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Biological control as the primary option in sustainable pest management: the cassava pest project

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The cassava mealybug (CM), *Phenacoccus manihoti* MATILE-FERRERO was unknown to science when it was first discovered in 1973, along the Congo-Zaire river in Central Africa. In 1981, following intensive exploration and taxonomic studies, CM was found to have originated from a limited area of South America, from where it was accidentally introduced to Africa in the late 1960s or early 1970s. In 1971, the cassava green mite (CGM), *Mononychellus tanajoa* (BONDAR) was discovered in Uganda; it has its origin also in South America. Since then, the pests have spread over most of the cassava belt of Africa, threatening to destroy cassava, the staple food crop of some 200 million Africans.

Classical biological control through the use of exotic natural enemies, provides the basis for an economically viable and environmentally sound solution. Also, this approach is particulary, but not exclusively, appropriate for low-input, subsistence agricultural systems since it requires little or no intervention by individual farmers or agricultural extension services. The extreme urgency of the problem, with its attendant threat of widespread famine, called for an unprecedented level of organization and international cooperation. Exploration, ecological and biological studies of natural enemies, the development of appropriate mass-rearing and distribution technologies, and a major program of manpower training, were undertaken through the formation of an extensive network of scientific collaborators in Africa, Europe and the Americas. Finally, follow-up studies, underpinned by the development of a simulation model and a benefit/cost analysis, have demonstrated that classical biological control, properly planned and implemented, can provide a timely, cost effective and ecologically safe solution to a major pest problem.

INTRODUCTION

History of pest introductions

Cassava, which was introduced into Africa from South America by Portuguese traders during the latter part of the 16th century, is now a major staple food crop on this continent. Its success is attributed to its hardiness and high adaptability to a variety of traditional farming systems and to the sub-Saharan climatic conditions. Cassava can not only grow and survive under harsh conditions, but its edible roots can remain in the ground for up to 2 years and provide food when other crops fail. The cassava mealybug (CM) *Phenacoccus manihoti* MATILE-FERRERO (Homoptera: Pseudococcidae) and the cassava green mite (CGM), *Mononychellus tanajoa* (BONDAR) (Acari: Tetranychidae) are now jeopardizing this essential source of calories and protein (leaves) for more than 200 million people living in the African cassava belt.

The cassava green mite was discovered in Uganda in 1971 and the cassava mealybug in Congo/Zaire in 1973 (Fig. 1). Both pests have their origin in South America and have now spread across the entire African cassava belt. The CM and CGM are causing devastating yield losses on a continent where famines, induced by adverse weather conditions, are frequent (Herren, 1981). The CGM and its area of origin were known at the time of introduction; this was not the case for the CM, which was an unknown species, described only in 1977 (Matile-Ferrero, 1977).

Project development

The involvement of the International Institute of Tropical Agriculture (IITA) in controlling the CM and CGM started in 1977 with the hosting of a workshop in Zaire to discuss possible control strategies (Nwanze & Leuschner, 1977). Two areas were identified for research, host plant resistance and biological control by parasitoids and predators. The work was to begin in Zaire, whose government asked for an immediate solution to the threat posed by the two pests. At this point, the CAB International Institute of Biological Control started exploration work in South America to identify natural enemies of CM and CGM while IITA concentrated its effort on finding sources of host plant resistance. As no progress was registered some two years later, the Governments of Zaire and Congo appealed to IITA to step up research efforts. As biological control was not a feature of IITA, nor of any other CGIAR Center, at the time, no funds were available from the system. Thus, what is today known as the IITA Biological Control Programm (BCP) started as a special project, with funds from the International Fund for Agricultural Development (IFAD) (Herren, 1987). The special project soon out-grew the financial support capacity of IFAD and called for the support by a group of donors.

Contributions from BCP donors total US$ 24 million from 1979 to 1988, incl. This sum includes US$ 4 million for capital developments, 3 million for training, 10 million for research and 7 million for support to National Biological Control Programs. The aid agencies of Austria, Belgium, Canada, Denmark, Federal Republic of Germany, Italy, Netherlands, Norway, United States of America, Sweden and Switzerland, and the African Development Bank, the Food and Agriculture Organization, the International Fund for Agricultural Development, the International Development and Research Center and the United Nations Development Program are gratefully acknowledged and thanked for their generous and valuable support.

