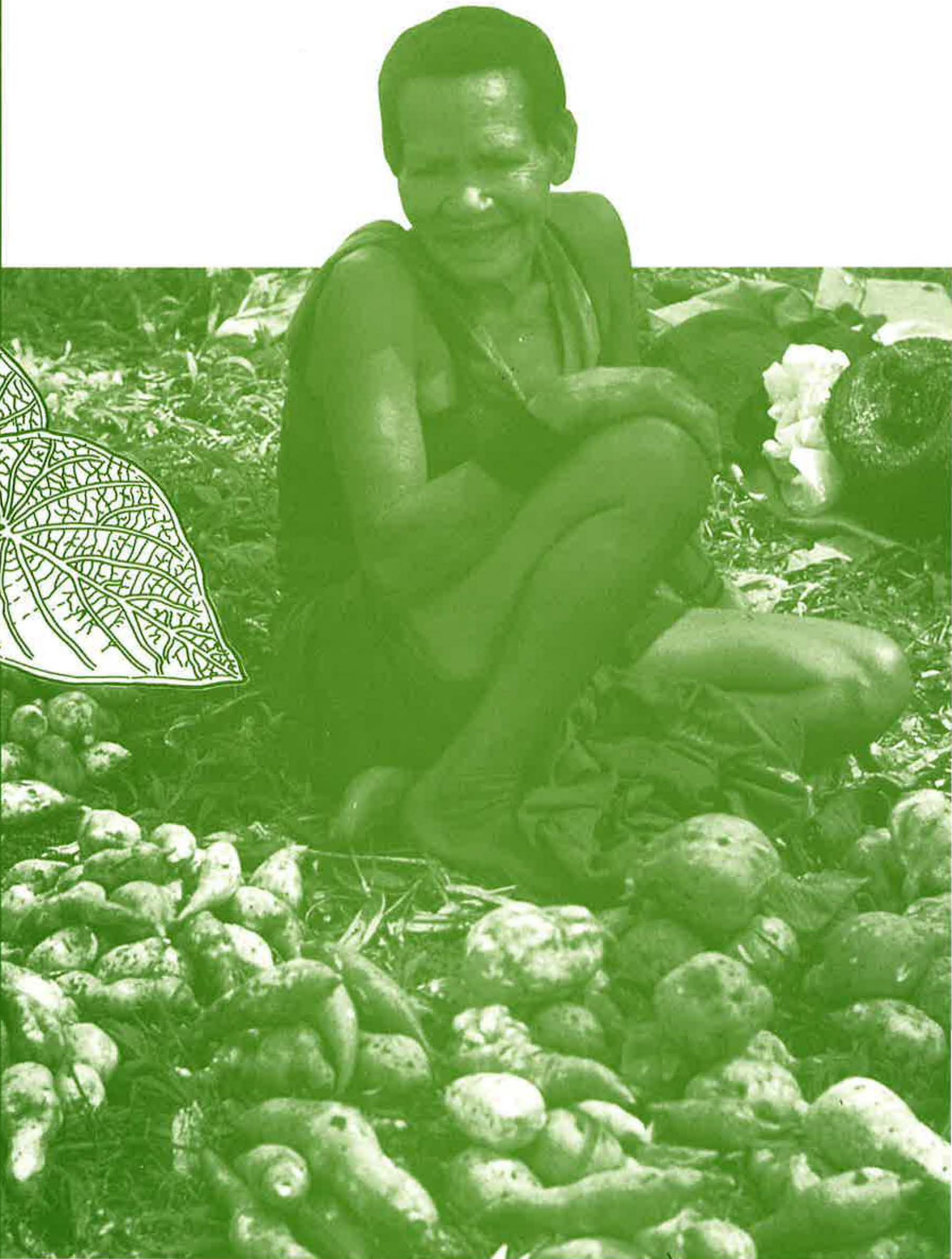
Natural Resources Institute

Bulletin No. 46

DISEASES AND PESTS OF SWEET POTATO



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DISEASES AND PESTS OF SWEET POTATO

SOUTH-EAST ASIA, THE PACIFIC AND EAST AFRICA

JILLIAN M. LENNÉ

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The Natural Resources Institute (NRI) is the scientific arm of Britain's Overseas Development Administration. NRI's principal aim is to increase the productivity of renewable natural resources in developing countries through the application of science and technology. Its areas of expertise are resource assessment and farming systems, integrated pest management, and food science and crop utilization.

