THE CONTRIBUTION OF BIOLOGICAL CONTROL FOR RESOURCE-POOR FARMERS IN AFRICA

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ABSTRACT

Biological control, along with the use of pest resistant planting material, offers resource-poor farmers plant protection technologies requiring no further inputs after planting. Classical biological control rapidly reverses the adverse effects of recent spectacular pest introductions, while similar biological control interventions, but based on more intensive ecological studies, offer incremental gains against long-standing problems with indigenous pests. Augmentative biocontrol techniques, including the use of biopesticides, can be justified in certain socio-economic situations, particularly where environmental or political concerns are important.

INTRODUCTION: THE CHANGING FACE OF AFRICAN AGRICULTURE

African agriculture is in a state of transition. Although there are exceptions, we are seeing a change from nomadic and pastoralist lifestyles to those involving sedentary agriculture, peri-urban cultures and horticulture. Three important crops in Africa are comparatively recent introductions - maize, cassava and rice. Coarse grains are grown mainly for their drought-hardiness; in African agriculture in general, with the possible exception of yam cultivation, we do not find the rich cultural heritage associated with food production that we see, for example, for rice in Asia and beans and maize in central America.

There are important political factors at play also - there is a tendency for governments to keep food prices low. For many men in Africa, travelling to a town to look for work is a more viable economic option than staying in the village to grow food. Finally, climatic and edaphic factors (unreliable rains and poor soils) make agriculture a high risk enterprise. With a high risk of failure and rather meagre rewards, farmers do everything possible to spread and minimize their risks. Overall, these factors make it likely that a significant proportion of men will leave the village in search of work, while women stay in the village to tend the crops and the family. Within this socio-economic context, IITA and other development organisations have a role to alleviate poverty and ensure sustainability. As well as promoting high-yielding locally adapted varieties, and examining issues of sustainability, IITA devotes resources to sustainable plant protection in the Plant Health Management Division; the emphasis being on biological control in an IPM context. However, the views presented in this paper represent the personal outlook of the authors and are not intended as a complete review.

Biological control offers producers a number of possible technologies. Here we group the different biological control options in two headings; classical and augmentative biological control. Classical biological control involves the control of an introduced pest by introducing a natural enemy, normally from the area of origin of the pest. A similar approach involves ecological study of the natural enemy complex on indigenous pests, and seeks to fill in any gaps or supplement the efficacy of the complex by introductions from other geographical areas. Augmentative biological control makes use of natural enemies which may not have the capacity to spread or persist naturally. The latter approach necessitates continuous input; the natural enemies have to be produced, transported and released and significant on-going costs are incurred which have to met by the farmers or aid agencies acting on their behalf. By contrast, classical approaches need no continued input, and, depending on the efficacy of the natural enemy, little farmer training or extension input is required (Neuenschwander, 1993). Classical biological control is therefore normally the cheapest and most sustainable option.

CLASSICAL BIOLOGICAL CONTROL

Africa has suffered from the invasion of a number of damaging pests over the last 30 years - cassava mealybug, cassava green mite, larger grain borer, mango mealybug, spiralling whitefly, leucaena psyllid. In cases such as these, the benefit of utilising classical biological control seldom has to be justified: the pests are causing severe damage, chemical biological control is either uneconomic or undesirable for health and environmental reasons, or both, and biological control has considerable precedent for success against similar pests.

