Biological control of armyworm in Africa: pitfalls and solutions

Caterpillars of the African armyworm moth are a major pest in sub-Saharan Africa. Outbreaks are typically dealt with by widespread pesticide application which may have unintended effects on human or environmental health. So what are the prospects for biological controls? Focusing on their experience in developing a microbial biopesticide for African armyworms in Tanzania, ***Kenneth Wilson****,* ***David Grzywacz*** *and* ***Wilfred Mushobozi*** *discuss the problems associated with developing sustainable biocontrol solutions for Africa.*

Caterpillars of the African armyworm moth (*Spodoptera exempta*) are a major migratory pest of crops in large parts of sub-Saharan Africa. Outbreaks occur most years but in some years, like 2008, they may continue for six to eight months, extend over many countries and attack hundreds of thousands of hectares of basic food crops. This can disastrously undermine the food supply of countries already struggling to feed their populations against a background of recurrent drought and civil unrest.

Outbreaks of African armyworms have been reported in virtually every country in sub-Saharan Africa, though their biggest impact is generally felt in the eastern half of the continent, in countries such as Yemen, Ethiopia, Kenya, Tanzania, Zimbabwe and South Africa[1].

The caterpillar stage feeds mainly on pasture grasses and staple cereal crops, such as maize, wheat, millet, sorghum and rice. Caterpillar densities, and hence crop damage, is extremely variable in both time and space, but typically range from tens or hundreds per square metre, up to a thousand per square metre; in 2008, it was estimated that 30,000 hectares (ha) of maize was destroyed in Kenya and 802,000 ha of crops and pasture were affected by armyworms in Ethiopia.

African armyworm caterpillars
Photo: Wilfred Mushobozi

The first outbreaks of the season generally appear in Kenya and Tanzania, and are considered serious in nine out of every ten years. The crop-eating caterpillars develop into a moth stage, which is capable of migrating hundreds of kilometres over just a few nights[2]. So, if weather patterns are favourable, these moths may initiate a second generation of armyworm outbreaks elsewhere in the region, and this pattern may be repeated over a period of many months. As a result, there is often a wave of armyworm outbreaks that spreads out from these primary outbreaks in East Africa to other parts of the continent, causing devastation in its wake.

Control strategies

Currently, the main control strategy for African armyworms relies on spraying expensive imported chemical insecticides. However, a socio-economic survey conducted in Kenya and Tanzania found that in most years only 30% of the armyworm outbreaks are treated[3]. This is partly due to cost, as many poor farmers cannot afford the $10 per ha that these chemicals cost[4]. In addition, spraying toxic chemicals is usually not possible or desirable in sensitive environments, such as national parks. A cheaper, more environmentally-friendly, alternative is therefore a priority and, over the last 10 years, we have been exploring the potential to develop a biological control agent against African armyworms. Our experiences in this regard flag up a number of issues that may explain why biopesticide use is not as widespread in Africa as it might be.

Identifying biopesticides

A major stumbling block to the development of a biopesticides is simply the fact that identifying and evaluating candidate natural enemies (baculoviruses, fungi and bacteria) can be an exacting and protracted process. In the case of the African armyworm, ecological research over many years had already identified the nucleopolyhedrovirus, SpexNPV, as a potential biocontrol agent, belonging to a well-understood group of pathogens (the baculoviruses) that are of known efficacy and assured safety[5]. SpexNPV is highly host-specific – it only attacks a single host species, *Spodoptera exempta*. Whilst this has the advantage that it poses no threat to humans, wildlife, or even other invertebrates, the down-side is that it is not effective against other insect pests. This may be seen as a problem in African farming, where the use of a single broad-spectrum pesticide for a range of pests is the norm.

Aerial spraying of SpexNPV baculovirus over armyworm-infested pasture in Tanzania. Within three to four days of spraying, more than 80% of armyworm caterpillars were dead.
Photo: Wilfred Mushobozi

When pest outbreaks do occur, the local community demands a rapid solution. However, many microbial biopesticides take much longer to take effect than traditional chemical solutions. SpexNPV kills within three to four days, compared with just a few minutes for chemical insecticides. Relative to most synthetic insecticides, biopesticides also tend to have reduced persistence, a disadvantage where preventative spraying is common. This is not such an issue with armyworms, as control even with chemicals is through directly spraying larvae. If pest scouting were practiced more effectively in Africa, the issues of speed of kill and persistence would be less of a constraint. However, despite integrated pest management being national policy in many African countries, insect pest scouting is rare outside the high-value commercial sector.

