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# ECOLOGICALLY SUSTAINABLE CASSAVA PLANT PROTECTION (ESCaPP): A MODEL FOR ENVIRONMENTALLY SOUND PEST MANAGEMENT IN AFRICA

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## ABSTRACT

**Integrating the management of cassava pests into a strategy which meets the needs of individual farmers requires a conceptual framework for development and implementation. The Ecologically Sustainable Cassava Plant Protection (ESCaPP) project which began in 1993 in West Africa provides such a working model. ESCaPP is a regional project to develop, test and adapt sustainable cassava plant protection technologies for the most important arthropod, pathogen and weed pests in West Africa. Multi-disciplinary teams of national plant protection experts join regionally with international experts to share expertise and pool efforts across agroecologies. Project activities are divided into three interrelated and overlapping phases. The major cassava pests are being identified in targeted agroecologies through initial diagnostic surveys. In the second phase, farmers' participation highlights the development and testing of appropriate intervention technologies. Concurrently, in-service training of researchers, extension agents and farmers in the principles and practices of sustainable crop production and protection is provided. Postgraduate training will be provided to women to strengthen their professional resource base in plant protection development activities. The third phase is an evaluation of the training objectives and technology implementation. Unique features of the project include nationally seconded multi-disciplinary teams, shared local expertise on a regional basis and activities based on local diagnoses. The project is a collaborative effort between the International Institute of Tropical Agriculture (IITA), national plant protection staff, extension workers and farmers in Cameroon, Nigeria, Benin and Ghana, with a parallel component in Brazil involving Centro Internacional de Agricutura Tropical (CIAT) and Empresa Brasileira de Pesquisa Agropecüaria (EMBRAPA). The research, training, implementation and evaluation paradigm used in this project can serve as a model for developing appropriate plant protection technologies and pest management strategies for other cropping systems.**

*Key Words*: Cassava, pests, diseases, weeds, multi-disciplinary, diagnosis, training, sustainable plant protection, West Africa

## RÉSUMÉ

**L'intégration de la gestion des ravageurs du manioc dans une stratégie qui réponde aux besoins de chaque paysan exige la création d'un cadre conceptuel pour son développement et sa mise en oeuvre. Le projet de Protection écologiquement durable du manioc (ESCaPP), qui a commencé en 1993 en Afrique de l'Ouest, fournit un modèle de travail. L'ESCaPP est un projet régional visant à mettre au point, tester et adapter des technologies de protection durables contre les arthropodes, les agents pathogènes et les adventices les plus importants en Afrique de l'Ouest. Des équipes pluridisciplinaires d'experts nationaux en protection des végétaux rencontrent des experts internationaux de la région pour partager leur savoir et mettre en commun leurs efforts. Les activitiés du projet sont divisées en trois phases qui sont étroitement liées et se chevauchent. Actuellement, des enquêtes-diagnosti préliminaires sont menées pour identifier les principaux ravageurs du manioc dans des écologies agricoles ciblées. Dans la deuxième phase, la participation des**

**paysans met en valeur la mise au point et l'expérimentation des technologies d'intervention appropriées. Dans le même temps, les chercheurs, les vulgarisateurs et les paysans reçoivent une formation sur les principes et les applications des techniques de production et de protection durables des cultures. Des formations universitaires de 3e cycle seront offertes à des femmes afin de renforcer leurs compétences professionnelles dans les activités liées au développement de la protection des végétaux. La troisième phase est une évaluation des objectifs de la formation et de l'application des technologies. Le projet a cela d'unique qu'il intègre des équipes pluridisciplinaires bénéficiant d'un appui national, des compétences locales partagées et mises en oeuvre régionalement et des activités basées sur des diagnostics effectués sur place. Le projet est le fruit de collaborations entre l'IITA, les services nationaux de protection des végétaux, les vulgarisateurs et les paysans du Cameroun, du Nigéria, du Bénin et du Ghana, avec un volet parallèle au Brésil faisant intervenir le CIAT et l'EMBRAPA. Le paradigme utilisé dans ce projet: recherche, formation, mise en oeuvre et évaluation, peut servir de modèle pour la mise au point de technologies appropriées pour la protection des végétaux et l'élaboration de stratégies de gestion des ravageurs dans d'autres systèmes culturaux.**