Cassava Mealybug

Cassava mealybug (*Phenacoccus manihoti* Hom.: Pseudococcidae) was accidentally introduced to Africa in the Congo in 1973; by 1986 it had spread to 25 countries, from Senegal to Malawi, covering 70% of the cassava belt. In extreme cases, cassava yields were reduced to nil and plants killed. Furthermore the loss of planting material resulted in the abandonment of cassava production in some places (Herren and Neuenschwander, 1991). The search for the mealy-bug's natural enemies in South America first involved some careful taxonomic work to distinguish *P. manihoti* from the closely related species *P. herreni*. Field populations of *P. manihoti* were found in 1981; collections of natural enemies continued until 1986. The work involved CIAT (Centro Internacional de Agricultura Tropical, GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit), CIBC (Commonwealth Institute of Biological Control, now IIBC the International Institute of Biological Control) and IITA. Natural enemies were shipped first to CIBC in UK then imported to Nigeria with the collaboration of the Nigerian Plant Quarantine service and the Inter-African Phytosanitary Council (IAPSC). Amongst the natural enemies evaluated, *Apoanagyrus (Epidinocarsis) lopezi* (Hym.: Encyrtidae) established and spread rapidly. Mass rearing facilities were set up by IITA at Cotonou, Benin, and starter cultures or bulk shipments provided to affected countries. *A. lopezi* proved to be incredibly versatile and mobile, and is now established in 25 countries in Africa, effectively bringing cassava mealybug under control. Efficacy evaluation was recently reviewed by Neuenschwander (1996). An early economic assessment showed a benefit: cost ration of 149:1 (Norgaard, 1988). Although this is an area which would benefit from more work, it is clear that biological control yields enormous returns on initial investment. But as the benefits do not necessarily accrue only to the investor, private individuals may not be motivated to invest (Klonsky, 1996).

On very poor soils, control by *A. lopezi* is not satisfactory. In these cases, mulching, and the release of exotic coccinellids of the genera *Diomus* and *Hyperaspis* may offer some improvement.

The story of the invasion and subsequent biological control of the cassava mealybug has attracted much beneficial publicity for biological control and has recently culminated in the award of the World Food Prize to Dr. Herren. The principal elements in the success of this work were the original taxonomic work and collaborative parasitoid search, a well funded and organised, and scientifically sound programme of releases, but principally the combination of intensive and extensive search behaviour of the parasitoid (Herren and Neuenschwander, 1991).

Mango Mealybug

Mango mealybug *Rastrococcus invadens* (Hom.: Pseudococcidae) was first reported in West Africa in 1981-82 in Togo, Ghana and Benin. It caused considerable damage to mango trees, often disrupting totally the local markets. The natural enemy complex was studied at its centre of origin in India, and two natural enemies *Gyranusoidea tebygi* (Hym.: Encyrtidae) and *Anagyrus mangicola* (Hym.: Encyrtidae) selected for study in quarantine by International Institute of Biological Control (IIBC) in UK. Following discussions between the national plant protection services and the Food and Agriculture Organisation of the United Nations (FAO), IAPSC, GTZ, IIBC and IITA, *G. tebygi* was released in Togo in 1987 and successfully controlled the mealybug (Agricola, 1989). Releases in Benin took place in 1988 and controlled the mealybug apart from a few 'hot-spots' in towns. In order to enhance control in these situations, *A. mangicola* was released and has been recovered. Detailed life history studies of the two parasitoid species were carried out and showed that their niches only partially overlap (Neuenschwander, 1996). An account of the releases in various African countries is given by Neuenschwander *et al.* (1994). The rapid implementation of this biological control project owed a lot to the training and infrastructure installed for cassava mealybug control.

Spiralling Whitefly

Spiralling whitefly, *Aleurodicus dispersus* (Hom.: Aleurodidae), a pest of Caribbean and Central American origin, was first reported from Nigeria in 1992, subsequently in Benin, Togo and Ghana (Akinlosotu *et al.,* 1993). Outbreaks in the inital phase are spectacular - more than 100 different species of plants belonging to 44 different families were recorded as hosts; among them cassava, tomatoes and chilies. The whitefly's natural enemies *Encarsia ?haitiensis* and *E. guadeloupae* (Hym.: Aphelinidae) were already known from work in Hawaii (Kumashiro *et al.,* 1983), but before they could be imported and released, they were found to have arrived serendipitously in Africa and were already spreading. The impact of these natural enemies was demonstrated by the correlation between declining damage and the duration of presence of the parasitoids (d'Almeida *et al.,* 1996).