STRATEGIES USED IN PROJECT EXECUTION

The selection of biological control to combat the CM and CGM is based on several criteria. The first was the exotic nature of the pests, which made them prime candidates for the classical biological control approach. Second, but also important, is the African farming environment, which – with its mixed and relay cropping patterns and the requirement for low or zero input practices – is particularly suitable for the implementation of biological control. Under these circumstances, biological control offers a unique opportunity, satisfying the prerequisites mentioned above and requiring no input from extension services. Pest control introduced to Africa requires the ability of the local governments to sustain it with financial support and staff, in order to achieve sustainability as well as environmental and human safety. Biological control fits the requirements perfectly and no effort should be too big to establish it as the pillar of a sustainable pest control strategy.

BCP has from the beginning been a multi-disciplinary, multi-institutional, multi-national and multi-continental undertaking, commensurate with the size of the pest problems (HERREN, 1982; HERREN, 1987; GLASS, 1988). New methodologies and technologies for exploration, rearing and releases had to be developed. Fortunately, many donors and scientists involved recognized the value and merit of what was being proposed and made it possible to carry on.

The basic concept of the BCP is the integration of all research, training, and implementation pertaining to one problem under one project, units of which can be executed by different institutions according to their comparative advantage, thus economizing funds and valuable time. The problem of implementing biological control in Africa had to be given special consideration in view of the lack of knowledge and logistical support in this field. It was recognized early that the CM biological control project could be used as a training model for African scientists and policy makers. In addition to the pest control itself, the goal of creating or developing national biological control capacities was added to the program (WODAGENEH & HERREN, 1987).

BCP followed the standard procedures of classical biological control, i.e. exploration, quarantine, introduction and release. Special attention was, and is being, given to aspect such as detailed ecological knowledge of the pest and the natural enemies in the area of origin (LOEHR *et al.*, 1990), detailed understanding of the agro-ecosystem in the area of introduction (NEUENSCHWANDER *et al.*, 1987a, b), and detailed follow-up and impact assessment of the releases (HERREN *et al.*, 1987b; NORGAARD, 1988; NEUENSCHWANDER *et al.*, 1989a, 1990).

The holistic approach used for the biological control of the CM and CGM (HERREN 1987; GUTIERREZ *et al.* 1987, 1988a, b, c,) and later other pests, the development of efficient technologies for exploration, rearing (HAUG *et al.*, 1987; KLAY, 1987; NEUENSCHWANDER *et. al.*, 1989b;) release (BIRD, 1987; HERREN *et al.*, 1987a), and impact assessment, and the overall project management are however new in the context of classical biological control.

In research, the philosophy of BCP is to pursue ecologically sound pest management practices based on a quantitative understanding of the important elements comprising a natural and agricultural agro-ecosystem (YANINEK & HERREN, 1989) so that, in the long run, the control part in pest management would decrease in favour of management practices minimizing pest build-up.

ACHIEVEMENTS

Exploration

Exploration by BCP and its collaborators for natural enemies of CM and CGM has identified over 90 species from Central and South America. So far, 15 species have been brought to Africa and released (HERREN *et al.*, 1987b). Exploration and ecological studies on the CM and its natural enemies in their area of origin is now completed. Major efforts are underway to complement our ecological knowledge on the CGM and its natural enemies in the area of origin and pre-select promising species for releases in Africa (YANINEK & HERREN, 1988).

Linked with the exploration were two taxonomic studies, a revision of the genus *Phenacoccus* of South America at the CAB International Institute of Entomology (IIE) and morphological and physiological studies to resolve the problem of how many species the CGM comprised at the International Center for Insect Physiology and Ecology (ICIPE). Ecological mapping and identification of matching zones in the areas of release and exploration is being carried out with the Centro Internacional de Agricultura Tropical (CIAT) to increase exploration efficiency and provide data for the pre-selection of predaceous mites.

