Biocontrol ***News and Information*** *2000 Vol. 21 No. 2* 51N – 56N

Review Article

Prospects for microbial pest control in West Africa

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Abstract

The prospects for development of microbial control in West Africa are bright, with many stakeholders in plant protection both within and beyond the region becoming increasingly interested. To date however, on the West African market, there are only two microbial products available, and many opportunities remain to be fully explored. Apart from commercially oriented pathways, alternative methods of pathogen propagation and implementation are being studied, to serve the needs of those agricultural sectors which do not provide sufficient profit margins, such as the mainly traditional subsistence systems. Several groups are developing common regional registration frameworks for pesticides, and the need for adapted regulations and guidelines for microbial products is being addressed. This is a strong opportunity for creating a framework which does not only promote commercial products, but also alternative implementation pathways.

Introduction

Microbial control has been a component of integrated pest management strategies in developing countries for many years, enjoying particular success in Asia and South America, although successful approaches for microbial control have evolved worldwide (Fuxa, 1987). In Africa too, there is a long history of projects which have sought microbial solutions to pest problems. All too often, and despite technically successful products, these have failed with the result that in Africa there are few examples of sustained microbial pest control.

In the developed countries, despite considerable popularity and optimistic predictions for the commercialization of biological control agents, the anticipated demand for these products has not materialized. The market for microbial pesticides is growing but still only represents less than 1% of the total crop protection market and most of this is accounted for by products based on *Bacillus thuringiensis* (Berliner) (*Bt*) (Lisansky, 1997). Various reasons are given for the lack of product development and market penetration of biopesticides including: expectations that the multinational agrochemical companies would take a lead in product development; over-investment from 'venture capital' initiatives (Waage, 2000); and pursuance of an inappropriate model for biopesticide development based on small research teams lacking the multidisciplinary expertise required (Dent, 1997, 1999).

In Europe and North America particularly, development of microbial control agents has typically followed the chemical pesticide model, taking a commercial route to implementation of a marketable product. Yet, this approach promotes the pesticide paradigm, a restrictive mindset that views microbial pesticides as analogues to abiotic synthetic chemical pesticides, which discriminates against those microbial products that do not fit the chemical pesticide mould, and which in the developed world is hindering the advancement of microbials (Waage, 1997).

The same is becoming a reality in many developing countries, although it is interesting to see that the pathogens on which the two successful microbial products in West Africa are based, *B. thuringiensis* and a strain of *Metarhizium anisopliae* var *acridum* Driver & Milner (Deuteromycotina, Hyphomycetes), fill most of these criteria and follow this approach.

Yet traditional West African agriculture is characterized by small farms, mixed crops and heterogeneous crop germplasm (Youm *et al.*, 1990). Many farmers in this sector are poor and lack the means to buy commercial products. For others, access to pesticides in remote regions is difficult. Here, niches for microbial insecticides, although small, offer opportunities for a diversity of implementation pathways. In other sectors too, the commercial pathway is not the only route available for the wide use of microbial control.

Historically, the use of microbial control agents in sub-Saharan West Africa has been limited to experimental trials and, with the two exceptions mentioned above, none have led to sustained control options or commercial products. Some of the reasons for this failure are the same as in industrialized countries, as cited above. Others are the lack of appropriate infrastructures and training and ineffective decision-making processes. Our paper explores the opportunities for and constraints to the future development of implementation pathways for microbial control in West Africa.

West Africa's Agricultural Sectors

The majority of pesticides used in sub-Saharan Africa are insecticides and their use is concentrated on high value cash crops intended for export. The leading consumers are therefore those countries with well developed cash crop sectors, but few agrochemical companies expect to see the African market become strategically important in the foreseeable future (Winrock International, 1994). This is reflected in the relatively few chemical products registered for use in the region, and those which are registered are often in short supply.

In West Africa, we distinguish three principal agricultural sectors of interest to the insecticide market. The larger sector, responsible for the great majority of insecticide purchases in the region, is driven by cash crops like cotton, cocoa and coffee (Adesina, 1994). Here, purchases are made by large parastatal companies (as in the cotton sector), by national plant protection agencies, and by the powerful farmers' cooperatives. However, consumption of insecticides in this sector is driven by international commodity prices which are subject to fluctuations.

