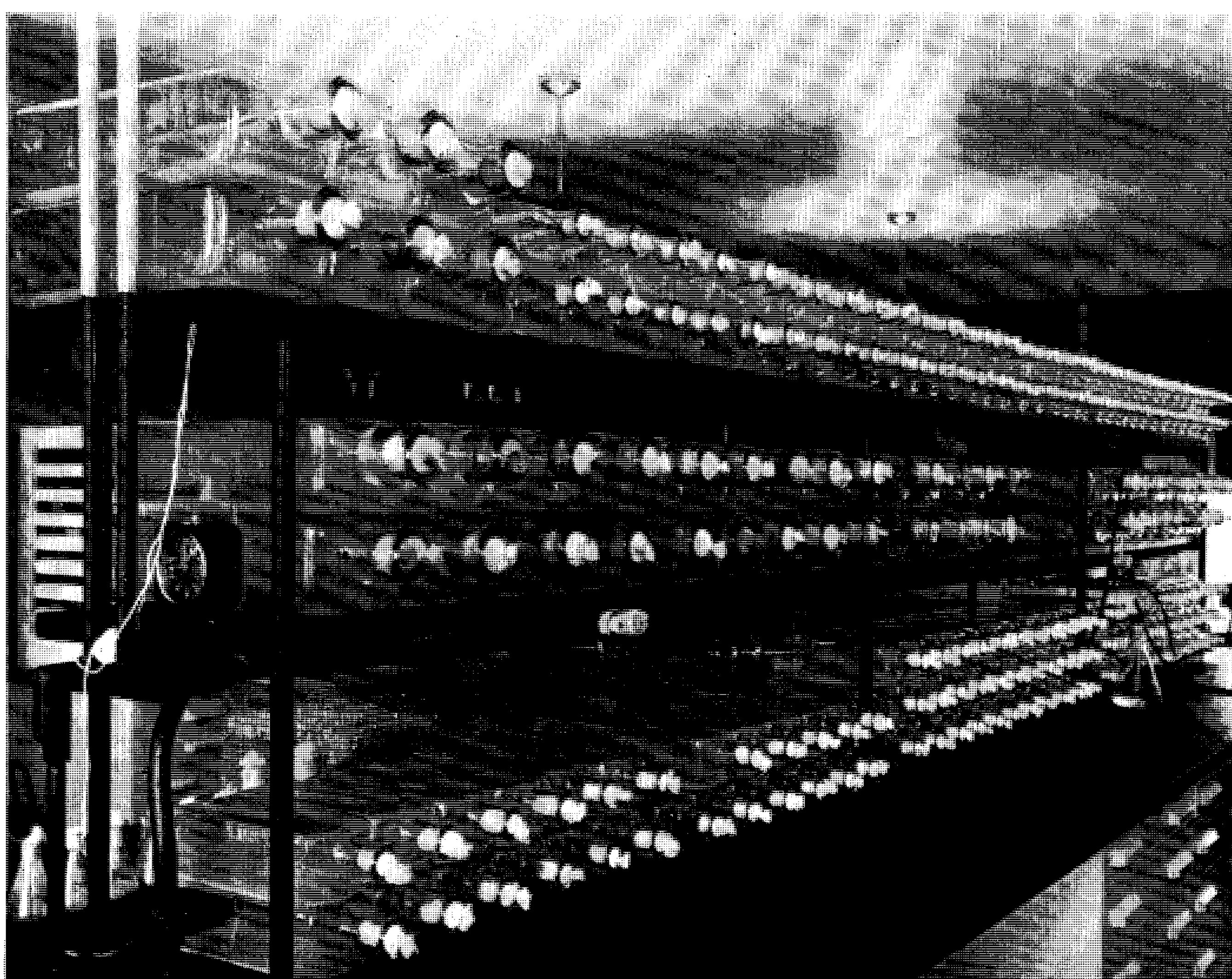
Another problem that must be faced in promoting the further development of microbial control is the recognition that a great deal more fundamental information is needed. To be sure, to say that more basic research is required is a truism that has almost become a cliché in most branches of science. Nevertheless, it is particularly appropriate in the case of insect pathology and microbial control.

Fundamental Research

A great deal of certain types of basic research is being accomplished both in this country and abroad, but some aspects and areas are being neglected, and some need more emphasis than they are now receiving. We refer here particularly to the need for epizootiological studies and an improvement in our understanding of the ecology of insect diseases. We must face up to the fact that much of what has been accomplished in the way of microbial control has been based on trial and error methods, and that we really do not yet have adequate fundamental knowledge on which to base our microbial control procedures. At times it appears that substantial developments in microbial control are held back because of our ignorance of what must be keystone principles. The gaining of such knowledge takes time. And, while we must be patient, it is highly essential that we proceed and support as much fundamental research as possible. Perhaps it is for the insect pathologists of future generations to realize the hopes we now have.

