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# Microbial Control : Its Place in Korean Agriculture and Forestry

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# 韓國農林業에서 病害蟲의 微生物的 防除의 位置

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## INTRODUCTION

I am extremely pleased to have the opportunity to talk to a group of plant pathologists about microbial control of insects. As you probably well know, the boundaries between the disciplines of plant pathology and insect pathology are not always distinct. We have a great deal in common with one another, especially in the area of basic research. One of my professors on my PhD committee was a plant virologist who was much more helpful to my research than my major professor, who was an insect pathologist. Also, as is so often the case, the plant pathologist had much better facilities and laboratory equipment. This is not to say that all insect pathologists are poorly equipped or underfunded, but in many cases, we have to depend upon our esteemed colleagues in the plant pathology department for the use of some sophisticated pieces of equipment that we do not possess. I hope that such cooperation and interchange may long continue.

## INTERATED PEST MANAGEMENT

Those of you that are concerned with field work are no doubt aware of the concept of Integrated Pest Management, or IPM for short (Table 1). This is a philosophy in which all available methods are used for management of plant pests, including both insects and diseases as well as the other pests. Many tactics may be utilized in IPM, but the bottom line is to manage the pest, not to eradicate it, nor to completely destroy it. Biological and chemical methods are both very important components of IPM. Insect pathogens have played a vital role and will continue to play such a role in the management of insect pests. I am reasonably certain that each of you have, at one time or another, observed microbial control in action. Perhaps you have walked through a vegetable field where virus infected worms were hanging from the leaves ready to spill their liquid contents upon your trousers leg as you walked past. This example, however, is not always the rule, since a great deal of microbial control occurs in a much quieter, less spectacular manner. Many insects are maintained below economic levels by microbial action without the presence of obvious manifestations, therefore, it is only natural that the grower might not realize the importance of insect control by such microorganisms. *Bacillus thuringiensis (B.t.)* sprayed onto a crop as a microbial insecticide does not cause an immediate response like many of the chemical insecticides that we use. The grower walking through the field the next day ıle 1. Integrated pest management (IPM)[a]

| |
|---|
| [ – The intelligent selection and use of pest ontrol actions that will ensure favorable econo-, ecological, and sociological consequences. bb, 1972) |
| Cultural methods |
| Resistant varieties |
| Crop rotation |
| etc. |
| Mechanical methods |
| Hand destruction |
| Screens |
| etc. |
| Physical methods |
| Heat |
| Cold |
| etc. |
| Biological methods |
| Protection of natural enemies |
| Introduction of parasites and predators |
| Insect pathogens |
| Chemical methods |
| Insecticides |
| Attractants |
| Repellents |
| etc. |
| Genetic methods |
| Regulatory methods |

[a] From Luckmann, W. H. and R. L. Metcalf, 1985.

ıds many living insects and concludes that B.t. is ı good, and immediately calls in the heavy artillery chemical insecticides. What he didn't realize was at the larvae had ceased feeding due to paralysis the gut and mortality would occur within a short ne. This same principle holds true with many of e microbial control agents. While waiting for such tural controls to do their job, populations will ten build up to uncomfortable levels, but the ɔwer should weigh the economic advantages pro-led by natural control with some loss of crop ainst the expense of chemical control measures th more minor losses. This principle has been terated many times, but it is a decision that grow-; and crop advisors everywhere, including here in orea, will have to make in order to utilize control ıeasures effectively and realize the greatest return, ot only with regard to microbial control of insects, ut with all other aspects of pest management.

## IMPORTANCE OF MICROBIAL CONTROL IN IPM

Well over 1000 species of microorganisms that are pathogenic to insects and mites have been described. Although many of these will never be important in agricultural control programs, quite a few are definitely promising as tools in IPM, and many have been around for years, assisting the grower with his control problems, often-times without his knowledge. Among this arsenal of pathogens viruses, bacteria, fungi, protozoa and parasitic nematodes are normally included in the list. A wide range of pest species are afflicted by these pathogens, often preventing these pests from attaining the economic numbers that they would reach otherwise. Insect viruses contain some of the most important of the naturally occurring insect pathogens, as well as promising candidates for microbial insecticides. The virus particles of many insect viruses are occluded in protein crystals called inclusion bodies or polyhedron. There are three main types of inclusion viruses, nuclear polyhedrosis, granulosis and cytoplasmic polyhedrosis viruses, which collectively contain the largest number of viruses known in insects.

