# SESSION 3
# TECHNOLOGICAL ISSUES

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# MICROBIAL INSECTICIDES: CAN FARMERS BE PERSUADED TO USE THEM?

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## ABSTRACT

Even though the market for microbial insecticides such as *Bt* products has been growing rapidly, only a handful of organisms have been developed into commercial products. This paper addresses some of the negative perceptions of microbial insecticides in an attempt to determine the degree to which these are inherent limitations or might be overcome by information, education and technological improvements. Potential markets and methods of encouraging the use of microbial products are also discussed, including the role of governments and regulatory bodies.

## INTRODUCTION

Widespread concern about the negative effects of chemical pesticides, combined with high agricultural production demands, has led to an increased interest in alternative pest control strategies. The market for biopesticides, and microbial insecticides in particular, has been growing rapidly (Georgis, 1996, Lisansky & Coombs, 1994). Nevertheless, only a limited number of the multitude of entomopathogenic microbial organisms have been developed commercially. Large agrochemical companies have shown little interest in developing microbial products which are seen by them as having limited market potential. Moreover, the level of demand for microbial insecticides appears to be uncertain. There are limitations to the use of these products, many of which are inherent to the biology of the pathogens. Whether these limitations form an insurmountable barrier to the widespread use of microbial insecticides remains to be seen. In part, this may depend upon the industry's ability to create a positive image of microbial products as effective and useful pest management tools. In order for this to happen there first needs to be a greater understanding of growers perceptions of microbial insecticides. It is then possible to assess the accuracy of these and determine the degree to which negative perceptions can be overcome through information, education and technological improvements in microbial products. With accurate assessment of product benefits and limitations, and thorough understanding of growers' demands and public perceptions, microbial products could be marketed more effectively. This paper addresses some of the perceptions about microbial insecticides and discusses ways in which use of these products might be encouraged.

## ADDRESSING PERCEPTIONS OF MICROBIAL INSECTICIDES

Despite the importance of understanding farmer's perceptions and demands of pest control products, little attempt appears to have been made to research farmer perceptions regarding microbial insecticides. Presumably companies developing microbial products fund individual feasibility studies (as the LUBILOSA project did for *Metarhizium flavoviride* use for Acridid control in Africa) (Stonehouse, 1995, Swanson, 1995). There do not, however, appear to be any such studies printed in public media. Those authors who have addressed perceptions of microbial insecticides have either done so from the view of the agrochemical industry (e.g. Payne, 1988) or in very general terms of past performance (e.g. Lisansky & Coombs, 1994). The general consensus appears to be that microbial insecticides are more expensive, more difficult to use, less reliable and essentially untried. If the use of microbial products is to become more common in agricultural practice these perceptions must be addressed and if possible, changed. The first step in this process is to determine how accurate these perceptions are and indeed if this view of them is correct.

It is true that microbial insecticides may be more expensive than low cost, broad spectrum chemical insecticides. In part, this is because cost is a function of scale and two of the limiting factors in the development of microbial insecticides are the small markets often defined by the narrow host ranges of pathogens and the difficulties in developing cost-effective mass production techniques for rearing biological organisms. In addition, relatively short shelf-lives and/or refrigeration requirements can add to the cost of microbial products. This is not to say that microbial insecticides can not be produced cost effectively. *Bacillus thuringiensis* (Bt) is a good example of a microbial insecticide which has maintained acceptably-priced products through large-scale production and large volume (and primarily high value) markets. It is unusual in that is mass produced by large agrochemical companies such as CIBA-Geigy and Sandoz, and therefore being distributed and marketed by the already well established and powerful networks of the agrochemical industry. Thus cost-effective production of microbial products is evidently possible but not all microbials may be as easy to produce. There are also examples of microbial insecticides being developed cost effectively on a smaller scale for less valuable markets. For example, Brooks (1988) describes a production method for *Nosema locustae*, a protozoan pathogen of grasshoppers. Production costs were low enough (around $0.25 per hectare) that the product could be economically viable for grasshopper control on rangelands (a very low value crop).