*Mots Clés*: **Manioc, ravageurs, maladies, mauvaises herbes, multidisciplinaire, diagnose, entraînement, protection durable des cultures, Afrique de L'Ouest**

## INTRODUCTION

Cassava in Africa is increasingly important as a food source for the rapidly expanding rural and urban populations. The crop is easy to grow, even under harsh agronomic conditions and cassava is the primary source of carbohydrates for more than 200 million people, including the poorest on the continent and provides food security to most subsistence farmers. However, increasing production demands together with finite agricultural resources threaten the sustainability of cassava agroecosystems in Africa (Nweke and Poulson, 1991). Pests, diseases, weeds and adverse agronomic conditions currently combine to reduce yields by an estimated 50% (Herren and Bennett, 1984).

Many of the important arthropod pests of cassava in Africa are exotic neotropical species. The cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr., was the most serious pest of cassava on the continent during the 1970s and 1980s (Herren and Neuenschwander, 1991; Neuenschwander, 1994a). The cassava green mite, *Mononychellus tanajoa* (Bondar), and the larger grain borer, *Prostephanus truncatus* (Horn), are also neotropical pests introduced into Africa in the early 1970s and 1980s, respectively (Nyiira, 1972; Dunstan and Magazine, 1981). Following the spectacularly successful control of the cassava mealybug, the cassava green mite is now the most important pest on cassava in many regions of the continent (Yaninek and Herren, 1988; Yaninek, 1994).

The more recently introduced larger grain borer is a serious pest of stored maize (Hodges *et al.*, 1983; Krall, 1984), but also attacks harvested and processed cassava. The whitefly vector of African cassava mosaic virus, *Bemisia tabaci* (Genn.) (Legg, 1994), has been a pest of cassava and many other crops in Africa for some time, but it is believed to be an exotic species of Mid-Eastern origin (Greathead, 1989). The only major indigenous arthropod pest is the polyphagous variegated grasshopper, *Zonocerus variegatus* (L.), found across the humid and sub-humid tropics in Africa (Modder, 1994). Large populations can defoliate cassava fields causing conspicuous and often significant damage (Page *et al.*, 1980), and can kill cassava plants if they are repeatedly defoliated or the bark is chewed off the stems. The spiraling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleurodidae), has been found attacking cassava and many other crops and ornamentals in Nigeria, Benin, Ghana and perhaps other countries in the region (Neuenschwander, 1994b; IITA, unpub. data). The yield losses caused by this pest and whether it transmits cassava viruses are unknown.

A number of foliar and root pathogens commonly affect cassava production in Africa (Makambila, 1994). The most important plant pathogen is the African cassava mosaic virus, which occurs throughout the cassava belt ( Otim-

Nape *et al.*, 1994; Thresh *et al.*, 1994). In the more humid regions, cassava bacterial blight, *Xanthomonas campestris* pv. *manihotis* (Arthaud-Berthet) Starr, *Cercospora* spp. and anthracnose damage can exceed that caused by mosaic virus (Terry, 1978). Root rots including those caused by *Fusarium, Phytophthora* and *Sclerotium* spp. are also major production constraints (Makambila, 1994). Numerous weed species can cause severe cassava production losses (Melifonwu, 1994). Among the most troublesome weeds in Africa are *Imperata cylindrica* (Anderss.) C. E. Hubbard and *Chromolaena odorata* (L.) R. M. King & Robinson.