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ABBREVIATIONS

AARD	Agency for Agricultural Research and Development (Indonesia)
ACIAR	Australian Centre for International Agricultural Research
AVRDC	Asian Vegetable Research and Development Center
BDDEA	British Development Division East Africa
BORIF	Bogor Research Institute for Food Crops (Indonesia)
CIAT	Centro Internacional de Agricultura Tropical
CIMMYT	Centro Internacional de Mejorimiento de Maiz y Trigo
CIP	Centro Internacional de la Papa
CRIFC	Central Research Institute for Food Crops (Indonesia)
DAL	Department of Agriculture and Livestock (Papua New Guinea)
EEC	European Economic Community
ESARRN	East and Southern African Rootcrops Research Network
FAO	Food and Agriculture Organization, United Nations
GTZ	German Agency for Technical Co-operation
IBPGR	International Board for Plant Genetic Resources
ICIPE	International Centre for Insect Physiology and Ecology
ICRISAT	International Centre for Research in the Semi-Arid Tropics
IDRC	International Development Research Centre
IIBC	CAB International Institute of Biological Control
IITA	International Institute of Tropical Agriculture
IRRI	International Rice Research Institute
ISAR	Institut des Sciences Agronomiques du Rwanda
ISNAR	International Service for National Agricultural Research
KARI	Kenya Agricultural Research Institute
MARIF	Malang Research Institute for Food Crops (Indonesia)
NAL	National Agriculture Laboratories (Kenya)
NRI	Natural Resources Institute
ODA	Overseas Development Administration
PRCRTC	Philippine Root Crop Research and Training Center
PRI	Plant Research Institute (Victoria, Australia)
SAPPRAD	South-east Asian Potato Production, Research and Development
UPLB	University of the Philippines, Los Baños

Summaries

SUMMARY

The bulletin reviews available information on biotic factors affecting sweet potato in eight countries in three important tropical production regions – south-east Asia, the Pacific, and east Africa. Information was obtained both from published reports, and directly from visits to key root- and tuber-crop research institutions and discussions with many researchers in the Philippines, Indonesia, Thailand, Papua New Guinea, Uganda, Rwanda and Kenya. The most important diseases and pests are identified; the current status of sweet-potato research is reviewed; and specific recommendations are made for future research in these countries.

Structure

The bulletin is divided into five sections. Section 1 outlines the importance of sweet potato in the regions and countries visited, and places the crop in a world perspective. Section 2 describes the many diverse agronomic practices used by farmers in the cultivation of sweet potato throughout south-east Asia, the Pacific and east Africa, and highlights implications for disease control strategies. Section 3 identifies and reviews the most important pests and diseases of sweet potato in the tropics. Section 4 summarizes the research resources available for sweet potato, including institutions, researchers, programmes and germplasm available in the countries visited. Section 5 makes specific recommendations for future research. The bulletin concludes with an extensive bibliography.

Section 1: The importance of sweet potato

Sweet potato is the world's second most important root and tuber crop. Of world production, 97% is from developing countries, with 86% being grown in China, 7% in the rest of Asia and 5% in Africa. Production and yield data provide a comparative assessment of the importance of the crop among countries, and within each country in relation to other major foods. Uses of both tubers and vines are described.