Basic research

Over the past eight years, much scientific knowledge has been accumulated on the cassava plant and on the taxonomy, biology, and ecology of the CM and CGM and their exotic and local natural enemies (BOUSSIENGUET & NEUENSCHWANDER, 1989; DE MORAES, 1987; HAMMOND & NEUENSCHWANDER, 1990; LOEHR *et al.,* 1988, 1989a, b; NEUENSCHWANDER & MADOJEMU, 1986; NEUENSCHWANDER *et al.,* 1987b, 1989b; SCHULTHESS *et al.,* 1987; SULLIVAN & NEUENSCHWANDER, 1988; NEUENSCHWANDER & HERREN, 1988; NEUENSCHWANDER & HAMMOND, 1988). Plant-pest interactions have been studied GUTIERREZ *et al.,* 1988a, b, c; SCHULTHESS *et al.,* 1987; YANINEK *et al.,* 1987; YANINEK *et al.,* 1989a, b) and sampling methods have been developed (SCHULTHESS *et al.,* 1989; YANINEK *et al.,* 1986; 1989a, 1990).

A computerized simulation model of the cassava cropping system is nearing completion (GUTIERREZ *et al.,* 1987; GUTIERREZ 1988a, b, c). The model includes the effects of temperature, solar radiation, nitrogen, and water on plant growth. Models of the CM and CGM have been developed and linked to the cassava plant model. Lastly, a model concerning the widely established parasitoid *Epidinocarsis lopezi* (DE SANTIS) (Hymenoptera: Encyrtidae) and indigenous coccinellids has been superimposed over the CM model, providing a powerful tool for analyzing tritrophic interactions.

Release and impact monitoring

Experimental and operational releases have been made on over 150 sites in 21 countries (LEMA & HERREN, 1985; HERREN *et al.,* 1987b; HERREN & NEUENSCHWANDER, 1991). Of the 14 species of parasitoids and predators so far released against CM, *E. lopezi,* and *Hyperaspis notata* and *Diomus* sp. (Coleoptera: Coccinellidae) have become established permanently against the CM. Pre- and post-release monitoring operations are carried out by national staff trained in specific follow-up techniques in collaboration with BCP scientists. One of the natural enemies, *E. lopezi,* has been established in 25 African countries over areas of about 2.7 million km^2 (Fig. 1). Detailed monitoring of releases in Benin, Côte d'Ivoire, Ghana, Malawi, Nigeria, and Zambia has shown that the CM populations are being brought under control, to below economic levels (NEUENSCHWANDER & HAMMOND, 1988; NEUENSCHWANDER *et al.,* 1989a; 1990).

Among the phytoseiid mite predators, nine different species or populations have been released, covering most ecological zones of Africa. Several exotic phytoseiids of Colombian origin were recovered for up to four months following release in the dry season, but invariably disappeared during the wet season. Promising results have, however, been recently obtained with two populations of *Neoseiulus idaeus* DENMARK & MUMA and *Typhlodromalus limonicus* (GARMAN & MCGREGORY) of Brazilian origin. Recoveries in the Republic of Benin were made throughout the wet season for up to 10 months, indicating that a strain appropriately adapted to the local conditions may have finally been found.