The second sector is the peri-urban sector, which is becoming increasingly important with the growth of urban populations. Supplying fruit, vegetables and basic commodities to the expanding urban populations, this high input sector is consuming increasing amounts of insecticides close to, and within, centres of human population. The risk to consumers from inappropriate use of insecticides is especially high in this sector.

A large part of West African agriculture lies outside these two commercial sectors. The third sector comprises the traditional agricultural and staple food crops. In West Africa, these staple foods are largely produced for family consumption, and in some countries crop protection in these crops, especially that directed against migratory pests, is the responsibility of government. Cash income from these crops tends to be too low to permit farmers to invest in 'off-the-shelf' crop protection measures. Where farmers can afford crop protection in staples, shortages can lead to inappropriate use of insecticides targeted to commercial crops. It is common, for example, to see products registered for use in cotton being used on food crops, causing serious health hazards. Price support mechanisms introduced by parastatals for insecticide purchases in cash crops do further encourage the abuse of products which are not suitable for staple crops.

The traditional staple food sector is fragmented, with parts influenced by donor agencies subsidizing insecticides for staples, although with the arrival of structural adjustment programmes, subsidies are being gradually removed. Several countries in sub-Saharan Africa receive pesticides in the form of agricultural development aid packages. This has a very important bearing on introduction of new products onto the market. The Japanese government, for example, provides pesticides as aid-in-kind grants under the KR2 programme to many sub-Saharan countries. Grasshopper and locust control is an important component of this sector, especially in Sahelian countries. Recently, in countries such as Benin and Côte d'Ivoire, pesticide subsidies have been removed and products are now bought on the open market.

Implementation of Microbial Pest Control in West Africa

These three areas of agricultural activity present opportunities and challenges for microbial insecticides to be implemented via a diversity of pathways. In the high value, export crop sector, there are opportunities for robust and efficient commercialized microbial products which target the major insect pests such as the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lep., Noctuidae), on cotton, and mirids on cocoa. Some of these products are already available from biopesticide companies in countries outside the region and could be introduced under licence for testing on the local markets. While some small and medium-sized companies have expressed interest in this market, others are hesitant to invest in the registration procedure where the market is perceived to be small, and particularly where separate registration is needed in each of the many countries of the region.

The use of entomopathogenic viruses in Africa was reviewed by Kunjeku *et al*. (1998). There has been, and still is, great interest in use of baculoviruses for control of *H. armigera* on its cash crop hosts such as cotton and tomatoes. Indeed, the nucleopolyhedrovirus (NPV) of *H. armigera* is probably the most widely tested baculovirus in Africa. Results have been highly variable but generally poorer on cotton than on other crops. The Canadian biopesticide company BioTEPP is collaborating on development of *H. armigera* NPV in Burkina Faso with the cotton industry (Sofitex) and the national agricultural research institute (INERA). The French company Natural Plant Protection (NPP) tested *Mamestra brassicae* (L.) (Lep., Noctuidae) NPV in Togo on a medium scale against *H. armigera* and although the results were excellent, the project was abandoned for logistical and technical reasons (M. Guillon, NPP, France, pers. comm.). And in Côte d'Ivoire, *H. armigera* NPV was successfully tested in cotton although at a rather high dose of more than 5×10^{12} occlusion bodies per hectare (Angelini & Vandamme, 1972). In Africa, *Bt* formulations have been tested against several lepidopteran cotton pests and were quite efficient against *Earias* spp. (Lep., Noctuidae), but not against cotton bollworm (Jacquemard, 1987). Applications of commercial products based on *Hirsutella thompsonii* Fisher (Deuteromycotina: Hyphomycetes) and *Verticillium lecanii* (Zimm.) Viégas (Deuteromycotina: Hyphomycetes) were not efficient against cotton aphids (Silvie & Papierok, 1991).

Sustained interest from international groups for organic cotton production within the region provides opportunities for insect pathogens as control agents for major pests such as *H. armigera* and aphids. The organic movement within the region as a whole is rather small but dedicated and represents an important outlet for microbial products, particularly in the peri-urban and cash crop sectors.

