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CASSAVA PEST AND DISEASE MANAGEMENT: AN OVERVIEW

H. R. HERREN
International Institute of Tropical Agriculture,
Plant Health Management Division,
BP 08-0932, Cotonou, Republic of Benin
Current address: International Centre of Insect Physiology and Ecology,
PO Box 30772, Nairobi, Kenya

ABSTRACT

The International Institute of Tropical Agriculture (IITA), the Centro International de Agricultura Tropical (CIAT), and many national agricultural research systems (NARS) have devoted considerable attention to cassava improvement. However, many biotic constraints still limit the expansion of this crop in many tropical areas. Host-plant resistance and biological control are the cornerstones of crop protection measures against biotic stresses on cassava (*Manihot esculenta* L.). Genetic improvement has focussed on African cassava mosaic disease, cassava bacterial blight and anthracnose diseases. Management of the cassava mealybug and the cassava green mite has been highly successful using parasitoids natural enemies introduced from Latin America, the original home of cassava. Sustainable plant health management (PHM) that considers the crop plant as a component of an agro-ecosystem holds promise for management of diseases and pests on cassava.

Key Words: **Biological control, host-plant resistance, *Manihot esculenta,* plant health management**

RÉSUMÉ

L'Institut International d'Agriculture Tropicale (IITA), le Centre International d'Agriculture Tropicale (CIAT), et plusieurs centres nationaux de recherche agronomique (NARS) ont dévoué une attention considérable à l'amélioration du manioc. Toutefois, un nombre important de contraintes limitent encore l' expansion de cette plante dans beaucoup de régions tropicales. La résistance génétique et la lutte biologique sont des points cardinaux parmi les mesures de protection contre les ravageurs et maladies et autres facteurs de stress biotiques du manioc (*Manihot esculenta*). L' amélioration génétique s'est concentrée sur la mosaïque Africaine du manioc, la bactériose et l'anthracnose. La cochenille et l'acarien vert du manioc ont été controlés avec succès par l'introduction d' antagonistes de la zone d'origine de ces deux ravageurs, l'Amérique Latine, qui est aussi la zone d'origine du manioc. Pour une gestion phytiatrique durable, il s'agit dans l'avenir de considérer la plante comme une composante intégrale de l'agro-écosystème. Ce mode de gestion est très promoteur pour le manioc.

Mots Clés: **Lutte biologique, résistance de la plante, *Manihot esculenta***

WHERE WE HAVE COME FROM

Cassava (*Manihot esculenta* Crantz) is an exotic crop to Africa and, when it was first introduced, it left behind in its neotropical area of origin most, if not all, diseases and pests. With time, endemic diseases and arthropods in Africa have overcome the defensive strategies of cassava through adaptation or mutation and have added it to their list of hosts. In other instances, modern transport technology has facilitated the movement of neotropical pests to Africa, where they have created havoc in the absence of coevolved natural control mechanisms.

The early successes of international and national research systems with host-plant resistance (HPR) against many diseases and, to a lesser extent arthropods, together with the availability of often cheap if not free pesticides, have provided a temporary relief from the major diseases and insect problems affecting food crops in Africa. A similar pattern has evolved with cassava. Selection among local varieties, breeding and chemical control have been successful in some individual cases. Cultural or agronomic control tactics have been investigated and developed, but with little success when it comes to the extension stage. It is only recently that integrated approaches to cassava pest prevention and control have been taken up seriously, as detailed by several other contributors to this volume.

The International Institute of Tropical Agriculture has been involved in research on cassava diseases since it was established 26 years ago. Following the pattern of the Consultative Group on International Agricultural Research (CGIAR) centres, IITA has concentrated mainly on genetic improvement and resistance breeding, initially directed at the African cassava mosaic disease (ACMD) and later to cassava bacterial blight (CBB) and anthracnose. In the mid-1970s, the introduction of arthropod pests, with their well known drastic effect on cassava yields and tragic consequences, heralded a new era for plant protection in Africa, when it was realised that genetic methods alone would not offer the 'silver bullet' solution. It soon became clear that host plant resistance (HPR) would not be available against the cassava mealybug (CM) and the cassava green mite (CGM) in time to avoid the elimination of the crop from most growing areas. The two pests are of South American origin, where they evolved with a complex of natural control mechanisms, including host plant tolerance but more importantly, with biotic agents such as pathogens and arthropods as natural enemies. Thus, there was no evolutionary advantage for cassava to have developed a strong resistance to these pests. This accounts for the lack of strongly resistant *Manihot esculenta* germplasm in the crop's area of origin.