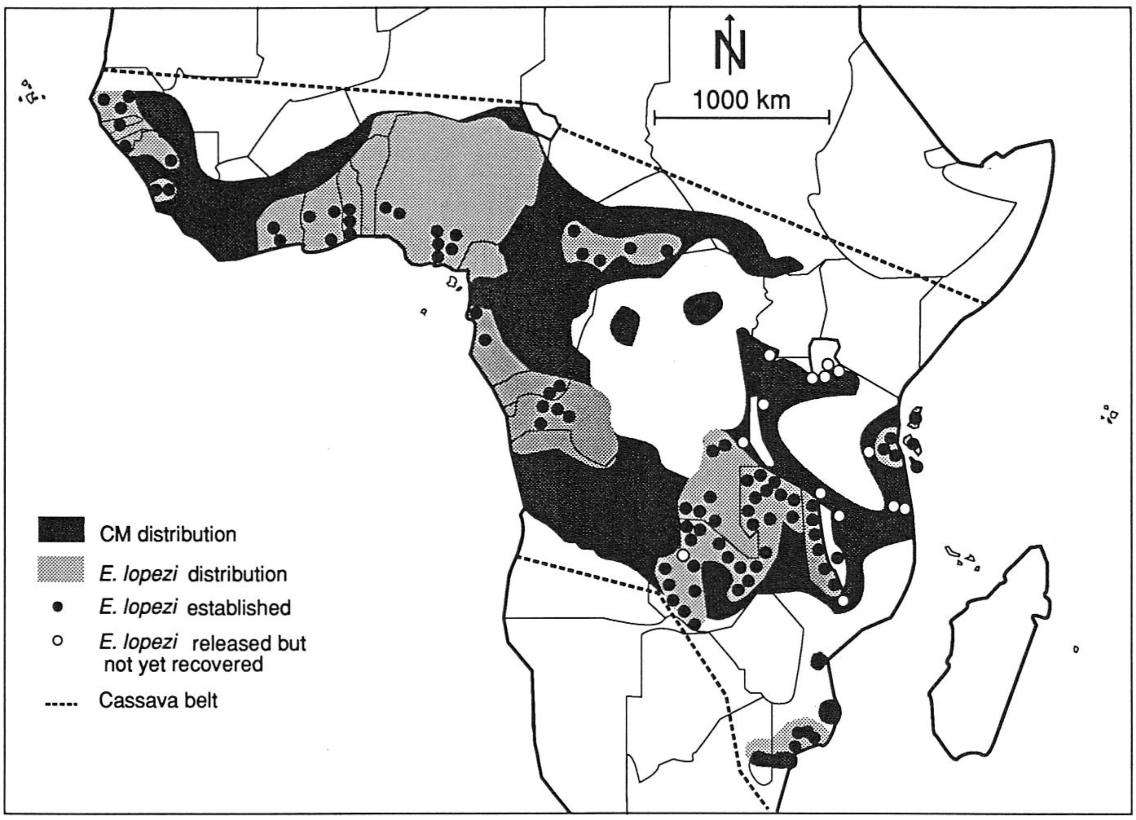

Fig. 1. Release sites of cassava mealybug natural enemies. Establishment and spread of *Epidinocarsis lopezi* and exotic coccinellids.

Technology development

Hydroponic culture techniques have been developed for cassava production, and efficient and reliable masss-rearing technologies for the CM and its natural enemies have been achieved (HAUG *et. al.,* 1987; NEUENSCHWANDER *et al.,* 1989b). Similarly, techniques have been developed for the CGM and the phytoseiid predators (KLAY, 1987; HAUG & MÉGEVAND, 1989). Presently, large numbers of CM and CGM natural enemies are being produced in the BCP central laboratory for both continent-wide releases to achieve rapid control of the CM and as starter cultures for their rearing in National Biological Control Programmes (NBCP).

The African cassava belt covers an area one and a half times the size of the USA. Such a large area presents a major obstacle to an efficient control operation utilizing conventional ground release methods for CM and CGM natural enemies. To cover this area efficiently and reach farmers beyond road access, BCP has developed aerial release and automatic packaging systems for adult natural enemies (HERREN *et. al.,* 1987a; BIRD, 1987) minimizing natural enemy mortality.

Training

As of May 1990, 430 trainees, most of whom are staff members of NBCPs, have received short term training at BCP. The curriculum covers all aspects of pest control with emphasis on biological control, including practicals on surveys, releases, and monitoring. Selected candidates have been sent to specialized courses (e.g., on taxonomy), giving these students a wider background in biological control practices.

Degree-related training is carried out at IITA and ICIPE in collaboration with universities in Africa, Europe, Canada and the USA, according to specialization, language, and other special needs. Twenty MSc and 18 PhD fellowships have been awarded so far. Scientists from this program will be the leader of the NBCPs and, hopefully, further develop their national programs (WODAGENEH & HERREN, 1987).