In the peri-urban farming sector pest problems are diverse and damage tolerance is low. Inputs, income and turnover are high, cropping cycles tend to be short, and the need is for fast acting, efficient products. Yet the range of pesticides in use at any one time is limited leading to high rates of resistance selection. Here, as in the cash crop sector, openings exist for commercial style products. Indeed, the first, and only commercially available microbial insecticides in the region are the *Bt*-based products Dipel 2X and BioBit from Abbott which are sold and widely used in southern Ghana, particularly on peri-urban farms, where *Bt* has been promoted under the UNDP (UN Development Programme) funded vegetable IPM programme.

The same UNDP-funded vegetable IPM programme, using a Farmer Field School (FFS) approach implemented through the FAO (the Food and Agriculture Organization of the United

Nations) and the Ghana Ministry of Food and Agriculture (MoFA), is promoting other alternatives to synthetic chemical insecticides, such as the botanical insecticides based on neem (*Azadirachta indica* Juss; Meliaceae) leaf and seed extract. The International Institute of Tropical Agriculture (IITA) together with the UK's Natural Resources Institute (NRI) is investigating options for distributing lepidopteran baculovirus inoculum via MoFA FFS trainers to peri-urban farms for farmer application and recovery. Recovered progeny virus from field infected insects would form the source of inoculum for applications in subsequent seasons.

The third sector, which includes traditional West African agriculture, presents opportunities for a diversity of microbial organisms, implementation routes and strategies. Success of commercial products depends on donor and national government crop protection policies, and the existence of subsidies and price support mechanisms, as well as the size of the market. But the diversity of target crops and pests, and low farmer incomes, market inaccessibility and lack of products, indicate a need for non-commercial approaches such as classical microbial control and systemic microbial pathogens and for augmentative approaches. At IITA's Plant Health Management Division in Cotonou, Benin, novel and traditional pathways are being explored for microbial control agents.

Green Muscle™, an industrially produced microbial insecticide based on the entomopathogenic fungus *M. anisopliae* var. *acridum* (strain IMI 330189) for grasshopper and locust control (Lomer *et al.*, 1997) is expected to appear soon on the West African market. It is a product of consistently high quality, originally developed by the LUBILOSA (LUtte BIologique contre les LOcustes et les SAuteriaux) project, and now produced by two specialized biological control companies, NPP in France and Biological Control Products of South Africa. LUBILOSA, a large multidisciplinary collaborative project between IITA, CABI Bioscience UK, Centre pour Agronomie, Hydroligie, Meteorologie of the Comité Inter-État de Lutte contre la Secheresse au Sahel (AGRHYMET-CILSS) and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), has followed the commercial implementation route and developed the first microbial control product targeted exclusively at Africa.

Using a similar approach, an international consortium comprising IITA, CABI BioScience UK and the International Centre for Insect Physiology and Ecology in Kenya (ICIPE) is developing a microbial insecticide based on the fungus *M. anisopliae* for termite control. Socio-economic studies have repeatedly shown that the willingness to pay for such a product is high, even in the subsistence farming communities, and that a commercial approach is valid under certain circumstances (Oke *et al.*, 1999).

The most notorious insect pests of maize in Africa are a number of lepidopteran stem- and cob-borers such as *Sesamia calamistis* Hampson and *Busseola fusca* (Fuller) (Lep., Noctuidae), and *Eldana saccharina* (Walker) and *Mussidia nigrivenella* Ragonot (Lep., Pyralidae). Yield losses due to multiple-species attack vary greatly with season, ecozone and country (Schulthess *et al*., 1997). Recent studies have revealed a complex of entomopathogens attacking these species (Cherry *et al*., 1999a) which present challenges to traditional implementation routes. A cypovirus (CPV) of *S. calamistis* has been found causing up to 25% natural mortality in southern Benin. These entomopathogenic RNA viruses, whose replication is specific to the epithelial midgut cells (Belloncik, 1996), have rather low *in vivo* yields compared to the baculoviruses, making their mass production expensive. But, although CPVs typically have low pathogenicity (Tanada & Kaya, 1993) with chronic rather that acute effects, their ability to transmit vertically from one generation to the next may allow them to be used as quasi-classical or augmentative biological control agents applied just once per season to suppress population growth.