Commercialisation

African markets for biological control agents are small, discouraging commercial industry from developing local African production and making supply a real issue. If registration processes for biological control agents were more transparent, and reliable, then importation from other countries would be an option. However, despite some harmonization of regulations, it is still relatively difficult to register biocontrol agents in many parts of Africa. To prepare for SpexNPV use in Tanzania, efforts are currently in hand to reform the registration process and align it with Kenya, where a

Box 1. Biocontrol agent registration in Africa

Biocontrol agents such as predators, parasites, insect viruses and entomopathogenic fungi, such as the 'Green Muscle' fungus used for locust control, differ profoundly from chemical insecticides in their characteristics and properties. A consequence of this is that the standard pesticide registration protocols designed for chemical pesticides are unsuitable for registering commercial biological control agents. In Europe and the USA, special procedures for registering biological agents have been developed and adopted, but most African countries have lacked the specialized expertise to do this, impeding the registration and use of these valuable new aids to farming. To help overcome this, there have been a number of initiatives by aid donors such as USAID and DFID to assist African countries to develop the local expertise to register these pesticides enabling countries such as Ghana and Kenya to adopt appropriate regulations that have stimulated the commercial sale and use of biological control in recent years.

MN Wabule, PN Ngaruiya FK Kimmins and P Silverside (eds). 2004. Registration for biocontrol agents in Kenya. Proceedings of the PCPB/KARI/DFID CPP Workshop Nakuru Kenya 14-16 May 2003. Natural Resources International.

working system is well established (Box 1).

The commercial cost of biological insecticides is often much more expensive than their chemical equivalents, which provides a major stumbling block to use by farmers. In Africa, an effective solution to this problem could be the sort of low-tech local production of biocontrol agents such as the *Helicoverpa armigera* NPV, *S. litura* NPV and the *Anticarsia gemmatalis* NPV that has recently been established in India, China, Thailand and Brazil[6]. Current plans are to mass-produce SpexNPV via field-based production[7] to ensure a cost of around US$ 3 per ha. This is significantly lower than the chemical alternatives, which sell at around US$ 10 per ha[8].

Many biopesticides also have limited shelf-life at ambient temperatures and require cool conditions for storage, not commonly available in rural Africa. To tackle both the problem of high cost and short shelf life for SpexNPV, we are adapting a system of field production combined with a low-cost powder formulation system with good shelf-life that has been developed in Brazil by EMBRAPA (Box 2)[9].

Even if biocontrol agents can be produced cheaply, promoting their adoption in resource-poor countries in Africa could be an issue. A commercial R&D route can work, as witnessed by products such as the *Cryptogram* baculovirus developed for control of false codling moth in South Africa, but this is probably viable only for high-value horticulture in South Africa and Kenya, where there are large-scale commercial export farms, highly organised and with the resources to fund the development of a new biocontrol agent. Public-private partnerships (PPPs) probably provide a more sustainable mechanism for local production in poorer countries of sub-Saharan Africa. A prime example of this is the 'Green Muscle' fungal insecticide for use against locusts and grasshoppers – which was developed for Africa using public sector aid funding, but subsequently transferred production to the private sector in South Africa. This sort of approach is especially appropriate for migratory and trans-boundary pests, like locusts and armyworms, where many countries are potential targets and beneficiaries.

Long-term prospects for SpexNPV development

SpexNPV has been shown to be highly effective in field trials against African armyworm[10], and its development has the full backing of the Tanzanian Government. However, further progress is constrained by the absence of funding mechanisms to bridge the gap between fundamental research and its application. The UK research councils will generally not support this sort of applied research, though they are currently funding our studies into the molecular ecology of SpexNPV in natural virus epidemics[11]. Development agencies are often hesitant to support the R&D needed to turn research into practice. SpexNPV development has continued for more than a decade, despite intermittent gaps in funding. The next step is to secure major funding to mass-produce the virus and 'test the market', both at farmer level and more widely. Until then, armyworm outbreaks will continue to be controlled using conventional synthetic chemical insecticides.