National biological control programs

The CM gave the opportunity of a model case for the application and reinforcement of biological control in Africa. BCP has therefore launched a program for the development of national capacities in biological control and has been assisting countries financially and technically. In response to their requests and after analysis of their specific needs, 15 countries have received assistance from BCP for the initiation of NBCPs. These are usually set up within the framework of the crop protection department and are the basis for survey, research, and follow-up activities. Through the BCP/FAO-technical cooperation program, four countries have received funds to start biological control activities with BCP backstopping. Another 10 countries have received technical assistance for surveys, yield loss assessment, and releases. In all these countries, pre-release surveys have been carried out and, where releases were made, post release monitoring is under way. These activities are implemented by the NBCPs, usually with aid by BCP. After this initial phase, the NBCPs are expected to be assisted financially by bilateral donors and backstopped by BCP.

Environmental impact evaluation

The CM project could also be evaluated from an environmental point of view. Biological control has saved Africa from the pesticide threadmill. To control the CM in BCP experimental plots, at least eight insecticide applications were required during the dry season. Extrapolating this figure over 10 million ha of cassava clearly indicates the magnitude of the ecological and health disaster which was avoided assuming the farmers had used chemicals for CM control.

Economic impact assessment

An economic impact study was made by Prof. R. Norgaard following a review of the BCP by a Winrock International team (NORGAARD, 1988). With conservative assumptions regarding yield loss reduction and a life time of benefits of 25 years, he calculated a benefit: cost ratio of 149:1. More recent data from BCP impact assessment studies have shown an increase of 2.5 tons per ha due to biological control (NEUENSCHWANDER *et al.*, 1989a), a benefit which continues without time limit and leads to even higher returns than those calculated by NORGAARD (1988).

Further economic benefits, which are not readily assessable, are training and its long term impact, and the environmental protection aspects. Thus it is hoped that the CM model case and the BCP will show the direction of the future in crop protection in Africa.

At the newly built Biological Control Center for Africa in Cotonou, Republic of Benin, the research, training, and implementation will cover pests, diseases and weeds. It will also become the center for inter-institutional collaboration in Africa linking NBCPs and common projects of the CGIAR centers, IIBC, and other interested institutions.

In addition to the CM and CGM projects, the BCP has started research on the cowpea and maize pests complexes, the mango mealybug and the locusts and grasshoppers in collaboration with IIBC. New project on the biological control of the weeds *Striga, Chromolaena,* and *Imperata* and of the banana weevil are being prepared.

The new BCP projects will, as the CM and CGM do, be based on detailed ecosystems studies. BCP will address the pest problems from a holistic point of view, and research natural as well as agricultural ecosystem and the interactions between them. The goal of the BCP is to develop ecologically sound and sustainable agricultural practices, which will minimize the use of control methods of any kind and, where needed, introduce biological control methods. The pest avoidance/control methods to be applied will be selected according to the result of these studies and may include, in addition to biological control, cultural practices and host plant resistance and make optimum use of available modern technologies. BCP will provide training in management of pest control projects, an area often responsible for failures in past undertakings. The continued linking of research, training, and development of national capacities, both at the level of national and international institutions, will provide the best possible environment for rapid progress in the pursuit of long-term and sustainable solutions to crop pest problems in Africa.

REFERENCES

Bird, T. J. 1987. Fighting African cassava pests from the air. *Aerogram 4: (5):* 6–7.

Boussienguet, J. & Neuenschwander, P. 1989. Le complexe de la cochenille du manioc en Afrique. – 3. Clé simplifiée et annotée pour la détermination des Hyménoptères parasites associés à ce ravageur. *Rev. Zool. Afr. 103:* 395–403.

De Moraes, G. J. 1987. Importance of taxonomy in biological control. *Insect Sci. Applic. 8:* 841–844.