Bacteria are broken down into non-spore forming, usually represented by the "potential pathogens" normally residing in the gut, and the spore-forming bacteria, represented by *Bacillus popilliae (B.p.)* and *B. thuringiensis. B.p.* infects the larvae of Japanese beetle and other scarabs by ingestion of spores which germinate and penetrate the body. This organism cannot be cultured in artificial media, so spores have to be produced in living grubs. *B.t.* is grown in artificial media and thousands of kilograms are manufactured each year for use against lepidopterous pests. When it sporulates, it forms a crystal which is toxic to many lepidopterous larvae. Many larvae are susceptible to the toxic action of the crystal alone, while others are susceptible only to the combined action of spores and crystals.

More than 40 different genera of fungi contain species that cause insect diseases. The genera most often seen are *Beauveria, Entomophtora, Metarrhizium* and *Aspergillus*. *Beauveria bassiana* is the most widely used for microbial control. It attacks about 500 insect species while *Metarrhizium anisoplia* attacks 200 species. Most fungi are transmitted by a spore, usually a conidium. The most common method of infection is through the body wall or cuticle.

In regard to protozoa, certain flagellates, ciliates, amoebas, coccidians and haplosporidians have pathogenic relationships with insects. Neogregarines and microsporidians are the most important. These are transmitted orally from one insect to another by a resistant spore form. Many species are also transmitted transovarially. Protozoa are not used for short-term, quick activity control purposes. They are more likely to be used in conjunction with other methods, and to decrease the insect ability to reproduce.

Several nematode families contain certain species that are parasitic to insects, with well over 100 species described. Most nematodes infect their hosts as juveniles which may enter directly through the cuticle or through the spiracles or midgut. Some species kill their hosts upon leaving to molt into an adult. Others transport bacteria which cause a fatal septicemia. Many nematodes are fairly host-specific while others infect a wide range of insect hos

Sufficient pathogens exist to work against of the major orders of insect and mite pests (Tat 2). Some are exceptionally efficacious against o group, but have no effect whatever against anoth The hypomycetic fungi are the only group list which will attack orders across the board. T bacilli group is much more specific, with *B.t.* on economically effective against lepidoptera ar mosquitoes. Most pathogens, including viruse fungi, and protozoa infect representatives of sever orders.

Examples of pathogens that are now importa adjuncts to the commercial market of insecticid are *Bacillus popilliae*, the milky disease of Japane beetle and *B. thuringiensis*, which is commerciall produced by a number of companies and is effe tive against a wide range of lepidopterous pest and others (Table 3). *B.t.* is particularly desirab because of its high degree of selectivity and its con plete safety to the environment and to warı blooded animals. In regard to spectrum of activit one of the problems with *B.t.* is its wide range c activity against lepidopterous insects. Althoug generally used as a selling point, this range als includes the silkworm, so much caution should b observed in its use around silkworm productio areas.

At least three viruses, *Heliothis zea* NPV, *Orgyi*

**Table 2.** Efficacy of some pathogens against different pest groups[a]

| Pathogen group | Lepidop | Orthop | Coleop | Dipt (Mosq.) | Homopt | Mites |
|---|---|---|---|---|---|---|
| *Bacillus popilliae* | – | – | +++++ | – | – | – |
| *B. thuringiensis* | +++ | – | – | + | – | – |
| *B. sphaericus sp.* | – | – | + | +++ | – | – |
| Baculoviruses | ++++ | ++ | + | + | – | ++++ |
| CPV | +++ | – | + | ++ | – | – |
| Other occluded viruses | ++ | ++ | + | + | – | – |
| Hyphomycetes | ++++ | +++ | ++++ | +++ | ++++ | +++ |
| Entomophthora | +++ | ++++ | – | + | +++++ | ++++ |
| Protozoa | +++ | +++ | ++ | +++ | – | – |
| Nematodes | +++ | ++ | +++ | +++++ | – | – |

[a] Adapted from Burges 1981. – : No natural occurrence, + : Occasionally enzootic, ++ : Often enzootic, +++ : Enzootic, cyclic epizootics, ++++ : Enzootic, cyclic epizootics – major control, +++++ : Keep below economic threshold.