IIBC and FAO are meanwhile continuing with the evaluation of the possibility of introducing the coccinellid *Nephaspis amnicola* from South America.

Cassava Green Mite

The cassava green mite, *Mononychellus tanajoa* (Acari: Tetranychidae) was first reported from Uganda in 1971; since then it has spread to Guinea in West Africa and Zambia in southern Africa (Yaninek and Herren, 1988). The mite itself is cryptic, although the damage symptoms are recognisable; yield losses have been estimated at anything between 13 and 80%, but Yaninek and Herren *ibid.* considered a more conservative figure of 30% as realistic. Although classical biological control of mites with predatory phytoseiid mites is a recognised method in green-houses, it has not previously been demonstrated on a large scale in the field. Field releases of the phytoseiid *Typhlodromalus aripo* (Acari, Phytoseiidae), indicate that this mite may provide control on a broad scale. The mite has spread over 150,000 km^2 of West Africa from initial release sites in Benin, Ghana and Nigeria, and now covers significant areas of Ghana, Togo, Benin, Nigeria, and Cameroon, and is also established in Kenya and Uganda (Yaninek *et al.,* 1993). Preliminary impact studies show highly significant pest reductions. This work was the culmination of many years collecting, rearing and releasing of South American phytoseiids in collaboration with CIAT, EMPRAPA (Empresa Brasileira de Pesquisa Agropecuaria) and the University of Amsterdam.

As it is not yet known whether *T. aripo* will be able to establish in all ecozones affected by cassava green mite, research is also on-going to compare the relative efficacy of strains of the entomophagous fungus *Neozygites floridana* (Entomophthorales) strains from Brazil and Benin. If the exotic Brazilian isolate proves efficacious, it could also be released as a classical biological control agent.

<u>Larger Grain Borer</u>

The larger grain borer, *Prostephanus truncatus* (Coleoptera: Bostrichidae) was first reported in Africa in Tanzania in 1981 and later in West Africa, in Togo and Benin, in 1984. Damage by the beetle is phenomenal; cobs can be reduced to dust in eight months. Losses were estimate by Hodges *et al.,* (1983) at 30% within a six-month period in Tanzania; however such a figure conceals the increased work and insecticide use that farmers are obliged to undertake. Work on insecticides, grain store design and pheromones is reviewed by Hodges (1994). Although some work on pathogens has been carried out and is currently being pursued by an informal network of collaborators involving IITA, IIBC, GTZ, Biologische Bundesanstalt, Institut für biologischen Pflanzenschutz (BBA) and Escuela Agrícola Panamericana (EAP), El Zamorano, Honduras, most hope for biological control rests on the predatory beetle *Teretriosoma nigrescens* (Coleoptera: Histeridae). Work to 1994 is reviewed by Markham *et al.* (1994); more recent unpublished data (C. Borgemeister, IITA) seem to indicate that under some climatic conditions, the histerid has a significant impact on its prey. A further important consideration is that natural vegetation provides an important reservoir for *P. truncatus; T. nigrescens* may have a significant impact here also (G. Hill, pers. comm.). In common with many biological control systems based on a predator as the key mortality factor, the predator is not expected to provide satisfactory control under all circumstances, and no single solution is expected to the *P. truncatus* problem. Rather a package of technologies, a holistic approach involving grain store design, is likely to yield dividends (Markham, 1994).

BIOLOGICAL CONTROL OF INDIGENOUS PESTS

The definition of classical biological control is often understood to refer to the introduction of exotic agents to control introduced pests. However, there are many occasions when a similar approach may be used to control indigenous pests; the essential point is that a detailed ecosystem analysis reveals gaps in the natural enemy complex of a pest, which can be filled either by a new association between pest and parasitoid (e.g. Carl, 1982) or by transferring biocontrol agents from one area to another (Schulthess *et al.* 1996).

Maize ecosystem - Stem borers

A complex of species of stem-borers attack maize in Africa, particularly in the forest zone. Maize is particularly prone to attack by these insects; as no tillering takes place, the plant is unable to compensate for damage. Thus a single insect attack can destroy a plant. Losses are highly variable across regions and seasons.