Glass, E. 1988. Biological control of cassava pests in Africa. *Annual Report 1987/88, Consultative Group on International Agricultural Research.*

Gutierrez, A. P., Wermelinger, B., Schulthess, F., Baumgärtner, J. U., Yaninek, J. S., Herren, H. R., Neuenschwander, P., Löhr, B., Hammond, W. N. O. & Ellis, C. K. 1987. An overview of a systems model of cassva pests in Africa. *Insect Sci. Applic. 8:* 919–924.

Gutierrez, A. P., Neuenschwander, P., Schulthess, F., Herren, H. R., Baumgärtner, J. U., Wermelinger, B., Löhr, B. & Ellis, C. K. 1988a. Analysis of biological control of cassava pests in Africa. II. Cassava mealybug *Phenacoccus manihoti. J. Appl. Ecol. 25:* 921–940.

Gutierrez, A. P., Wermelinger, B., Schulthess, F., Baumgärtner, J. U. Herren, H. R., Ellis, C. K. & Yaninek, J. S. 1988b. Analysis of biological control of cassava pests in Africa. I. Simulation of carbon, nitrogen and water dynamics in cassava. *J. Appl. Ecol. 25:* 901–920.

Gutierrez, A. P., Wermelinger, B., Schulthess, F., Baumgärtner, J. U., Yaninek, J. S. & Ellis, C. K. 1988c. Analysis of biological control of cassava pests in Africa: III. cassava green mite *Mononychellus tanajoa. J. Appl. Ecol. 25:* 941–950.

Hammond, W. N. O. & Neuenschwander, P. 1990. Sustained biological control of the cassava mealybug *Phenacoccus manihoti* (Hom.: Pseudococcidae) by *Epidinocarsis lopezi* (Hym: Encyrtidae) in Nigeria. *Entomophaga 35* (in press).

Haug, T., Herren, H. R., Nadel, D. J. & Akinwumi, J. B. 1987. Technologies for the mass-rearing of cassava mealybugs, cassava green mites and their natural enemies. *Insect Sci. Applic. 8:* 879–881.

HAUG, T. & MÉGEVAND, B. 1989. Development of technologies in support of contemporary biological control. pp. 141–146 in: *Biological control: a sustainable solution to crop pest problems in Africa.* eds. J. S. YANINEK & H. R. HERREN. IITA, Ibadan, Nigeria.

HERREN, H. R. 1981. IITA's role and action in controlling the cassava mealybug in Africa. *IITA Research Briefs 2:* 1–4.

HERREN, H. R. 1982. Cassava mealybug: An example of international collaboration. *Biocontrol News and Info., C.A.B., 3:* 1.

HERREN, H. R. 1987. Africa-wide biological control project of cassava mealybug and cassava green mites: a review of objectives and achievements. *Insect Sci. Applic. 8:* 837–840.

HERREN, H. R. & NEUENSCHWANDER, P. 1991. Biological control of cassava pests in Africa. *Ann. Rev. Entomol. 36:* 257–283.

HERREN, H. R., BIRD, T. J. & NADEL, D. J. 1987a. Technology for automated aerial release of natural enemies of the cassava mealybug and cassava green mite. *Insect Sci. Applic. 8:* 883–885.

HERREN, H. R., NEUENSCHWANDER, P., HENNESSEY, R. D. & HAMMOND, W. N. O. 1987b. Introduction and dispersal of *Epidinocarsis lopezi* (Hymenoptera: Encyrtidae), an exotic parasitoid of the cassava mealybug, *Phenacoccus manihoti* (Homoptera: Pseudococcidae), in Africa. *Agric. Ecosystems Environ. 19:* 131–144.

KLAY, A. 1990. The cassava green spider mite biological control programme: the use of population models to monitor mass-production of natural enemies. *Workshop on status and prospect of integrated pest management for root and tuber crops in the tropics, IITA, Ibadan, 25–30 Oct. 1987* (in press).

LEMA, K. M. & HERREN, H. R. 1985. Release and establishment in Nigeria of *Epidinocarsis lopezi* a parasitoid of the cassava mealybug. *Phenacoccus manihoti. Entomol. exp. appl. 38:* 171–175.