Product shelf-life is another factor which influences both the cost of the product and its feasibility as an insecticide. Chemicals are generally expected to have a long shelf life of five years or more. The shelf-life of microbial pesticides may not be so reliable. Many microbes can only be stored for a matter of weeks or require freezing or refrigeration. Progress, however, is being made in this area. A mycoinsecticide based on *Metarhizium flavoviride* currently being developed for locust control in Africa, for instance, appears to have remained active for **x** years once it is packaged, although this does require refrigeration below 4°C (Bateman pers. comm.) The aim of LUBILOSA (a consortium sponsoring work on the aforementioned product) is to achieve six months storage time at 30°C (Swanson, 1995). Protozoan spores have also been shown to survive for up to 10 years when kept at low temperatures in clean aqueous solution (Brooks, 1988). Refrigeration requirements, however, add to the cost of the product. Farmers may be reluctant to invest in refrigeration themselves. Thus while the increased shelf-life resulting from lowered temperatures may allow the industry to stockpile a product prior to demand, shelf-lives at room temperature may be more important from the farmer's point of view.

This leads to the question of how limited shelf-life may affect product supply. In order for a company to retain a market, farmers must have a reliable product source which is capable of meeting their demands for pest control. Producers of microbial insecticides must be able to assure farmers of continuity of supply. Supply demands may vary depending on whether the pest is sporadic or shows regular occurrences which can be anticipated. If pest outbreaks are sporadic and unpredictable, microbial insecticide producers may be faced with difficult production issues. Do they, for instance, produce the maximum required levels of pathogens at all times and throw away the excess? The answer to this will in part depend upon the shelf life of the product and the production costs since there will be a need to balance the production and storage costs. The longer the shelf life, the easier it will be to stockpile the product for sudden increases in demand without wasting the product during periods of low demand. This helps keep production costs at a minimum. On the other hand, if periods of demand can be identified and anticipated, it may be possible to lower production during periods of low demand and then build up production capacity in preparation for pest outbreaks, thus reducing wastage and ensuring adequate supplies for products with a short shelf-life.

Availability of product also depends upon the speed of delivery. This is particularly important for those with a limited shelf-life. Potential users must be accessible to suppliers, for instance by frequent air freight delivery services. While this is less likely to be a problem for European markets than for those in less developed countries, it may affect product costs. Fast, low cost delivery systems may be more feasible for products developed by large agrochemical companies which already have a well developed distribution network. However, it will also depend on the market, supplying a single, large customer in locust control will be easier than supplying a large number of small, scattered clients.

Many of the factors which determine the feasibility of microbial insecticides revolve around the product formulation and the methods of application. Ideally, microbial insecticides should not require special equipment and the technical expertise required to use the product effectively should be kept to a minimum. Formulations of products should ideally either be compatible with popular application methods or be inexpensive and easy to apply by some other method. Producers can expect less interest in products which require new equipment, costly adaptations or specialist technical advice. Users are most likely to be attracted to methods which are familiar to them, and in this respect, microbial pesticides which can be used in the same manner as chemical pesticides may have more appeal to farmers than products or management systems which require significant alterations to their farming practices. IPM systems and microbial insecticides which are not compatible with existing technology may face greater farmer reluctance. The producers of such products will need to be more effective in proving and communicating their benefits. In order to justify investments in new technology or training, they must also be able to convince growers of long term availability of the products. In the past some microbial insecticides have been commercialised and then discarded in favour of new chemicals.

The perception that microbial insecticides are more difficult to use than chemicals often arises from biological features of the pest or microbial agent. Some microbes are only capable of attacking specific stages of the pest. For example most entomopathogenic protozoa, for example, must be ingested by a particular stage of the host, most commonly the larval or nymphal stages (Brooks, 1988) and therefore, treatment must be timed with the pest's life cycle. Microbial insecticides also tend to have particular environmental requirements. Many bacteria, fungi and protozoa cannot survive or effectively control pests in dry, sunny conditions (Brooks, 1988, McCoy *et al.*, 1988). It may be that through careful product development and formulation, some of the limitations inherent in micro-organism may be overcome. For example, the effectiveness of *Metarhizium flavoviride* in dry conditions can by improved by using oil formulations (Bateman *et al.*, 1993). The addition of UV-protectants into the formulated product may help protect the microbes from the deleterious effects of sunlight (Bull, 1978, Ignoffo & Batzer, 1971, Ignoffo, *et al.*, 1976). Such limitations on the use of microbial insecticides do not generally exist for chemical insecticides and thus a greater level of knowledge is required for the use of microbial products. Understanding the limitations and particular requirements of microbial insecticides is essential to their use. The greater level of knowledge required to co-ordinate the application of microbes with environmental and biological factors requires higher levels of training and expertise than generally required by chemicals. Thus the impression that microbial agents are more difficult to use than chemicals may be an accurate one. This does not, however, mean that microbial products can not be used easily and effectively: 'more difficult' does not necessarily mean 'too difficult'. The effective use of microbial insecticides becomes more feasible with complete and accurate instructions, or short training sessions. It is important that the producers of microbial insecticides make farmers aware of their strengths and weaknesses so that they may be used in an optimal manner. Payne (1988) suggests that unrealistic claims for biopesticide control have led to past misuse, resulting in ineffective and unreliable pest control.