## CASSAVA PEST MANAGEMENT IN AFRICA

Cassava and most other subsistence food crops were neglected by agricultural researchers early in the 20th century. Cassava was considered a low-value food crop with little prestige as a subject for research. Work on cassava eventually began with resistance breeding on African cassava mosaic virus in the 1930s (Bock and Guthrie, 1970). In the 1960s, research on cassava in Africa expanded beyond disease resistance and yield improvement to include agronomy and early farming systems research. Research on cassava became multi-disciplinary in the 1970s. A farming systems approach was widely adopted to measure the production constraints confronted by peasant farmers. This research model was also used to test technologies being developed by research stations in farmers' fields. The approach was "top down", in the sense that the client farmers were not involved at any stage in the technology development and testing. Most technologies were too difficult to transfer and many pest constraints were overlooked. Research to develop, test and adopt "appropriate" technologies on-farm flourished during the 1980s. But increasing concerns over the widespread devastation caused by several exotic pests and the need for an urgent, sustainable solution provided the attention needed to attract support for pest management research. Plant protectionists, i.e., entomologists, plant pathologists and weed scientists, began addressing cassava pests as subjects of pest management research and not simply as objects of resistance breeding.

By the 1990s, a systems approach with biological control as the centre piece, had become the basis for developing environmentally sound and economically feasible plant protection for basic food crops. A systems approach to pest diagnosis and treatment provides a quantitative basis for measuring production losses, developing ecologically appropriate plant protection and assessing the impact of intervention technologies. The objectives of this approach are to: 1) assure that the species under consideration are indeed pests worthy of further research, 2) determine which ecological conditions prompt pest outbreaks, 3) learn which ecological conditions limit pest populations, and 4) identify agronomic and socioeconomic factors that affect pest/crop interactions. See Yaninek and Schulthess (1993) for a more complete account of the history of cassava pest management in Africa.

Traditionally, plant protection components have been developed by research teams isolated within their disciplines (Fabres *et al.*, 1994). Such narrow perspectives often result in control measures that are inadequate, impractical, unacceptable or unnecessary. Multi-disciplinary teams working together are best suited to resolve these often complex and interrelated ecological, agronomic and socioeconomic issues that confront farmers. Diagnosis by several disciplines covers a wide range of conditions and interactions that influence the status of a pest in a given agroecosystem. Such an approach also provides a basis for selecting and developing intervention technologies that are more likely to represent the conditions that the farmer experiences in the targeted agroecosystem. Early and continuous interactions with farmers and extension agents familiar with their local agroecosystems help assure the appropriateness of any plant protection strategy. However, there is no obvious model from other crops for such a collection of multi-disciplinary collaborators.

## ECOLOGICALLY SUSTAINABLE CASSAVA PLANT PROTECTION (ESCAPP)

**Project Description.** The Ecologically Sustainable Cassava Plant Protection (ESCaPP) project is a regional project to develop, test and

adapt sustainable cassava plant protection technologies for the most important pests found in West Africa. Multi-disciplinary teams of national plant protection experts join regionally with international experts to share expertise and pool efforts across agroecologies. The project is a collaborative effort between the International Institute of Tropical Agriculture (IITA), national plant protection staff, extension workers and farmers in Cameroon, Nigeria, Benin and Ghana, with a parallel component in Brazil involving the Centro Internacional de Agricultura Tropical (CIAT) and the Empresa Brasileira de Pesquisa Agropecüaria (EMBRAPA). The four interested countries in Africa have ecologically similar production areas, are accessible by road and air, and possess the necessary institutional capacity and commitment to contribute and benefit from the project.

The specific objectives of the ESCaPP project are to: (i) assemble multi-disciplinary national programme teams in each participating country and carry out diagnostic surveys to identify and map the major pest constraints, record farmers' perceptions and current practices and estimate losses due to major constraints in the mandate area; (ii) determine the level and type of research required to overcome the major pest constraints identified through the diagnostic surveys, estimate losses due to suspected constraints and identify sites for farmer evaluation of available cassava protection technologies; (iii) develop and implement a training programme for national programme researchers, extension workers and farmers in the principles and practices of ecologically sustainable crop protection; (iv) test, adapt and evaluate pest and disease control technologies in collaboration with national programme researchers, extension workers and farmers over a range of ecological, agronomic and socioeconomic conditions; (v) evaluate the effectiveness and impact of the training programme, and evaluate adoption and impact of the technology components adapted by farmers.