The problem required immediate action in order to save cassava from certain extinction in most growing areas of the African cassava belt. Specifically, Zaire and the Republic of Congo requested that IITA and other specialised agencies provide a 'solution immediate' to the CM problem as early as 1977, a few years after the invasion of those countries by the new pests. The time lag between the development phase and then subsequent multiplication of a vegetatively propagated crop gave HPR little chance of rapid success. Agronomic practices were not appropriate either, nor was chemical control. At a special workshop held in Zaire in 1977 (Leuschner, 1978), it was decided that biological control should be investigated as a matter of priority, given the exotic nature of the pests and previous successes in controlling invading organisms with antagonistic ones from their area of origin. IITA started the Africa-wide Biological Control Programme in 1979, following an earlier attempt by the International Institute of Biological Control (IIBC). The complete history of this programme has been widely reported, in particular by Herren and Neuenschwander (1991). More information on the cassava mealybug biological control project is discussed by Neuenschwander (1994a).

The Centro International de Agricultura Tropical (CIAT) continues to collaborate closely with IITA on biological control and germplasm improvement. L'Institut français de recherche scientifique pour le développement en coopération (ORSTOM) has been mainly involved in research on cassava bacterial blight (CBB), African cassava mosaic disease (ACMD), biological control by local natural enemies and host plant/pest interactions, in collaboration with the national agricultural research systems (NARS) of the Congo, Côte d'Ivoire and Togo (Fabres *et al.*, 1994). The Natural Resources Institute (NRI) is working mainly on ACMD and nematode pests in collaboration with NARS, and in particular with the Ugandan National Agricultural Research Organisation (NARO). For further details see Thresh *et al.* (1994) and Coyne (1994).

In the area of sustainable weed control, the development of low branching varieties at IITA provided the expected result of supressing weeds. However, the use of such varieties is somewhat incompatible with the traditional practice of mixed cropping. The best results in weed control are based on crop rotations, in which the fallow period is used to grow weed-suppressive cover crops such as *Mucuna* (Melifonwu, 1994).

The NARS across Africa have been involved in cassava plant protection activities, mainly concerned with developing HPR against diseases. This reflects the influence of the international agricultural research centres (IARCs) and IITA in particular, who have trained a large cadre of cassava breeders and pathologists. There have been some attempts in breeding for resistance to CM and CGM, in particular in Zaire, here again following the specialist training of national scientists at IITA. In comparison with the progress in breeding for resistance against CBB, anthracnose and ACMD, there is little to show for the efforts on developing HPR against insects and mites.

At the beginning of the cassava mealybug disaster in Africa, there was little if any knowledge of cassava entomology, not to speak of acarology, and for good reason: There were no problems to deal with! The two introduced pests changed the picture dramatically and there are now about 800 national plant protection scientists and research technicians from across the cassava belt who have received training at various levels to cope with the onslaught of the CM and the CGM; about 80 of these experts hold MSc. or PhD.

WHERE WE ARE NOW

The plant health management approach. In modifying its approach to protecting crops through the management of plant health, IITA is guided by a concern for practical measures that national programmes and non-governmental organisations (NGOs) will adopt for adaptation and implementation with farmers. The focus on health reflects holistic thinking and consideration of ecological systems, while the management approach invites biological manipulations and technological solutions.

Sustainable plant health management (PHM) is, therefore, not just a new combination of 'buzzwords.' The concept of sustainability in agricultural research has taken a central place in view of the rapid degradation of the natural resource base including agro-biodiversity, accentuated by crop production practices involving inappropriate technologies. Sustainable agriculture goes beyond the narrow and short term goal of increasing crop yields by also including effective management of the soil, water and plant health. The emphasis on health reflects the approach that considers the crop plant as one of the components of a complex system governed by ecological interactions, i.e., the entire agro-ecosystem. The peculiarity of these interactions with the other elements of the system, i.e., climate, soil, and particularly biotic factors, is vital in determining the ability of the plant to grow and yield. If the biotic factors exert a detrimental effect on plant health, then we speak of 'pests', meaning here arthropods, nematodes, vertebrates, pathogens and weeds, including parasitic weeds.