Table 3. Bacterial and fungal commercial preparations[a]

| Pathogen | Year released | Target | Country in use |
|---|---|---|---|
| *Beauveria bassiana* | 1960's (?) | Col. potato beetle | USSR |
| *Beauveria bassiana* | 1960's (?) | Corn borer<br>Forest leps | P. R. China |
| *Hirsutella thompsonii* | 1981 | Citrus rust mite | USA |
| *Metarhizium anisopliae* | 1979 | Spittle bug | Brazil |
| *Vertacillium lecani* | 1981 | G. H. aphids | Great Britain |
| *Bacillus popilliae*<br>*Bacillus lentimorbus* | 1946<br>1975 | Japanese beetle | USA |
| *Bacillus thuringiensis* var *kurstaki*, HD-1 | 1979<br>1981 | Many<br>Lepidoptera | Worldwide |
| *Bacillus thuringiensis* var *aizawai* | 1981 | Wax moth | USA |
| *Bacillus thuringiensis* var *israelensis* | 1981 | Mosquitoes<br>Blackfly | Worldwide |

[a]From Hamm, J.J. 1984.

Table 4. Insect viruses[a]

| Virus group | Particle shape | NA | Inclusion body |
|---|---|---|---|
| Family : Baculoviridae | | | |
| Gen. : Baculovirus | Bacilliform | DNA | |
| A. Nuclear polyhedrosis virus (NPV) | | | + |
| B. Granulosis virus (GV) | | | + |
| C. Oryctes virus | | | − |
| Family : Poxviridae | | | |
| Gen. : Entomopoxvirus (EPV) | Ovoid or brick-shape | DNA | + |
| Family : Iridoviridae | | | |
| Gen. : Iridovirus | Isometric | DNA | − |
| Family : Parvoviridae | | | |
| Gen. : Densovirus | Isometric | DNA | − |
| Family : Reoviridae | | | |
| Gen. : Cypovirus (CPV)[b] | Isometric | RNA | + |
| Family : Rhabdoviridae | | | |
| Gen. : Sigmavirus[c] | Bullet shape | UNK | − |
| Unclassified viruses | Isometric or ovoid | RNA | − |

[a] From Mathews, 1979
[b] Similar to wound tumor – rice dwarf
[c] Similar to lettuce necrotic yellows – sowthistle yellow vein – Potato yellow dwarf.

PV, and *Lymantria* NPV, have been cleared for ommercial production in the US and are now availle for applications. There are several families of ruses which contain important insect pathogens able 4). Of these, two (Reoviridae and Rhabdoidae) have some biochemical and biophysical nilarities to plant pathogens. Baculoviruses, which are among the most prevalent and important pathogens for insects and to which most major research efforts have been directed, have been proven to have potential as components of IPM in both agricultural and forest systems. The limiting factors in large scale use are high cost of virus production and need of more effective application technologies. It was reported by Ko and Lee in 1972, that a cytoplasmic polyhedrosis virus (Smithia virus) was cultured in Korea beginning in 1968 and was very effective against the pine caterpillar. This virus has been applied annually against the pine caterpillar since 1981. Similarly, a nuclear polyhedrosis virus has been applied since 1981 for control of fall webworm. Both have only been tested in small areas because of the expense. A muscardine fungus looked good in early tests against pine caterpillar, and *B. thuringiensis* has been very effective in both forest and urban situations against fall webworm here in Korea. Successes with these and other pathogens have shown that microorganisms, when properly developed, formulated and applied, are equal to the best insecticides. In addition, resistance, if it does occur, will not develop nearly as rapidly as with chemicals.

In pest management, one of the greatest difficulties in developing an integrated control program is the scarcity of selective chemicals and the problem of using wide spectrum materials in a selective manner. The restricted host range of many insect pathogens shows promise for utilization in integrated systems. Microorganisms can either be used as microbial insecticides, such as *B.t.*, or as introductions leading to enzootic establishment and continued persistence within the agroecosystem. Also, in some instances the pathogen is naturally present and it becomes a case of simply letting it do its work. As one might expect, the introduction of pathogens into insect populations for long-ter suppression has been most successful on crop that tolerate a relatively high level of host densit This is especially true of forest pests, and sever insect pathogens introduced into populations forest pests have provided satisfactory contro

Microbial control is usually more effective whe combined with other types of control, such as wit chemicals, resistant varieties, cultural practices an other pathogens. Non-target organisms are no affected, leaving parasites and predators active to add to the pressure against the pest. Microbes mus have certain attributes in order to do the job usually depending on whether they are to be introduced to become an enzootic part of the ecosystem or to be applied as microbial insecticides (Table 5) Not all of the microbes attempted will have ever a majority of these attributes, but those that do wil be the most successful in the control of pests