LÖHR, B., NEUENSCHWANDER, P., VARELA, A. M. & SANTOS, B. 1988. Interactions between the female parasitoid *Epidinocarsis lopezi* (Hym: Encyrtidae) and its host, the cassava mealybug, *Phenacoccus manihoti* (Hom: Pseudococcidae). *Z. ang. Entomol. 105:* 403–412.

LÖHR, B. & SANTOS, B. & VARELA, A.M. 1989a. Larval development and morphometry of *Epidinocarsis lopezi* (DE SANTIS) (Hym.; Encyrtidae), parasitoid of the cassava mealybug, *Phenacoccus manihoti* MAT.-FERR. (Hom.: Pseudococcidae), *J. Appl. Entomol. 107:* 334–343.

LÖHR, B., VARELA, A. M. & SANTOS, B. 1989b. Life-table studies of *Epidinocarsis lopezi* (DE SANTIS) (Hym., Encyrtidae), a parasitoid of the cassava mealybug, *Phenacoccus manihoti.* MAT.-FERR. (Hom., Pseudococcidae), *Z. ang. Entomol. 107:* 425–434.

LÖHR, B. & SANTOS, B. & VARELA, A. M. 1990. Exploration for natural enemies of the cassava mealybug, *Phenacoccus manihoti* (Hemiptera: Pseudococcidae), in South America for the biological control of this introduced pest in Africa. *Bull. Entomol. Res.* (in press).

MATILE-FERRERO, D. 1977. Une cochenille nouvelle nuisible au manioc en Afrique équatoriale, *Phenacoccus manihoti* n. sp. (Hom. Coccoidea Pseudococcidae). *Ann. Soc. Entomol. Fr. (N.S.) 13:* 145–152.

NEUENSCHWANDER, P. & HAMMOND, W. N. O. 1988. Natural enemy activity following the introduction of *Epidinocarsis lopezi* (Hymenoptera: Encyrtidae) against the cassava mealybug, *Phenacoccus manihoti* (Homoptera: Pseudococcidae), in Southwestern Nigeria. *Environ. Entomol. 17:* 894–902.

NEUENSCHWANDER, P. & HERREN, H. R. 1988. Biological control of the cassava mealybug, *Phenacoccus manihoti,* by the exotic parasitoid *Epidinocarsis lopezi* in Africa. *Phil. Trans. R. Soc. Lond. B. 318:* 319–333.

NEUENSCHWANDER, P. & MADOJEMU, E. 1986. Mortality of the cassava mealybug *Phenacoccus manihoti* MAT.-FERR. (Hom., Pseudococcidae) associated with an attack by *Epidinocarsis lopezi* (DE SANTIS) (Hym. Encyrtidae). *Bull. Soc. ent. Suisse 59:* 57–62.

NEUENSCHWANDER, P., SCHULTHESS, F. & MADOJEMU, E. 1986. Experimental evaluation of the efficiency of *Epidinocarsis lopezi,* a parasitoid introduced into Africa against the cassava mealybug *Phenacoccus manihoti. Entomol. exp. appl. 42:* 133–138.

NEUENSCHWANDER, P., HAMMOND, W.N.O. & HENNESSEY, R.D. 1987a. Changes in the composition of the fauna associated with the cassava mealybug, *Phenacoccus manihoti,* following the introduction of the parasitoid *Epidinocarsis lopezi. Insect Sci. Applic. 8:* 893–898.

NEUENSCHWANDER, P., HENNESSEY, R. D., HERREN, H. R. 1987b. Food web of insects associated with the cassava mealybug, *Phenacoccus manihoti* MATILE-FERRERO (Hemiptera: Pseudococcidae), and its introduced parasitoid *Epidinocarsis lopezi* (DE SANTIS) (Hymenoptera: Encyrtidae), in Africa. *Bull. Entomol. Res. 77:* 177–189.

NEUENSCHWANDER, P., HAMMOND, W. N. O., GUTIERREZ, A. P., CUDJOE, A. R., ADJAKLOE, R., BAUMGÄRTNER, J. U. & REGEV, U. 1989a. Impact assessment of the biological control of cassava mealybug, *Phenacoccus manihoti* MATILE-FERRERO (Hemoptera: Pseudaoccoidae), by the introduced parasitoid *Epidinocarsis lopezi* (De Santis) (Hymenoptera: Encyrtidae). *Bull. Entomol. Res. 79:* 579–594.