Ecologically-oriented plant protection is bringing together ecologists, entomologists, plant pathologists and weed scientists to address pest outbreaks as problems of ecosystem management, and not simply as problems for HPR, biological control or cultural practices in isolation from each other. The need for self-sustaining solutions to pest problems has motivated this interdisciplinary effort. Artificial interventions are minimised in favour of technologies which promote ecological stability and system resilience (Yaninek *et al.*, 1994).

Right for Africa, right for the tropics. Plant health management from this perspective is particularly suited to agro-ecosystems in Africa and the tropics in general, where smallscale and resource-poor farmers produce a diversity of locally adapted crops by using few resources other than their own labour.

Plant health management in this setting aims at maintaining good crop productivity within the dynamic balance of forces in the agro-ecosystem, using a combination of plant breeding and systems management strategies. This ecological approach to crop protection seeks to avoid the need for environmentally hazardous pesticides, which are purchased inputs that need continuous renewal.

Here, PHM differs from integrated pest management (IPM), which integrates components such as HPR, biological and cultural control practices with the judicious use of pesticides. PHM is the logical evolution of IPM towards a more sustainable and ecologically and economically sound approach.

Integrated Pest Management as usually known is a strategy rather than a technology. In its original classical sense, it is the integration of appropriate control measures to reduce or keep the pest populations below an economic threshold. Integrated Pest Management was developed primarily to reduce pesticide use in view of insect/mite resistance development and environmental and health concerns.

The IPM strategy assumes the compatibility between different prevention (natural enemies, HPR, agronomic practices) and therapeutic (biological, biotechnical, genetic, chemical, etc.) interventions. There are, however, two major problems with classical IPM. The first concerns compatibility with pesticides, since these are usually not specific to the target pests, and thus (even at low doses) disrupt natural control agents. The second shortcoming is the reliance of IPM on economic or injury thresholds to decide on the correct time for therapeutic interventions. Economic thresholds are very difficult to establish in a non-economic (subsistence) environment, as is usually the case in most of Africa. In addition, the knowledge needed to implement preventive measures is still generally lacking.

The fact that IPM, involving pesticides, is not sustainable is a further drawback at times when sustainability and economic factors have priority over short-term benefits. From a scientific and also a long-term economic point of view, it would be more sensible to tackle the *cause* of the problem rather than the *symptoms*. Such an approach would address both the environmental and economic aspects, such as sustainability.

Moreover, the ecological approach works to conserve the efficacy of the pest's natural enemies, by obviating the use of pesticides which usually eliminate the enemies together with the pests. Without the toxic residues which normally accompany pesticide use, the integrity of the food chain and of water resources is preserved in the targeted ecosystem.

To manage plant health from an ecological perspective, the first step is to gain an understanding of the dynamics and interactions within the ecosystem and of the biotic potential of both crop and pests in the farm setting, as well as their key interactions; knowledge of these will reveal opportunities for management intervention. The research should be a team effort among multi-disciplinary scientists of various biological and social disciplines as well as extension agents and client farmers. Analysis of the agro-ecosystem with its pest/plant/farmer interaction is facilitated by the development of simulation models as tools for ultimately optimising appropriate technologies to achieve plant health and ultimately to control the pests (Fargette and Thresh, 1994).

WHAT ARE THE AVAILABLE TOOLS FOR ECOLOGICALLY SUSTAINABLE PLANT HEALTH MANAGEMENT (PHM)?

Sustainable plant health technologies can be grouped into three types of interventions in order of preference: habitat management, biological control and HPR.

Habitat management practices, including agronomic, for enhancing crop production are well known, but those for controlling pests are poorly documented. In Africa they have hardly begun to evolve as means for coping with the threat of exotic pests and diseases, not to mention the endemic ones. Systems research and good agronomic practices already suggest possibilities, including selection of planting material free of contamination by pathogens and pests. Fallow management can reduce undesirable weeds while maintaining desirable refuges for natural enemies.