Misuse of microbial insecticides may in part be responsible for perceptions of unreliability. Nevertheless it is admittedly unusual for microbes to achieve mortality rates of greater than 95%, as chemicals often do. This may make them more suitable for pests with higher economic injury levels or within an IPM program which is able to compensate for lower mortality rates. There are, as always, exceptions. Some microbial pathogens are perfectly capable of achieving high mortality rates suitable for pests which can cause severe damage even in low densities. For example, field tests of *Metarhizium flavoviride* against locusts in Africa have shown greater than 90% mortality in many of the trials (LUBILOSA, 1996, Kooyman & Godonou, in press, Lomer *et al.*, in press). Swanson (1995) suggests that mycoinsecticides should aim for 80% average mortality. Other microbial products may be marketable despite low mortality rates. This is witnessed by the large market value of *Bt* despite its expected efficacy of 64% (i.e. it kills 80% of insects 80% of the time) (Swanson, 1995).

Another feature of microbes which may contribute to the perception of unreliability is the generally slow speed of kill. This is a very important consideration for the development of microbial products, particularly as chemical alternatives may kill very quickly. The delay between application and death of the insect pest is often due to the biology of the control agent, its ability to invade the host's tissues, reproduce, consume the host, produce toxins, etc. During this period the pest may continue to cause damage to the crop. This is less of a problem with toxin-producing organisms, such as *Bt*, as large levels of the toxin may be present in the formulated product applied to the crop, thereby increasing the speed of kill. Other microbial insecticides require a period of growth or development (often following ingestion of the microbe by the insect) before death of the pest occurs. *Metarhizium flavoviride*, for example, requires approximately 7 days to cause host mortality (LUBILOSA, 1996). This delay between application and pest mortality may be unacceptable to the farmer, particularly if the pest is capable of damaging the crop during this period. While some microbial insecticides, such as *Bt*s, are capable of reducing the pest's feeding and reproductive abilities prior to mortality, others are not. Some authors suggest that low, non-lethal levels of pesticides applied with the microbial agents might increase the susceptibility of the pest to microbial infection and reduce pre-mortality damage (McCoy *et al.*, 1988). For microbes which need to be ingested by the insect, formulating the microbes into baits, or adding a feeding stimulant, may speed the process (Bell & Romine, 1980, Ignoffo *et al.*, 1976). It is also possible that negative perceptions of delayed mortality can be overcome through education and information. Jackson *et al.* (1992) cites a very favourable response from farmers in New Zealand using bacterial insecticide (Invade$^{TM}$) despite the delay in mortality of more than one month.

If a pest problem can be accurately forecast, microbial insecticides can be applied in anticipation of pest outbreaks and the damage to the crop resulting from the delayed activity of the microbe may be counteracted. However, this may require complicated or coordinated monitoring systems reliant on technical expertise and manpower. There is the additional complication that if a preventative treatment works, the farmer may develop the mistaken impression that the pest problem did not exist and therefore there was no need for control.

Finally, the perception that microbial insecticides are 'essentially untried' must be addressed. This perception is probably true to some degree. Although *Bt* was first commercialised over 50 years ago as a French microbial insecticide (Sporeine), the use of most other microbial insecticides is in its infancy. There have only been a handful of microbial pesticides licensed for use in the Western world. Resistance to change and the lack of interest of large 'trusted' agrochemical companies may result in reluctance to try microbial products. Wide-scale use of microbial insecticides has only occurred in a few countries, particularly Brazil, China and the former USSR. A review of currently used microbial insecticides is given in Lacey & Goettel (1995). Interestingly, Lisansky & Coombs (1994) project an annual growth rate for the biopesticide industry of around 10% for at least the next three years. With pressures on governments and food producers to reduce their pesticide use, producers of new microbial insecticides may be able to take advantage of Bt's success in positively promoting the use of microbial agents.