A number of isolates of the deuteromycete fungus *Beauveria bassiana* (Bals.) Vuill. demonstrate a capacity to develop endophytically within maize plants, and lead to a season-long reduction in tunneling by cereal stem borers (Cherry *et al*., 1999a). The challenge now is to find a suitable mechanism for achieving consistently high endophytic establishment rates in the maize plant.

The banana weevil, *Cosmopolites sordidus* (Germar) (Col., Curculionidae) and plant parasitic nematodes are major constraints to banana production (Gold *et al.,* 1994; Speijer *et al.,* 1994). Microbial control may provide an effective means of contributing to the control of both banana weevils and nematodes. IITA is implementing the use of naturally occurring strains of the endophytic fungi *Fusarium oxysporum* Schlechtendal and *Fusarium solani* (Mart.) Sacc. (Deuteromycotina, Hyphomycetes), which cause mortality in nematodes in banana tissues (IITA, 1997). These fungi can be inoculated into tissue culture plants. Strains of non-endophytic *B. bassiana* are effective in killing banana weevils in the laboratory (Nankinga, 1995; Godonou, 1999). Data on population suppression under field conditions are limited, although preliminary field trials suggest that these pathogens may persist in the field (Godonou, 1999) and be transmitted between weevils (Nankinga, 1999). Additionally, dipping suckers in suspensions of *B. bassiana* resulted in reduced damage suggesting that the fungus either acted as a repellent or had a systemic effect on weevil eggs and larvae (Godonou, 1999).

One of the greatest challenges to the inundative use of microbial control agents is to find an economically competitive means of mass production. Green Muscle™ is industrially produced because economic analyses showed that a cottage style production unit offers no economies if production is scaled up to the quantities required for locust and grasshopper control in West Africa (Swanson, 1997; Jenkins *et al*., 1998; Cherry *et al.*, 1999b). This is so for *M. anisopliae* strain IMI 330189 because it competes poorly with contaminants and this dictates careful control of production parameters. But for robust strains or species, such as some strains of *B. bassiana,* which are less sensitive to contaminants during mass production, cottage style production can be a cheap and feasible approach which could be implemented by parastatal companies and used for treatment of germplasm, like banana suckers or maize seed. Examples from Brazil and Russia are described by Ferron, (1981), and particularly for *B. bassiana* with an emphasis on China, by Feng *et al.* (1994).

For the baculoviruses, large scale propagation is still constrained by *in vivo* methodology, despite the advances in bioreactor technology, and as a consequence baculovirus production tends to be expensive. However, baculoviruses are rather robust and alternative approaches for cheap mass production are being explored. Viruses intended for local use, for example, are highly amenable to small scale production, even at a village or farmer level. This approach has been successful in India (Anon., 1997) and Thailand (K. Jones, NRI, UK, pers. comm.), although product quality control can be inadequate (Grzywacz, 1995). The approach employed in Brazil for field production of *Anticarsia gemmatalis* (Hübner) (Lep., Noctuidae) NPV (Moscardi, 1999) could be applied in West Africa, provided that adequate quality control measures can be put in place

Policies, Regulatory Frameworks and Registration

A range of recent international conventions is having an impact on policies relating to biological control (Wellings, 1996). Since the

United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro in June 1992, environmental conservation and the protection of biodiversity has become a priority of most donor agencies. The Convention on Biological Diversity (http://www.biodiv.org/) has the potential to have a substantial impact on the use of biological control agents (Waage, 1995). Some agencies are no longer supporting pesticide purchase at all because of strong environmentalist lobbies in their countries of origin. The development of Green Muscle™ is an example of donors' positive response to public concern over excessive use of synthetic chemical insecticides during the latest desert locust plague in the late 1980s (Lomer *et al*., 1997).