Biological control can follow three strategies: classical biological control, whereby ecologically adapted natural enemies are introduced from the area of origin of the pest to the target area; conservation of natural enemies present in the ecosystem, through cultural practices or habitat management that enhance their activity; and artificial augmentation of local natural enemy populations.

Host-plant resistance using the plants' characteristics such as antifeedants, repellents and antibiosis is widely used and underpins all plant protection research at IITA and other CGIAR centres. Biotechnology will provide the tools to accelerate the transfer of useful genes within and between plant species, saving precious time and overcoming natural barriers in the development of HPR. The long-term impact of these biotechnologies, in particular in the areas of resistance development in target pests and gene transfer from transgenic crops to their wild relatives, is far from being known and needs to be carefully studied without further delay.

Many ecological and socio-economic constraints to crop production also affect plant health management. The weather varies unpredictably. Water is insufficient in some places or seasons and sometimes for long periods. Farm sizes are small, and sometimes fragmented, with uncertain land tenure. Harsh living conditions engender poor health among farmers. Women farmers are subjected to less certain land tenure than men, less access to credit, and greater restrictions in making decisions about their own crops.

Implementation of most plant protection technologies requires help from farmers and such agro-ecosystem developers and managers as extension agents and researchers. A cadre of properly trained managers is needed to pass the knowledge and technologies to the whole farming population and also to provide the feed-back loop to scientists as discussed by Otim-Nape *et al.*, (1994). However, given the problems facing farmers in their day-to-day existence, their involvement must be balanced with the biological and socio-economic constraints being addressed.

Among the causes for hope is that a large national capacity in biological control, breeding and pathology has been developed throughout sub-Saharan Africa over the past two decades. This capacity provides a basis for new work in biological control and HPR to develop new plant health interventions. Such activities will contribute to the development of PHM in Africa and the tropics, on which the future of sustained crop production depends. Unfortunately, there are few systems scientists to deal with habitat management issues and even fewer social scientists with specialised skills in plant health matters.

Approaches to PHM. Managing plant health implies two distinct processes. First, the noxiousness of a particular organism needs to be assessed by a diagnostic process. Before attempting to manage a system, it is necessary to have an understanding of it's features and functioning. All too often, pest control projects fail because a simplistic approach is adopted that neglects the very nature of the problem. Depending on the complexity of the system under study, this differentiation is often possible only through ecosystems analysis, investigating the interactions between (e.g. plant-pest-antagonist) and across trophic levels (e.g. crop-alternative host plants). The underlying idea is to avoid treating symptoms and instead tackle the problems at the roots.

Having characterised the problem, it is then possible to begin the process of defining the most appropriate strategy. Thus, the results of the diagnostic assessment are used to tailor prevention and/or control tactics in a multi-disciplinary effort. In this context, it is worth emphasising the prevention concept, in which, for instance, the use of 'clean' planting material and resistant/tolerant varieties, together with the strict implementation of quarantine rules, are of crucial importance in avoiding pest outbreaks. In contrast to crop protection, where the word 'protection' already implies an intervention-oriented control strategy, often narrowed down to the application of pesticides, plant health management advocates a holistic approach to prevent pest problems from occurring in the first place or solving them in the framework of the agro-ecosystem in question.

PHM for cassava. Current cassava plant protection activities illustrate how ecologically sound plant health management strategies can be based on knowledge of pest/plant/farmer interrelationships. Concerted research and development efforts by IARCs and NARS in the direction of an integrated approach to cassava plant protection on a regional and a global scale have just started. The most sustainable solution proposed thus far for Africa has been biological control, which aims at establishing an ecological equilibrium between host plant, pest and natural enemy populations, much like the one existing in South America. Advances in HPR against ACMD and CBB as well as the successes and breakthroughs with CM and CGM using biological control are showing the great potential of these tactics, as described by other contributors to this volume.

The use of cultural practices, although very promising for prevention through encouraging healthy plant growth, remain mostly theoretical in view of the need for an effective extension service which is seldom available. Positive developments in this regard are coming from NGOs, which are now often complementing, if not replacing, the governmental extension services. Selection of locally well-adapted cultivars and use of sanitation with such planting material may be one of the most promising and rapidly adoptable solutions (Thresh and Otim-Nape, 1994). The research and development efforts now under way in this direction are expected to improve yields substantially and also very quickly (Boher and Verdier, 1994; Thresh *et al.*, 1994).