Analysis of the natural enemy complex of maize stem-borers in West Africa revealed a paucity of larval parasitoids on crops even in indigenous insects such as *Sesamia calamistis*, *S. botanephaga*, *Busseola fusca* (Lep.: Noctuidae), *Eldana saccharina*, and *Mussidia nigrivenella* (Lep.: Pyralidae) which have evolved with native grasses or cereals such as sorghum and millet. Other pests such as the stem borer *Chilo partellus* (Lep.: Pyralidae) have been accidentally introduced from Asia and similarly lack a full complement of natural enemies. However, identifying the most promising species of natural enemies is a complex task. Much progress has been made since the pioneering work of Mohyuddin *et al.*, (1981). Schulthess *et al.,* (1996) describe the tri-trophic level studies at sites selected to have apparently favourable climatic conditions for pests, but with low actual pest pressure. Findings show the key role of natural grasses as reservoirs for the pests and their natural enemies, while work by Hailemichael *et al.* (1996) has shown that the natural enemies, mainly *Cotesia* species, select their hosts on the basis of the plant's suitability for oviposition rather than on the species of host insect. The introduction of *Cotesia* strains, particularly from East Africa, appears to offer a promising approach in this situation.

Cowpea and grain legume systems

Many insect pests attack cowpea in Africa (Singh *et al.*, 1990) but recent demographic studies have helped to identify key pests affecting production, which include the bean flower thrips, *Megalurothrips sjostedti* (Thys.: Thripidae) (Tamo *et al.* 1993). The lack of hymenopterous parasitoids of the larval stage of this thrip on cowpea led to the hypothesis that *M. sjostedti* is actually a moderately recent introduction to Africa. The thrips are mainly parasitized by *Ceranisus menes* (Hym.: Eulophidae) (Tamò *et al.*, 1996) when present on an Indian shrub, *Tephrosia candida;* on cowpea the parasitism rate is <0.1%. A search for natural enemies in the centre of diversity of the genus *Megalurothrips* in South-East Asia led to tests on the larval parasitoids of the genus *Ceranisus* capable of parasitizing thrips larvae on leguminous plants. This work is on-going, and probably a broader gene-pool of potential biocontrol agents will need to be studied.

A very similar situation was observed for the natural enemies of *Hindola* spp. (Hom.: Machaerotidae), vectors of Sumatra disease of clove in Java and Sumatra, Indonesia. A much higher incidence of parasitism occurred on wild host plants of the genus *Melastoma* than on clove; and in one area of Sumatra, nymphal parasitoids (*Carabunia* sp. (Hym.: Encyrtidae) occurred on clove also (Lomer *et al,* 1993).

AUGMENTATIVE BIOLOGICAL CONTROL AND OTHER INTERVENTIONS

In many cases of the implementation of biological control, the farmers' involvement is rather minimal (Neuenschwander, 1994); the socio-economic constraints affecting resource-poor farmers favour this approach. Nevertheless, as agriculture develops and cash returns become more attractive, the possibility of greater farmer input, including pesticides increase. This may be particularly the case for cash crops such as cotton, and higher value crops such as rice and vegetables. In order to contain pesticide use and improve farmer's understanding of the role of pests and diseases, the Farmer Field School Integrated Pest Management (FFS-IPM) approach has proved successful in South-East Asia and central America. It is now being established with success in Africa. A pilot scheme on irrigated rice at the Dawhenya Irrigation Project in Ghana organised by FAO has shown the practicality of the approach in Africa. The approach has been included as official government policy and has been applied to cowpea also (Salifu, pers. comm.). Gains due to the FFS approach in rice are easily quantified in terms of reduced pesticide use. In other situations, farmer participatory approaches and on-farm experimentation have been used, but where gains are less clear-cut, the motivation of farmers is less. Several integrated rural development schemes, often run by NGOs, are successful in this respect, and show clearly that villagers basic concerns in terms of infrastructure and basic health care need to be met before they become greatly concerned with plant protection. Nevertheless, the FFS approach provides a secure base for subsequent ecologically sound pest management options.