## PERSUADING FARMERS TO USE MICROBIAL INSECTICIDES

There is no doubt that microbial insecticides form a growing industry. The market growth of biopesticides was greater than 25% per annum from 1982 to 1992, and in 1995 the biopesticide market equalled \$380 M. A breakdown of this market by Georgis (1996) shows a microbial insecticide market value of \$132 M. The majority of this market share was taken up by *Bt* (nearly 70% giving a market value for *Bt* of \$92 M). In looking to the future, numerous authors have attempted to identify potential markets for microbial products. These often focus on niche markets -- crops with unique pests or environmental requirements which make common chemical insecticides inappropriate. Niche markets are generally neglected by large agrochemical companies because the small size of the market limits the potential profitability. Low value niche markets are particularly unprofitable. While it is often suggested that such niche's offer an ideal opportunity for microbial insecticides to fill a vacancy in the market, it is not certain that these markets can profitably support microbial insecticides any more than they can chemical insecticides.

Some pest problems are simply too difficult to control effectively with chemicals. Soil pests and pest of protected environments can be very difficult to treat. Such pests may be protected from the effects of insecticidal sprays, particularly the more environmentally-friendly chemicals. Entomopathogenic nematodes, on the other hand, are perfectly suited to attacking these pests. Moreover, the fact that nematodes are exempt from registration requirements in many countries reduces their development costs and thus, presumably, results in less expensive products. In addition, there are other markets which agrochemical companies are no longer able to fill due to the development of pest resistance to common insecticides. These are often high value markets which previously invested heavily in chemical pesticides. The vacuum created by lack of availability of effective chemicals creates a potentially important market for microbial products. Another market which the agrochemical industry has been largely unable to address is that of pest control in environmentally-sensitive areas. The high selectivity of microbial insecticides and their low environmental toxicity makes them ideal for this market. Pest control programs in environmentally-sensitive areas often receive government support or subsidies. This raises the economic value of this market, even when low-value crops are involved.

An important benefit and selling point of microbial insecticides is their 'green credentials'. While the selective nature of most microbial products limits their potential market value, it makes them far more environmentally friendly than chemicals. In recognition of this fact, *Metarhizium flavoviride* has received FAO approval and recommendation for use in environmentally-sensitive areas. In addition to selectivity and low environmental toxicity, microbial insecticides typically have extremely low human toxicity. The health benefits for farm workers and the lack of pesticide residues left on the crops, increase their appeal. Moreover, because of their selective nature, they do not have the side effect of causing secondary pest outbreaks, and may even help to control resurgent pest problems.

They can also be used effectively in resistance management. While resistance has been reported against *Bt* other microbial insecticides may be less at risk of creating resistance in pest populations due to their more complex interactions with the pest. There is inherent genetic variability in living organisms which greatly reduces the possibility of resistance in comparison with chemicals. The use of microbial insecticides are particularly unlikely to get effective single gene resistance developing as it does with traditional insecticides. Even if resistance does begin to develop, there is a good chance that co-evolution will develop in the pathogen to overcome this. Another paper in this symposium will address the subject of resistance in more detail.

Where microbial insecticides are in direct competition with chemicals, they may face a number of obstacles to their successful integration into farming practices. Microbial insecticides might be at a disadvantage when competing with new insecticides being produced by companies which already have strong marketing and distribution channels. On the other hand, increasing registration costs are making new chemical insecticides more difficult and expensive to produce. The motivation for the development of new chemical insecticides is often the same as that of new microbial insecticides: a demand for pest management products which can control pests effectively, overcome resistance problems, control secondary pest incidences, do not harm non target organisms (particularly beneficial insects such as pollinators), are safe to humans and the environment and provide a crop which meets consumer demands (such as unblemished fruit and vegetables or no pesticide residues). If indeed these are the criteria which new insecticide products are trying to fulfil, microbial insecticides may be at an advantage. It is difficult to produce selective chemical insecticides with low environmental and human toxicity while these features are often inherent properties of microbes. Thus if these benefits can be proven and communicated effectively, microbial insecticides may be able to compete with new chemical products. One foreseeable difficulty is that farmers may be more likely to trust new technologies coming from large agrochemical companies with which they are familiar than from small or unfamiliar producers.