Neuenschwander, P., Haug, T., Ajuonu, O., Davis, H., Akinwumi, B. & Madojemu, E. 1989b. Quality requirements in natural enemies used for inoculative release. Practical experience from a successful biological control programme. *J. Appl. Entomol. 108:* 409–420.

Neuenschwander, P., Hammond, W. N. O., Ajuonu, O., Gado, A., Echendu, N., Bokonon-Ganta, A. H., Allomasso, R. & Okon, I. 1990. Biological control of the cassava mealybug. *Phenacoccus manihoti* Hom., Pseudococcidae) by *Epidinocarsis lopezi* (Hym., Encyrtidae) in West Africa, as influenced by climate and soil. *Agric. Ecosyst. Environ.* (in press).

Norgaard, R. B. 1988. The Biological control of cassava mealybug in Africa. *Am. J. agric. Econ. 70:* 366–371.

Nwanze, K. F. & Leuschner, K. 1977. Proceeding International Workshop on the Cassava Mealybug *Phenacoccus manihoti* Mat.-Ferr. (Pseudococcidae). Zaire, June 26–28, 1977.

Schulthess, F., Baumgärtner, J. U. & Herren, H. R. 1987. Factors influencing the life table statistics of the cassava mealybug *Phenacoccus manihoti. Insect Sci. Applic. 8:* 851–856.

Schulthess, F., Baumgärtner, J. U., Herren, H. R. 1989. Sampling *Phenacoccus manihoti* in cassava fields in Nigeria. *Trop. Pest. Managt. 35:* 193–200.

Sullivan, D. J. & Neuenschwander, P. 1988. Melanization of eggs and larvae of the parasitoid, *Epidinocarsis lopezi* (Hymenoptera: Encyrtidae), by the cassava mealybug, *Phenacoccus manihoti* (Homoptera: Pseudococcidae), *Can. Entomol. 120:* 63–71.

Wodageneh, A. & Herren, H. R. 1987. International co-operation: training and initiation of national biological control programmes. *Insect Sci. Applic. 8:* 915–918.

Yaninek, J. S., Baumgärtner, J. & Gutierrez, A. P. 1991. Sampling *Mononychellus tanajoa* (Bondar) (Acari: Tetranychidae) in Africa. *Bull. Entomol. Res.* (in press).

Yaninek, J. S., Gutierrez, A. P. & Herren, H. R. 1989. Dynamics of *Mononychellus tanajoa* (Acari: Tetranychidae) in Africa: experimental evidence of the effects of temperature and host plant population growth rates. *Environ. Entomol. 18:* 633–640.

Yaninek, J. S. & Herren, H. R. 1988. Introduction and spread of the cassava green mite, *Mononychellus tanajoa* (Bondar) (Acari: Tetranychidae), an exotic pest in Africa and the search for appropriate control methods: a review. *Bull. Entomol. Res. 78:* 1–13.

Yaninek, J. S. & Herren, H. R. (eds.) 1989. *Biological control: a sustainable solution to crop pest problems in Africa.* IITA, Ibadan, Nigeria, 210 pp.

Yaninek, J. S., Herren, H. R. & Gutierrez, A. P. 1987. The biological basis for the seasonal outbreak of cassava green mites in Africa. *Insect Sci. Appl. 8:* 861–865.

Yaninek, J. S., Herren, H. R. & Gutierrez, A. P. 1989. The dynamics of *Mononychellus tanajoa* (Acari: Tetranychidae) in Africa: seasonal factors affecting phenology and abundance. *Environ. Entomol. 18:* 625–632.

Yaninek, J. S., Herren, H. R. & Gutierrez, A. P. 1989. The dynamics of *Mononychellus tanajoa* (Acari: Tetranychidae) in Africa: experimental evidence of the effects of temperature and host plant on population growth rates. *Environ. Entomol. 18:* 633–640.