It is also well for us to remember that insect pathology while, in a sense, not a young discipline, is not a fully developed one. With certain notable exceptions many attempts to use microorganisms in the control of insects have been made in a dilettante manner. Fortunately, in recent years insect pathology has come to be considered as a distinct branch of entomology, and serious efforts have been made to place it on a firm scientific foundation. Eventually, if not now, microbial control should attract a greater amount of moral and financial support, in a manner similar to the

Povitsky flasks containing a nutrient medium upon which *Bacillus thuringiensis* is being grown and spores produced. After a week spores will be harvested, dried, and prepared to test against insects. Total surface of medium amounts to about 70 square feet. Yield of spores (0.5 to 0.7 gram dry weight per bottle) is small compared to possibilities of mass production



way such support came to chemical control methods when the latter proved to be successful.

Having emphasized the need for and the importance of more basic research, it is now pertinent to highlight the fact that in all probability we can do more than we are doing with the basic information we do have. As pointed out in a previous paragraph, a relatively large number of microorganisms pathogenic for insects are known. And while their mass production awaits greater know-how, a great many more plot tests and experimental trials could be taking place. In other words, more effective screening programs could be carried out. The deficiencies are largely those of manpower and opportunities to test the pathogens against the appropriate insects. Moreover, greater variations in the manner of application could be tried, keeping in mind the four major possibilities: Some pathogens may be: (1) introduced and/or colonized; (2) applied as sprays or dusts; (3) used with insecticides, both compatibly and synergistically; and (4) used with parasites and predators.

What of the Future?

What are the potentialities of microbial control methods as they appear to us on the basis of our present knowledge? These questions, asked in a serious and sincere manner, require that we at least make an attempt to appraise the new horizons with the hope that we may discern the true path to microbial control—one of the applications of insect pathology. The present status and the future outlook for microbial control may be summarized as follows:

Microbial control offers no panacea for the control of destructive insects. It should not be over-sold or advanced as a cure-all. Although in the long run the advantages of microbial control, in certain instances, over other means of control make it a practical and attractive means of reducing harmful populations of insects, in other situations it has definite limitations.

On the other hand, the potentialities of microbial control should not be underestimated. It has already proved itself in a number of instances, and in certain situations and under certain conditions is superior to other methods of control. The ultimate scoring is likely to read to the effect that in some instances microbial control is the method of choice, in other cases it excells at times but not at other times, and in still other instances it offers little or no advantage over other methods.

Considered from the broad viewpoint and for the good of agriculture, microbial control should not be thought of so much as a competitor of other methods of control but rather as a complement or supplement to other methods. To be sure, in some cases the use of microorganisms has replaced and will replace chemical insecticides, but, in general, microbial control methods pose no serious threat to the use of chemicals—contrary to published statements to this effect.

Preparations of entomogenous microorganisms, when used as sprays or dusts, may be considered as living insecticides. As such, they might logically be produced and marketed by the insecticide industry. Or, they might be produced by those concerns that manufacture antibiotics, fermentation products, vaccines, or other biologicals, and be marketed and distributed by insecticide companies.

The principal bottleneck to the wider use of microbial agents in the control of insects appears to be the unavailability of such products on the market. A number of promising insect pathogens have been tested experimentally but are waiting to be manufactured and to be made available to the grower. In some cases, adequate information is needed regarding their application and use in a commercial sense.

Although the potentialities of microbial control have been considered by scientists for a long time, our fund of basic and applied knowledge is not sufficient at this time to predict safely the extent to which such methods of control will be useful. With an increase in our understanding of how diseases spread and manifest themselves in nature, how their causative agents can be produced easily and in abundance, and how and under which conditions these agents can best be applied and disseminated—with an adequate knowledge of these matters, we may be sure that microbial control will assume its rightful place in the arsenal of weapons with which man is destined to combat his insect enemies.

Liability of Pesticide Manufacturers

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Whether or not a manufacturer is held to strict liability can depend on the adequacy of testing and the adequacy of directions for use

ESSENTIAL to an understanding of the legal liability of the manufacturers of pesticides for injury arising out of pesticide use is some knowledge of their products. In former times the chemical compounds used in pest control were relatively safe, that is their properties were generally known and they were applied in ways which enabled even the inexperienced user to confine their application to definite areas. Such a pesticide is treated by the law as an ordinary good. This is to say, any injury resulting from the use of it is presumed to arise from the negligence of the user rather than from any dereliction on the part of the manufacturer. But all modern pesticides are not ordinary goods. Some are what the law calls inherently dangerous—goods with respect to which the manufacturers or distributor can reasonably foresee that any failure of duty on his part may operate, without contributory negligence on the part of another person, to work injury. For reasons which are apparent application by airplane increases risk.

Early Rule and Warranty

In general, the common law rule is that the manufacturer of an article is not liable for injury arising from its use, unless the manufacturer has entered into a contract with the user.