As in industrialized countries, a further motive for introduction of microbials to West Africa is the development of resistance to chemical insecticides. Resistance to pyrethroids has recently been documented in the cotton bollworm in Benin (E. Gnanhoui, Institute de Recherche Agricole du Benin, pers. comm.), although in other parts of the world it has been documented for nearly 20 years (Forrester *et al*., 1993). And in Ghana *Bt* is used to control lepidopteran pests of vegetables which have become resistant to pyrethroids (J. Akatse, MoFA, Ghana, pers. comm.).

Regulations and guidelines for the registration of microbial pesticides have been in place in most industrialized countries for less than 15 years (Betz *et al*., 1990). A survey by the Organisation for Economic Co-operation and Development (OECD, 1996) on data requirements for biopesticide registration found that registration of various types of biopesticides was well underway in OECD member countries, and that many countries had adopted similar requirements to structuring their data. The FAO guidelines on the registration of biological pest control agents (FAO, 1988) provided an essential basic framework in this direction, and were followed by the FAO Code of Conduct for the Import and Release of Exotic Biological Control Agents (FAO, 1996).

Essential to the process of commercializing a microbial insecticide is the issue of protecting a producer's rights. The key element of the World Trade Organization – Trade Related Aspects of Intellectual Property Rights (WTO-TRIPS) agreement for food and farming is the requirement for WTO members to make patents available for any product or process (Tansey, 1999), although members may exclude from patentability plants and animals other than micro-organisms. While the terms of the agreement are subject to legal interpretation, this does suggest that the WTO favours protection for inventors of microbial insecticides and is good news for development of commercial products.

Pro-pesticide policies, including subsidies and donations, have been very common in West Africa (Adesina, 1994). Many countries have now adopted IPM as part of their national crop protection strategy to diversify away from unilateral dependence on chemical products (Fleischer *et al*., 1998) promoting alternatives such as microbial insecticides. But while registration of pesticides has become more predictable in many major markets (Lisansky, 1997), available information suggests that in Africa, the pesticide regulatory framework is still poorly developed. Although many countries in West Africa do have their own framework, few have the resources to adequately implement or police the system. Regional organizations do exist, and in terms of pesticide regulation the most advanced is CILSS which comprises nine Sahelian member countries. CILSS has installed a common pesticide registration scheme which is expected to take over from national registration frameworks in 2000. A similar programme has been initiated across the coastal West African countries (http://www.isysphyt.ci).

In West Africa the national regulatory authorities have little or no experience in handling biopesticide registration dossiers, which are either dealt with following standard chemical registration guidelines, or on an *ad hoc* basis. However, awareness of biological control among West African authorities has increased recently, partly due to the successful classical biological control programmes conducted by IITA as well as other national and regional institutions, and there is a genuine widespread enthusiasm for, and recognition of a need for separate biopesticides regulations with regionally harmonized data requirements. This could be achieved in the first instance by proposing a minimum 'common core data set' (OECD, 1996). The CILSS pesticide committee has already taken steps in this direction for its member countries and a regulatory framework for microbial control products is currently being discussed.

Conclusions and Prospects

Increasing awareness of the benefits of IPM and biological control, as well as of the economic and environmental costs of chemical pesticides, are the driving forces behind changes in plant protection policies in Africa (Fleischer *et al*., 1998). The future for entomopathogens as insect pest management tools in developing countries is promising, and in West Africa there is a broad enthusiasm for their widespread introduction.

Many groups including multilateral and bilateral donors, beyond the boundaries of the region are playing a role in biopesticide and microbial pesticide promotion. The International Biopesticide Consortium for Development (http://www.biopesticide.org/), a joint venture between CAB Bioscience UK, the International Pesticide Application Research Centre, NRI, IITA and Biologische Bundes-Anstalt, Darmstadt, Germany (BBA) is an example of an initiative addressing the needs of biopesticides in developing countries and which has a focus on Africa. USAID (the US Agency for International Development) is promoting such developments through its Sustainable Tree Crops Program for West Africa, and through Virginia Polytechnic Institute, USA, which is collaborating with CILSS and with advice of FAO on biopesticide regulations. A survey of existing biopesticide regulations in Africa, parallel to the OECD survey of 1993-94, being led by IITA will provide useful information in order to harmonize these over the whole region.