The project will refine the existing knowledge base on major pests of cassava through diagnostic surveys. Farmers will participate in the development and testing of a range of crop protection technologies following the surveys. On-farm testing for adaptation and efficacy of natural enemies, impact assessment studies of pest and natural enemies and crop yield loss studies will be undertaken. Methods for decentralised mass rearing and field release of biological control agents, strain selection of fungal pathogens of arthropod pests and quick diagnostic procedures for pest and pathogen scoring will be developed. Cultural, genetic and biological control methods will be integrated into cassava production techniques for the management of key constraints. The parallel efforts in the four West African countries will rely on shared information (arthropod, agroecological and socioeconomic databases and simulation models), expertise (e.g., classical biological control, cultural control, mass rearing systems, taxonomy, microbial control, modeling, population biology, information management) and resources (e.g., information systems, natural enemy sources, common quarantine arrangements) leading to economies of scale.

The project is expected to improve the capability of national programmes for multi-disciplinary research on plant protection problems. Women leaders with appropriate plant protection expertise will become part of programmes previously devoid of women's participation. The development and implementation of similar plant protection initiatives in the future should be facilitated by the information resources generated by the project. The productivity of small-scale cassava farmers should be enhanced without threatening the quality of the environment and human health. These benefits will begin with the collaborators in participating countries and are expected to cross national boundaries in the continent. The project is also expected to provide a model for other pests and other cropping systems in the future.

**ESCaPP Participants.** The ESCaPP IITA team consists of a Project Leader, a Training/Liaison Officer, a Plant Productionist and a Plant Protectionist. As a unit, they share responsibilities for: (i) working with counterpart national programme staff to develop protocols and procedures for developing, testing and implementing sustainable cassava plant protection; (ii) participating in a diagnosis of the major cassava pests (arthropods, pathogens and weeds) in the four selected countries through

extensive surveys and intensive studies; (iii) adopting and testing sustainable pest intervention technologies on-farm; (iv) developing a plant protection curriculum and training national programme staff, extensionists, farmers and post-graduates in the principles of sustainable plant protection; (v) implementing and evaluating proven pest interventions on-farm.

The ESCaPP IITA team is responsible for liaising with national teams at the local level, coordinating project activities regionally and linking with international collaborators. This contact creates bridges among isolated groups within the continent with similar cassava production problems that provides access to natural enemies, resistant germplasm and expertise essential for developing and implementing appropriate cassava plant protection technologies.

The four national ESCaPP project teams are formed around a nucleus of multi-disciplinary and inter-institutional seconded members from the national system consisting of one National Project Coordinator and three Project Scientists to include a plant productionist, a plant protectionist and a socioeconomist. Each team member is expected to devote full-time attention to the execution of their respective duties. The teams were formed at the start of the project and meet regularly in planning workshops to prepare detailed work plans, survey protocols, sampling procedures, strategic research and on-farm trials, and a range of training activities prior to initiating specific activities.

The National Project Coordinator is responsible for: (i) the leadership of the National Team and the management and administration of the national ESCaPP Programme. The National Project Coordinator is also a liaison between ESCaPP IITA; (ii) preparing country-specific work plans and budget, in consultation with other national team members; (iii) harmonising the work plan and budget with regional project activities, in consultation with ESCaPP IITA; organising, supervising and participating in country laboratory and field activities; (iv) participating in interdisciplinary project activities across the region; (v) identifying priority areas/disciplines and women candidates, in consultation with other national team members, for academic post-graduate training; (vi) organising and supervising different levels of in-country training and identifying participants for in-country training; and (vii) preparing country project reports and conducting any other duties that may be assigned by ESCaPP, IITA.

The three National Project Scientists are responsible for: (i) assisting the National Project Coordinator in planning and carrying out the national project work plans and budget; (ii) participating in regional and national interdisciplinary ESCaPP project activities; (iii) conducting laboratory, field and training activities as specified in the work plans; (iv) acting as trainers in all in-country training sessions for front line extension agents and farmers; (v) serving as ESCaPP internal supervisors to the country-based ESCaPP Winrock Fellows; (vi) undertaking research in ESCaPP-identified country-specific problems; and (vii) undertaking any other project duties as may be assigned to them by the National Coordinator or ESCaPP IITA.