Conclusions

In conclusion, there are still many factors constraining the use of biological control agents in Africa. Some of these issues can be addressed by high-quality scientific research, such as a better understanding of the interaction between the pest and its natural enemies (potential biocontrol agents), but others relate to the context of African agriculture and require national or regional policy changes. However, with appropriate R&D, sufficient funding and political goodwill, microbial biopesticides could play a significant role in containing pest threats to African food production and alleviate poverty.

Box 2. Low-cost production of NPV

An innovative and highly successful approach to developing affordable biological control suitable for small farmers in developing countries is used for controlling the Velvet bean caterpillar (*Anticarsia gemmatalis*) on soybean by the Brazilian research institute EMBRAPA. Here, a natural pathogen of the caterpillar, the *A. gemmatalis* NPV (AgNPV), is used as a biological insecticide spray in place of chemical pesticides. In order to produce AgNPV, the EMBRAPA team developed a system of field production in which specific localised heavy outbreaks were sprayed with a low innoculative dose of the AgNPV. The farmers in these outbreak areas are paid to leave these production infestations to develop and the AgNPV to multiply. Subsequently, infected insects are harvested from these outbreaks by hand picking for later processing into AgNPV biopesticide. It needs as little as 50 infected insects produce enough AgNPV to treat a hectare of soybean. By combining this cheap production system with a stable low-cost clay formulation, AgNPV can be produced at a much lower price than chemical pesticides. This system is now responsible for producing AgNPV for one million hectares and is run by local commercial producers co-ordinated by EMBRAPA.

References
1. Rose DJW, Dewhurst CF and Page WW (2000) The African Armyworm Handbook: The Status, Biology, Ecology, Epidemiology and Management of Spodoptera exempta (Lepidoptera: Noctuidae). 2nd edition. Chatham, UK: Natural Resources Institute.
2. Ibid.
3. Njuki J and Mushobozi W. (2003) Improving armyworm forecasting and control in Tanzania: a socio-economic survey. CABI ARC Nairobi, 39, Unpublished.
4. Iles M, Dewhurst C. (eds) (2002) Responses by farmers to African Armyworm outbreaks. Field survey data from Kenya and Tanzania. A synopsis of previously unpublished data. Chatham, UK: Natural Resources Institute.
5. OECD (2002) Consensus document on information used in assessment of environmental applications involving baculoviruses. Series on harmonisation of regulatory oversight in biotechnology No. 20. ENV/JM/MONO(2002)1 OECD.
6. Moscardi, F. (1999) Assessment of the application of baculoviruses for the control of Lepidoptera. Annual Review of Entomology 44: 257-289.
7. Mushobozi WL, Grzywacz D, Musebe R, Kimani M and Wilson K. (2005) New approaches to improve the livelihoods of poor farmers and pastoralists in Tanzania through monitoring and control of African armyworm, Spodoptera exempta. Aspects of Applied Biology 75: 37-45.
8. Ibid.
9. Op cit 6.
10. Grzywacz D, Mushobozi, W.L., Parnell M, Jolliffe F. and Wilson K. (2008) Evaluation of Spodoptera exempta nucleopolyhedrovirus (SpexNPV) for the field control of African armyworm (Spodoptera exempta) in Tanzania. Crop Protection 27: 17-24.
11. Armyweb (2009) Armyweb: A web resource for the Armyworm Biological Control Consortium. http://www.lancs.ac.uk/staff/wilsonk4/ARMYWEB/ARMYWEB.html

Kenneth Wilson, Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, UK ken.wilson@lancaster.ac.uk
David Grzywacz, Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Kent ME4 4TB, U.K. d.grzywacz@greenwich.ac.uk
Wilfred Mushobozi, Eco Agri Consultancy Services Ltd, Nairobi Road, Kwa Idd, P.O. Box 15040, Arusha, Tanzania. w.mushobozi@ecoagriconsult.com