It is likely that the present pest situation in cassava will continue to be dynamic. New pest introductions are very likely in view of the increased traffic and movement of people between continents and the large number of potential cassava pests known (Bellotti *et al.*,1994). Also, just as any other plant, cassava is not immune to the attack of non-specific pests, endemic or exotic. This is exemplified by the recent outbreaks of the spiralling whitefly *(Aleurodicus dispersus* Russel), an exotic insect recently discovered in Africa. The initial severe damage caused by the exploding spiraling white fly populations seen in 1992 are already disappearing, as a result of a serendipitously introduced natural enemy, *Encarsia ? haitiensis* (Neuenschwander, 1994b).

Intensification through improved, but genetically impoverished, varieties and the expansion of cassava as a monocrop for urban and industrial use are likely to favour pest development. Furthermore, intensification will decrease soil fertility since the use of fertilizers is unlikely to increase with the present trend of subsidy removal. In addition, the shortened fallow periods necessitated by population pressure will in turn affect plant health and natural tolerance of pests and diseases.

Further progress in sustainable pest control will require a better and more basic understanding of the agro-ecosystem and the biotic, abiotic and socio-economic factors influencing it. From a strict commodity approach, IITA's research has evolved toward an eco-regional one, in which the emphasis is not on a specific crop but on a particular cropping system in a defined ecological zone in which diverse crops are cultivated. Plant health research is directed toward the analysis of the constraints in the system, and determination of which manipulations are firstly, adoptable and secondly, necessary to bring about changes which are in harmony with the environment and which will produce optimum and sustainable yields.

WHERE DO WE GO FROM HERE?

Characterisation and assessment of cassava pests and diseases. It is estimated that pests (including weeds) currently reduce potential yields by almost half. Cassava pests must be assessed for their ecological, agronomic and socio-economic importance and impact before allocating resources to significant research and development activities. The International Institute of Tropical Agriculture is highlighting the needs to acquire reliable quantitative data in respect of pest distribution, impact and ecology as the basis for investment in research and development projects. Feasibility studies need, therefore, to precede fully-fledged projects, to provide the necessary background information for efficient and focused design and execution and as the basis for impact assessment. This is certainly also true for other national and international institutions. [Examples of this approach can be found in the IITA/NARS Collaborative Study of Cassava in Africa (COSCA) described by Nweke (1994) and the IITA projects on cassava plant health].

African cassava mosaic disease still remains the major constraint across ecological zones (Geddes, 1990). The disease is closely followed in importance by CBB and CGM. Although more restricted in area, the yield losses incurred through the variegated grasshopper (*Zonocerus variegatus*) are perceived as sufficiently important to justify annual pesticide applications (Modder, 1994).

The characterisation work, which needs to be continued, requires the evaluation of key multi-trophic and multi-disciplinary interactions in the context of the cassava-based agro-ecosystems in addition to socio-economic constraints in the adoption of PHM practices. Understanding traditional systems of cassava-based cultivation is an ideal starting point for identifying significant production constraints. Species which are ecologically abundant, and which are associated with measurable crop damage and by extension, have the potential to cause significant economic impact, are considered to be pests worthy of further consideration and should be included in future research activities.

The characterisation work to be undertaken by different partners should cover among others: (i) regional and national cassava pest and disease diagnosis by agro-ecological zones; (ii) faunistic inventory and biodiversity of plant pathogens and indigenous phytoseiid predators of the cassava agro-ecosystem; (iii) etiology of cassava viruses and characterisation of viruses involved; (iv) epidemiology of ACMD and cassava brown streak virus disease in relation to whitefly vectors and their agro-ecological zones; (v) etiology, epidemiology, yield losses and characterisation of CBB in different agro-ecological zones; (vi) factors affecting pre- and post-harvest root rots.

The above-described activities will identify important production constraints and key agro-ecosystem interactions which may be exploited in the development of appropriate control strategies.