Augmentative biological control by definition involves some continuing input, either by the farmers or by some agency acting on their behalf. Although in the future we many hope to see commercial, NGO or government agencies involved in, e.g., egg parasitoid production in Africa, the example we discuss here is that of locusts and grasshoppers, where the migratory nature and heavy damage of the pests justifies interventions. While this programme focuses on the use of a biological control agent indigenous to Africa, it has revealed some interesting perspectives on what constitutes an indigenous and a non-indigenous agent.

Locust and grasshopper biocontrol

The LUBILOSA (LUtte BIologique contre les LOcustes et SAuteriaux) project, in which IITA collaborates with IIBC, GTZ and the Comité Inter-états de Lutte contre la Sécheresse dans le Sahel (CILSS), aims to put in place IPM schemes for locusts and grasshoppers including a biological pesticide based on oil suspensions of spores of the fungus *Metarhizium flavoviride* (Lomer *et al,* 1996). The project started in 1990; numerous technical constraints had to be overcome, but recent field successes have included control of *Oedaleus senegalensis* (Orth.: Acrididae) on 50 ha plots in Niger (86% control in 22 days; J. Langewald, pers. comm.). *Zonocerus variegatus* (Orth.: Pyrgomorphidae) was readily controlled by the mycopesticide; trials in 1993 gave 90% control in 15 days (Douro-Kpindou, *et al.,* 1995); subsequent trials reduced the dose from 100g to 2g/ha. Quantitative results with Desert Locust (*Schistocerca gregaria* Orth.: Acrididae) hopper bands have been difficult to obtain owing to the slow kill time of the fungus. A method has been developed, and these trials are being repeated in Sudan and Mauritania (J. Langewald, pers. comm.). Although principally developed for its immediate impact, we are finding increasing evidence that *Metarhizium* spores will survive between seasons, and that under certain conditions, spores from a fungus-killed grasshopper will go on to infect healthy insects (Thomas *et al.,* 1996).

In this project, the emphasis has been on the use of indigenous pathogens for two reasons. Firstly, surveys and bioassays showed that local strains of *Metarhizium* were widespread and of higher or equal virulence than any known strains (Bateman *et al.*, 1996 IN PRESS). Secondly, many African national authorities insist on documentation on host range and specificity of imported biological control agents; as deuteromycete fungi are frequently able to infect honey bees and some parasitic wasps, albeit at high doses under stressful laboratory conditions, import permission may be refused. Madagascan and Nigerian authorities are particularly firm in this regard, and insist on the sole use of indigenous strains of pathogens. Conversely, most of the Sahelian countries accept an ecozonal definition of indigenous, and the use of a strain of *Metarhizium* from Niger has been accepted by Sudan, Mali, Benin, Burkina Faso, Senegal and Gambia. Given that these countries are within the migratory flight range of Desert Locust, this policy makes good sense.

CONCLUSION

Where a recently-introduced pest population explodes in a new habitat, as has been the case of several pests in Africa cited above, the biological control interventions are reasonably straightforward. Good taxonomy, good collaboration between the organisations involved, including the donors, good information flow between participants and sound science are the key elements. For pests believed to be indigenous, a detailed systems analysis approach is necessary to reveal the gaps in the natural enemy complex. In particular, the interaction between the natural enemy and the host plant must be understood; there are many cases of adequate parasitism occurring on the wild host plants but not on the crop plants.

Often in the case of introduced pests, particularly homopterans, control by hymenopterous parasitoids is satisfactory with one or two natural enemies. For other pests, particularly when the natural enemies are predators, a broader complex may be required.

Similarly for indigenous pests the answers are often not straightforward. Resistance breeding is an important control element, and even partial resistance may provide some degree of control when coupled with biological control. In some circumstances, augmentative biocontrol interventions including biopesticides, and habitat management options, all of which require farmers' inputs, may be necessary.

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