**International Collaboration.** The success of the project will be based on the complementary expertise and comparative advantages of the collaborating institutions and the unified approach to developing, testing and implementing plant protection technologies. Both IITA and CIAT maintain strong links with institutions that have a comparative advantage in carrying out specialised research and training, or facilitating the dissemination of information between institutions. The University of Amsterdam provides quarantine services; the University of California, Berkeley and the Swiss Federal Institute of Technology Zurich are developing a cassava ecosystems model. The Knowledge Laboratory of Texas A & M University has expertise in the development of tactical and strategic models with user-friendly interfaces. The University of Massachusetts, Amherst, has expertise in the behaviour and ecology of *P. herreni* and several enemies. The University of Amsterdam collaborates on behaviour and biology studies of natural enemies, and many other universities (University of British Colombia, University of California, Berkeley, Purdue University, McGill University, University of Laval, Wye College, Imperial College, Reading

University, ETH/Zurich, University of Regensburg, Ohio State University, University of Ibadan, University of Port Harcourt, University of Nairobi) to train post-graduates selected from national programmes participating in the control campaign. The Organisation of African Unity (OAU) and the United Nations Food and Agriculture Organisation (FAO) facilitate information exchange between institutions and help create an atmosphere conducive for sustainable plant protection research in the third world through education and training programmes. International Institute of Tropical Agriculture has had considerable research, quarantine and training links with the International Institute of Biological Control (formally the Commonwealth Institute of Biological Control) since the early 1980s. In a recent development, IITA will link with Winrock International in a special programme to select and train African women agriculturalists in the principles and practices of sustainable plant protection.

**Plan of Operations.** During a regional workshop, ESCaPP team members reached a consensus on which areas the project would concentrate. An objectives tree and an analysis of participating institutions and target groups were used as the guiding frame for delineating action areas or broad objectives for the project. Four action areas were identified and ranked in order of priority as follows: (i) Project Coordination at Regional and National Levels, (ii) Information Resource Development, (iii) Human Resource Development, (iv) Intervention Technology Development and Implementation.

**Project Coordination at Regional and National Levels.** Project coordination provides the structure for organising and managing project activities within and between participating countries and individuals. This includes identification, selection and preparation of national teams and planning country activities, organisation of regional workshops and ESCaPP evaluation and reporting.

The preliminary organisational activities following international staff recruitment included presentation of the project to collaborating countries at consultative meetings with national cassava scientists and farmers, the selection of national counterpart teams following country consultations, the preparation of work plans and budgets and the provision of technical and material logistics. Implementation agreements stipulating responsibilities, commitments and other contractual obligations to guide the project's operations at national levels were signed between IITA and the participating countries. Additionally, contracts have been implemented for women postgraduates training with Winrock's programme on African Women Leaders in Agriculture and Environment (AWLAE), natural enemy quarantine with the University of Amsterdam and digitised information resources with the University of Florida.

A regional workshop on Goal Oriented Project Planning was held in 1993 involving ESCaPP IITA project management, Winrock International and the four country teams. The workshop planned for the effective implementation of the project. Regional and country-specific plans of operations and budgets were finalised and harmonised to provide an implementation management tool with performance indicators, objective/target setting and inputs for project monitoring and evaluation. Targets were related to available inputs, personnel, funds, equipment, materials, deadlines set by when activities should begin and end and responsibilities assigned to team members and/or collaborating agencies, thereby removing ambiguities about responsibilities during project implementation. During a second regional workshop in 1994 on Diagnostic Survey Protocols, sampling and site selection procedures were presented, tested and finalised.

Regular international scientific and technical interaction continues among regional staff, international collaborators and the national teams. Through these interactions various resources, opportunities and features of the national programmes and other country institutions within which ESCaPP activities can be accommodated are identified. The opportunity is also used to promote a team approach and highlight the need for interdependence of disciplines and tasks as prerequisites for success in the project.

**Information Resource Development.** Information resources are being developed to facilitate processing, summarisation,

interpretation and communication of the large amount of multi-disciplinary data anticipated during the project. These include development of information resources, taxonomic resources, digitised interactive information resources and systems analysis.