Other pest management procedures have great effect on microbial control. Full efficacy of a persistent microbial agent is usually assured only i motile vectors are present. Accordingly, preservation of some faunal diversity of an ecosysten contributes to dispersion and therefore to continue efficacy. This has been given the unfortunate title of 'the dirty field concept'. However, it is a descriptive name for what is needed to make microbia and indeed, any type of biological control work effectively. It is also directly contrary to the curren chemical control tactics used in Korea as well a

**Table 5.** Desirable attributes of microbial control agents and nematodes[a]

| Attribute | Method of application |
|---|---|
| Rapid spread | |
| Power of search for host | |
| Persistence | INTRODUCTIONS |
| Safe – Aesthetically acceptable | |
| Control to sub-economic levels | |
| Predictable control | |
| Virulence | MICROBIAL |
| Easy production | INSECTICIDES |
| Low cost | |
| Good storage | |
| Easy application | |

[a] From Burges and Hussey 1971.

other developed countries. At one time in the ;, we had an adage 'the only good bug is a dead g'. This thinking is of course obsolete, as well dangerous, and hopefully will be recognized as ɛ anachronism which it is.

## TRAINING IN INSECT PATHOLOGY

As mentioned before, the term, integrated pest ınagement, is a very inclusive term, taking into count all aspects of the ecosystem and including suitable techniques to manage the pests at such level that plants are protected from economic ury. Unfortunately, however, in actual practice, o many advocates of pest management fail to nsider insect pathogens, even though their impornce has been well documented. Possibly, the ıson for this neglect is simply failure to recognize e importance of such control or perhaps failure recognize diseases when they are confronted. order to utilize microbial control to its maximum ficacy, one must have a knowledge of the many riables that affect such control measures. Some of ese factors require a considerable amount of basic d applied research by scientists trained in the field insect pathology. In regard to pathogen introıctions, the three main characteristics of the thogen that influence its ability to spread throughıt the host population are virulence and infecti:y, capacity to survive, and capacity to disperse. ıportant components of the host population volved are density and susceptibility to the disease. knowledge is also important of the effects that ıysical factors can have on control; temperature, ımidity and rain, radiation, wind and many other ıvironmental factors have a great influence on icrobes. Humidity is particularly important with ngi and nematodes, neither of which can be infec/e without water. Ultraviolet radiation is much ore important than temperature where most .thogens are concerned, particularly those which e applied as microbial control agents. Most pathons are inactivated in a very short time in the prence of UV. An advisor must also be aware that epizootics, which are usually caused by viruses or fungi, occur and can completely decimate a pest population in a short time. However, such events are sporadic and are difficult to predict, but there are ways that we can work with natural epizootics. An advisor should first know the damage threshold of the insect population he is working with. He must also be familiar with the most important diseases in this population. Then he can carefully watch for the epizootic and avoid treatment with insecticides for as long as possible. He should never apply such controls before the damage reaches the economic damage threshold.

As you can thus see, advanced training in insect pathology is required in order to successfully utilize this exciting and challenging IPM concept. For this reason, I would recommend that, as the Republic of Korea is becoming more and more sophisticated in their pest control tactics, and as more young people are being trained in pest management techniques, that a course of study in insect pathology should be included in their curriculum. A specialist in pest management without such training is not and will not be fully armed for the conflicts that he or she is about to face. I believe that you, as scientists in the field of plant pathology, vitally concerned as you are with plant protection, can be very effective in promoting this aspect of pest management. A student with a good background in entomology and plant pathology, who desired to enter the field of insect pathology and microbial control, could receive advanced training in basic virology and microbiology in your laboratories. This would enable him to advance into his desired field. Hopefully, in time, there will be more trained insect pathologists within the universities who may share in this goal of training the next generation of pest management specialists.

## CONCLUSION

The development of integrated pest management systems will continue to progress here in Korea and in all developed nations because of the inherent benefits already proven and documented. The incorporation of microbial control into these systems should not be overlooked. I would like to paraphrase what one of my colleagues has remarked concerning viruses, enlarging it to encompass the whole field of microbial control. "The future of microbial control in agricultural ecosystems does not depend wholly upon overwhelming proof of its effectiveness or economy but in the eventual acceptance by the grower, by the researcher and by the pest management specialists of a newer, more challenging approach to insect control".

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