The development of microbial control in West Africa continues to receive support from donor funds channeled through the International Agricultural Research Centres such as IITA, and related institutes, to projects and initiatives which have brought a novel approach to biopesticide development models. Small and medium-sized private enterprises beyond the region share the enthusiasm for microbial solutions to pest problems in West Africa and are bringing an extra dimension and multidisciplinarity to biopesticide development projects. Such projects have the advantage of being less constrained by commercial sensitivities, economic pressures and deadlines, allowing greater freedom to explore partnerships for development of sustainable microbial control solutions, to the long-term benefit of consumers, farmers and the environment.

The region is rich with both international and local NGOs, many of whom have strongly pro-environmental agendas. Their independent decision making, links to Western lobby groups and proximity to farming communities give them a vital role as partners in the promotion of environmentally sound technologies and especially of those implementation strategies which are not based on commercial products.

Yet in many microbial control projects and initiatives, pest problems have been approached with no clear implementation route in mind. It is also true that most have sought solutions which would replace a chemical product with a microbial product, but have failed to bridge the gaps between research, technology transfer and implementation. For the future success of the development of microbial control in West Africa it is essential to identify at an early stage potential areas of impact (i.e. markets), consumer behaviour (willingness to pay) and related governmental and donor policies before making decisions on implementation pathways.

Those microbial products, however, which have wide host range, those which target pests of major importance in principal crops, and those which are rather robust and are applied inundatively, can work better when developed commercially. In the long term Africa's agriculture will, following its demographic development, become more intensive, and commercial pathways will become increasingly important (Avery, 1997). It is noteworthy that the two microbial control methods which have been developed successfully in West Africa, *Bt* in Ghana and Green Muscle™ for grasshopper and locust control, have followed a commercial route. Neither is significantly cheaper than conventional chemical insecticides, and their success lies in their capacity, to one degree or another, to emulate the characteristics of chemical products.

For those microbial agents which have narrow host ranges, which are more sensitive and which do not fit the chemical pesticide mould, implementation pathways are needed that move away from a fully commercial product approach. While this is valid for all three agricultural sectors it is especially needed in the traditional farming systems where commercial inputs are less economically feasible.

In India, where the national government has actively adopted a pro-biopesticide stance, there has been an expansion in the number of small and micro-enterprises supplying microbial and other biological pesticides to minor markets. In West Africa where there are many small market niches, there is scope, given an appropriate infrastructural support, for establishment of similar local enterprises to supply specific microbial products.

In West Africa there are several groups considering, or in the process of developing separate biopesticide regulatory frameworks, and this presents unique opportunities to develop inclusive rather than exclusive frameworks, which would be open to, and encourage, diverse production systems and implementation routes, while taking into account the importance of establishing quality control assurance procedures. The delay in this process gives an opportunity for harmonization of policies across a whole region, which can take into account the most recent developments in microbial control.

IITA's strategy for promotion of microbial control focuses in several complimentary directions. A short-term goal is the promotion of microbial control products in West Africa through existing pesticide registration frameworks. These are products which may already be available on-the-shelf elsewhere, as well as those developed especially for the needs of African farmers. Candidate products are those based on insect viruses against lepidopteran pests, and Green Muscle™ with its expected spin-off products, for instance for termite control. We continue to encourage, and actively support the development of microbial insecticide registration guidelines and regulatory frameworks. The outcome of the registration of existing products provides case studies to assist national and regional authorities in this endeavour. With the goal of bringing a wider range of microbial control agents within the reach of West African farmers, and to address the needs of small niches and those sectors where profit margins are low, we are investigating development of robust, inexpensive and sustainable pathogen production and distribution systems. Alternative pathogen implementation pathways such as use of endophytes with systemic action, and augmentative approaches address the same goal.

Ultimately, successful adoption of microbial control in West Africa depends crucially on a collaborative approach in which all stakeholders take a participatory role. We must move away from the narrow mindset which sees microbial control agents as poor substitutes for chemical pesticides, and away from 'silver bullet' solutions. Microbial control is rarely going to provide a complete solution; to take advantage of the long term benefits of microbial control, integrated systems must be pursued.

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