A preliminary effort was made in each country to identify and compile into a database the national root crop plant protection literature which is often difficult to find e.g. theses, dissertations, project documents, annual reports, etc. Other databases being compiled include one on cassava research personnel and cassava projects in Africa, plus a worldwide bibliography of cassava literature. Literature reviews of all major cassava plant protection constraints have been completed by ESCaPP team members, while taxonomic redescriptions and keys for important species of cassava pests on both continents are still under preparation.

Project databases, training materials and taxonomic keys have been digitised and shipped to the University of Florida for inclusion on a cassava information almanac CD-ROM under development. The prototype CD should be available by the end of 1995, and will consist of a cassava plant protection directory of personnel and institutions, a digitised version of the Handbook of Common Pests and Diseases of African Root Crops, a digitised version of the Handbook on Cassava Green Mite and a bibliography of plant protection literature for Africa.

A systems approach will be used to integrate the inter-disciplinary data being generated by the project. Strategic and tactical models are being developed for use in identification of critical interactions, and evaluation of the potential impact of tested technologies. This is a practical way to characterise the complex interactions found in an agroecosystem given a multi-disciplinary perspective. Validated inter-disciplinary systems models will be developed as tools for evaluating the response of simulated agroecosystems under a range of conditions, and for day-to-day decision-making in cassava plant protection.

**Human Resource Development.** The focus of the human resource development activity is training which includes the development of a plant protection curriculum and training materials, individual and group training, and postgraduate and AWLAE training.

The training goal is to enhance the effectiveness of national programme participants to facilitate the integration of ecologically sound plant protection practices into sustainable cassava production at farm level. In this regard, training and extension delivery structures and operations, methodologies, activities, materials and guidelines have been studied during needs assessment visits. Follow-up task analysis will determine participants level of plant protection knowledge, skills and experience and identify impact points for inclusion into the curriculum.

The unified extension system which is adopted and externally supported in the ESCaPP countries provides the project with an opportunity to execute its in-service training programme within existing training structures and operations. This system delivers extension services to farmers through a single national line of command in which extension agents are relieved of previous duties in credit management, input distribution and other non-extension responsibilities to enable them to concentrate on technology transfer to farmers. It also provides for effective contact with farmers, agricultural development workers and NGOs. The identified national collaborating institutions are the *Centre d'Action Régionale pour le Développement Rural* (CARDER) in Benin, the National Agricultural Extension Training Programme (NAETP) in Cameroon, the Department of Agricultural Extension Services (DAES) in Ghana and the Agricultural Development Projects (ADP) in Nigeria.

Researchers, extension trainers and village-based extension agents working within these national institutions will be trained in the principles and practices of ecologically sustainable cassava plant protection. Target farmers will be largely those already participating in the unified extension projects. Agricultural development workers and volunteers will be considered alongside extension agents as primary farmer trainers. The curriculum features refresher courses preceding periodic training sessions, teaching syllabi, didactic training and extension support materials and methodologies, on-farm and laboratory practicals and demonstrations and farmers' field days.

The postgraduate training programme aims at strengthening the professional women resource base for plant protection research, training and extension. It involves the provision of 14 masters degree fellowships to women from the ESCaPP participating countries to equip them with the technical, research and leadership skills needed for the development of sustainable plant protection at national and international levels while recognising gender-related issues for plant protection decision-making. In collaboration with Winrock International's AWLAE programme the project has placed selected candidates in overseas and African universities. The fellows will have the opportunity to conduct their dissertation work within the project's national work plans, thereby helping to consolidate the gains made by the in-service training programme.

**Intervention Technology Development and Implementation.** Intervention technology development and implementation is the heart of the scientific research proposed in this project and includes extensive and intensive diagnosis, on-farm trials, strategic laboratory and field studies, decentralised intervention technologies, and implementation and evaluation.