Ecologically sustainable plant health management in cassava. It is critical to develop and apply ecologically sustainable pest management systems to avoid the use of synthetic pesticides. So we must proceed with strategic research in all areas of plant health. Appropriate utilisation of biological control, resistant germplasm and cultural practices form the basis of ecologically sound and sustainable plant health, which is by nature a preventive measure. It is this particular point of *prevention* rather than *cure* that should be emphasised at all times. A point to remember is that the PHM strategy should be the application of one or more pest mitigation or control tactics *in concert*.

A multi-disciplinary strategy is needed, taking into account that the farmers consider pest problems as an integral part of the agronomic and socio-economic issues they face. In times when the word 'sustainable' is used in almost every other sentence, I would like to emphasise the need to have 'sustainable funding' to support long-term strategic as well as applied research, training and national programme development activities. I strongly disagree with the now often-used argument that there are enough crop protection technologies 'on the shelf' and that 'research' should yield the stage to 'implementation'. This is a dangerous course of action which will lead to a mad scramble for innovations in the very near foreseeable future. Sustainability can be promoted through the continuation of intensive training activities at degree and production course levels in the field of PHM and IPM. This, however, requires sustainable funding from donors and governments, both of whom need to demonstrate their commitment to agricultural production and plant health.

For an integrated and multi-disciplinary approach to cassava plant health research, implementation and training, the following activities need to be included: (i) completing the cassava agro-ecosystem modeling, including the addition of a phytoseiid predation sub-model and multi-cropping system linkages; (ii) large scale production of CGM natural enemies for distribution to NARS for mass production and releases; (iii) implementing and evaluating large-scale releases of CGM natural enemies in targeted agro-ecologies; (iv) assessing yield loss and making experimental releases of CGM predators in the mid-altitude ecologies; (v) assessing yield loss due to variegated grasshopper and testing of entomopathogens; (vi) continuing with germplasm evaluation, selection and breeding for disease and CGM resistance /tolerance; (vi) on-farm testing and implementation of integrated cassava plant health intervention technologies in representative agro-ecological zones; (vii) developing, testing and implementing sanitation strategies for cassava cuttings, and (viii) developing and delivering a cassava plant health curriculum, information resources and general plant protection support to selected NARS.

These and other research activities are discussed in further detail by other contributors to this volume and will provide the necessary information for ecologically sustainable cassava plant health management to be tested, adapted, and implemented in targeted agro-ecological zones.

CONCLUSIONS

Currently, IITA research emphasises the systems approach in resolving pest problems of cassava and also other crops. The need to look beyond the boundaries of the crop field has been recognised and research is developing single crop/pest models as a basis for more complex integrated ecosystem models. Full integration of all disciplines has yet to be achieved, but already IITA, together with its partners in the IARCs and NARS, is making this approach a priority in its effort to develop sustainable plant health and protection technologies.

Although much work has gone into resolving cassava pest problems, there are still major issues to be addressed. It is most important to go to the roots of the problem and address the causes rather than to treat symptoms with 'quick fixes'; the most urgent problems being ACMD, CGM and CBB. Cassava brown streak virus disease still needs further diagnosis before a research programme can be justified. Perhaps the most important step in promoting PHM in cassava is the production and distribution of ecologically adapted, healthy and vigorous planting material. This is a process which needs strong support from extension services and NGOs, but is one for which the knowledge base already exists and, so implementation can be done immediately. The approach currently being adopted in Uganda is described by Otim-Nape *et al.* (1994). In the case of weeds, weed scientists and agronomists will need to be included in plant health research teams to work with farmers and extensionists (see Melifonwu, 1994).

We should also address the general lack of skills in NARS such as those of systems analyst scientists who will be able to link the different disciplines necessary to research and implement PHM.

In order to tune the technologies to the end users from the start, research should be carried out in closer collaboration with research and extension institutions across Africa and elsewhere. High priority must be given to the training of NARS scientists and extension specialists in the PHM approach.

Cassava, the hardy staple of over 200 million Africans may not be the most nutritionally preferred food crop, but despite its susceptibility to certain important pests, it has a formidable potential to survive and recover from damage and to grow even under very unfavourable conditions. These features explain it's unique role in food security, especially in Africa. Paradoxically, this may be its biggest problem, since its hardiness has, in the past, diverted research toward more nutritious and often less robust crops.

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