Marketing is all about communication. In order to persuade growers to buy microbial insecticides, producers must be able to convince them that they are **better than chemicals** in at least one of the following; risk to human health, the environment in general (and non-target invertebrates and mammals in particular), that they are easy to use with existing technology, affordable and effective. It is important in this respect that all of the farmers' concerns regarding pesticides, particularly microbial pesticides, are identified and addressed. The biggest 'selling point' may be their green credentials, in which case a concentration on eco-toxicity studies well beyond those generally undertaken by chemical pesticide producers might be worthwhile. This could be one way of convincing governments, growers and the public at large of the overwhelming benefits of using microbial insecticides. Whilst consumer pressure may be relatively high for reduced input or environmentally more friendly approaches to crop production this may not translate into new policy since the feedback mechanism on environmental controls to policy-makers is poor (Mumford, 1992)

Marketing is a complex process. The methods by which a producer can communicate the benefits of their product to potential customers are many and varied. One method, which should not be overlooked by small companies producing microbial insecticides, even for low value markets, is the packaging. The packaging is the producers last chance to communicate the benefits of the product and the opportunity to do so should be taken advantage of. Biological pest control products very often have simple packaging which provides minimal information. Perhaps a more conscious approach to packaging with complete instructions on use and statements of benefits would help to ensure that biological products are used effectively and appropriately. Moreover, professional-looking packaging is more likely to instil the consumer with confidence in the product.

The importance of government bodies in regard to marketing opportunities and the development of incentives should not be overlooked. Governments themselves provide a potential market -- many pest control programs for low value crops or environmentally-sensitive areas are run or funded by government organisations. Likewise, international organisations, aid bodies and donors, create a large market which may respond well to the green credentials of microbial insecticides. Government organisations and departments also control national and international subsidies for crop protection. Persuading these bodies that their money would better be spent supporting and encouraging environmentally-friendly microbial insecticides might drastically increase the potential market for microbial products and make them more appealing to growers. Much of the recent national and international legislation regarding the environment, such as the UK 1995 Environmental Act, Agenda 21 of the Earth Summit and the 1996 Convention on Biological Diversity, has stated a commitment to sustainable agriculture and environmental protection. It is now up to the scientific community and producers of microbial products to convince governments that reducing the use of chemicals in favour of biological methods of pest control provides an ideal opportunity to fulfil these responsibilities. Perhaps if national governments took a more holistic view of the total cost of pesticide use, including in this assessment values relating to environmental damage, health care costs and so on, potential economic benefits from non-chemical methods of pest control might be more apparent. While this sort of economic evaluation might be difficult, it is certainly possible. Higley and Wintersteen (1992), for example, outline a detailed method for evaluating environmental costs (water contamination, risk to non-target organisms, etc.) of pesticide use. There is no reason why human health costs, such as hospitalisation and medical treatment, days off work and long-term health effects could not be evaluated as well. Recognition of these costs could be extremely useful in evaluating the benefits of microbial insecticides.

Furthermore, governments are responsible for the regulation of both chemical and microbial insecticides. Regulation of pesticide use may encourage the use of non-chemical pesticides. There are regulations governing acceptable levels of pesticide residues in soils, water and foods. The increasingly difficult registration requirements for new chemical insecticides and re-registration requirements for older products are reducing the availability of chemical insecticides. Thus the demand for alternative pest control products is increasing. However, microbial insecticide development can also be hindered through regulation. Few would argue with the need for regulation to ensure safe and effective products. Nevertheless, it is important that registration requirements are appropriate for assessing the safety of microbial products whose risks may be very different from those associated with chemicals. From an industry-wide perspective, international harmonisation of registration requirements may be essential for the viability of the microbial insecticide industry. As pointed out by Lisansky (1994), even small differences in registration procedures between countries can severely increase the cost of developing microbial insecticides without necessarily improving their safety. Such consideration may be far more important for microbial insecticides than for chemicals due to the limited potential market of any single product (an effect of the selective nature of microbial organisms). It is important that the requirements and cost of registration, while being sufficient to ensure environmental and human safety, product efficacy and quality, be low enough that products remain economical to develop and affordable to the consumer.

## WILL THE MICROBIAL INSECTICIDE INDUSTRY BE A SUCCESS STORY?

While the future for microbial insecticides is still uncertain, it does look promising. Many of the negative perceptions of microbial products might be overcome through improved formulation and technological improvements. Simply providing more accurate and thorough information and education could result in greater understanding of inherent limitations and more effective use of microbial products. Several potentially profitable markets have been identified here as well as the importance of government organisations and regulatory bodies. Certainly as environmental concern and government commitment to conservation and sustainability increases, opportunities for the use of microbial insecticides will continue to grow. With legislative pressures to lower the environmental toxicity of agricultural practices and consumer demands for lower pesticide residues in food products, farmers may become more willing to try microbial products and more tolerant of their limitations.

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