The International Institute of Tropical Agriculture ESCaPP has taken the lead in developing a multi- and inter-disciplinary sampling framework needed for extensive diagnostic surveys. Protocols have been developed by ESCaPP members, tested in the field by discipline-specific ESCaPP teams and taught to other team members during the second regional workshop on protocol development and survey site selection in 1994. The protocols are now validated and printed as a project document, but will be published soon for wider distribution. The diagnostic survey includes dry and wet season evaluations of sampled sites. Ambiguous results from the extensive survey will be followed up by a period of intensive monitoring when necessary to determine the importance of a given constraint in a given ecology.

Farmers will participate in the development and testing of a range of crop protection technologies following the surveys. On-farm trials of the impact of pests and natural enemies, crop yield loss studies, adaptation and efficacy of natural enemies and plant germplasm preferences among others will be undertaken. Methods for decentralised mass rearing and field release of biological control agents, strain selection of fungal pathogens, quick diagnostic procedures for pest and pathogen scoring and strategies to manage crop germplasm including a protocol for 'cleaning', producing and distributing planting material will be developed.

Strategic laboratory and field studies are planned for several known problem areas. National ESCaPP counterparts have developed proposals for specific research activities throughout the region. Some of these projects include work on cutting sanitation, cassava green mite biological control, germplasm screening for natural resistance and soil and weed management. This includes strain selection of fungal pathogens for control of cassava green mite, integration of cultural, genetic and biological control methods for sustainable root production, development of a quick diagnostic procedure for cassava mosaic virus, impact of biological control agents on non-target organisms, cover crops to suppress weeds, mulching to enhance soil fertility and screening technology components for undesirable environmental effects. These collaborative activities were initiated as bilateral research proposals with national programme scientists in participating countries. Further activities are anticipated in these countries as the results of the diagnostic surveys are analysed.

Cultural, genetic and biological control methods will be integrated into cassava production techniques for the management of key constraints. Progress in achieving the research objectives and technology implementation, with a particular focus on consumer acceptance and farmer adoption of recommended technologies, will be evaluated routinely throughout the life of the project.

## CONCLUSION

The interest in cassava production, both as a food and as a cash crop, continues to grow throughout the humid and subhumid tropics of Africa. Producers are demanding more and better tools to deal with production constraints that limit plant biomass, agronomic yields and expected economic returns. A multi-disciplinary approach is needed to examine these constraints in a comprehensive

manner. Concern for pests, diseases and weeds without regard for the availability of appropriate interventions, local preferences, labour and market constraints will be of little interest to client farmers. A number of promising technologies are already available for a range of cassava production constraints. However, many have never been tested on farmers' fields, and even fewer are available to extension agents and their client farmers. Interventions developed in an inter-disciplinary manner will have a better chance of success. A systems analysis which includes multi-trophic interactions for given agroecosystems and the socioeconomic concerns of the farmer provides a paradigm for linking the ecological, agronomic and socioeconomic milieu in which constraints are evaluated and informed decisions can be made.

Ecologically sustainable cassava plant protection is a model for developing a comprehensive sustainable cassava plant protection strategy. This approach links national and international research scientists of different disciplines with extension agents and farmers to diagnosis, evaluate and implement appropriate intervention technologies within countries by working through existing national structures. ESCaPP provides a forum for regional interactions between countries with similar agroecologies and similar production problems. Ecologically sustainable cassava plant protection (ESCaPP) research and development activities are result driven. Diagnostic surveys provide the background information needed to implement agroecosystem-specific on-farm trials and intervention technology decentralisation, distribution and evaluation. Strategic research activities of regional importance are identified through regional consensus, and pursued by sharing the local expertise available from participating countries. The development and distribution of timely cassava information resources will improve the exchange of ideas between interested groups at the national, international and inter-continental levels. The databases, bibliographies and resources materials being developed by ESCaPP will provide a legacy of plant protection information for the future.

The key to providing sustainable cassava plant protection technologies will require two elements. The first will be to formulate a multi-disciplinary strategy for diagnosis and technology development which includes client farmers and extension agents in partnership with research scientists. The second will be to package and disseminate the technologies and information for the farmers through the national extension services. This implies a dedicated and disciplined national training and extension policy. In the end, the farmer wins when concerned researchers and extension agents work together for a common purpose.

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