Section 2: Cultivation and agronomy

The location, diversity and complexity of traditional sweet potato production systems are described and compared on a country basis. Sweet potato is grown in monoculture or in intercropping or multiple-cropping systems; in rotation with fallow or a wide range of crops; and as single varieties or complex varietal mixtures. In south-east Asia, sweet potato is commonly grown in rotation with rice; in the highland areas of south-east Asia and the Pacific, it is generally rotated with fallow; while in east Africa, rotations involve a range of crops. Intercropping with maize, sorghum, legumes and cassava is common. Simple to complex varietal mixtures are widely grown in the Philippines, Papua New Guinea, Irian Jaya, Uganda and Rwanda. Cultivation practices include the use of a wide variety of mounds throughout Papua New Guinea, Irian Jaya, Uganda and Rwanda; compost mounding in Papua New Guinea and Irian Jaya; the "giu" technique of soil conservation in Papua New Guinea; and rice-straw mulching in Java. All of these agronomic and cultural practices may affect the incidence and severity of diseases and the success of control strategies. Major production problems and priorities for research on sweet-potato improvement are defined by key researchers in each country.

Section 3: Diseases and pests of sweet potato

DISEASES

Diseases of sweet potato caused by fungi, bacteria, a mycoplasma, viruses and nematodes are reviewed. Much research to date has been done on diseases of sweet potato in temperate developed countries. With the exceptions of scab (*Elsinoe batatas*) and little leaf mycoplasma (LLM) in south-east Asia and the Pacific, and viruses in Africa, limited work has been done in the tropics. The most damaging diseases in the regions under study are viruses, scab, LLM and Alternaria diseases. Information on the importance, distribution and current control strategies of these diseases is reviewed.

Scab: Leaf and stem scab caused by the fungus *Elsinoe batatas* is the most serious disease of sweet potato throughout south-east Asia and the Pacific. Control strategies include chemicals, cultural practices, sanitation – especially the use of scab-free planting material – and resistant varieties.

Alternaria diseases: The complex of diseases of sweet potato, caused by at least five different species of *Alternaria*, is described. One of these, stem blight, is becoming increasingly important in east Africa and Papua New Guinea. The association of stem blight with acid, infertile soils in Rwanda and Burundi is discussed. Potential sources of resistance have been identified.

Little leaf mycoplasma: LLM of sweet potato, caused by mycoplasma-like organisms and reported throughout Asia and the Pacific region, is reviewed. LLM is more severe under dry conditions which favour its two leaf-hopper vectors *Orosius lotophagorum* and *Nesophrosyne ryukyuensis*. Control strategies including sanitation and quarantine, cultural practices, chemical control and resistance are described.

Viruses: The common and widespread observation of virus-like symptoms on sweet potato, but generally poor understanding of the causal viruses and sweet potato virus pathosystems, is highlighted. At least 16 different viruses described on sweet potato world-wide are reported. The best known and most widely distributed is sweet potato feathery mottle virus (SPFMV), a potyvirus, four strains of which have been described. Sweet potato virus disease complex (SPVDC), a complex of SPFMV and a whitefly-borne sweet potato virus-like agent (SPVLA), is known only from Africa and Israel. A complex of SPFMV and sweet potato mild mottle virus (SPMMV) also occurs in east Africa causing similar symptoms to SPVDC. Other viruses reported from Asia, the Pacific and east Africa include SPMMV, a potyvirus from Africa; sweet potato caulimo-like virus (SPCLV) from Puerto Rico, the Pacific and east Africa; sweet potato latent virus (SPLV), a potyvirus; sweet potato yellow dwarf virus (SPYDV) and sweet potato leaf curl virus (SPLCV) from Taiwan; sweet potato ringspot virus (SPRV) from Papua New Guinea; and sweet potato phytoreo virus (SPRLV) from Thailand. Important strategies for control include production and dissemination of virus-free planting material, and resistant varieties.

Nematodes: Root-knot nematode *Meloidogyne incognita* and the reniform nematode *Rotylenchus reniformis* are described as the most important nematodes affecting sweet potato. *Meloidogyne incognita* is widespread and often serious while *R. reniformis* is common in tropical regions. In many cases serious losses are caused by poor cultural practices such as continuous cropping on nematode-infested soils. Control strategies for both nematodes include cultural practices such as crop rotation and use of nematode-free planting material; chemical treatment of soil and planting material; and resistance. The finding of high levels of resistance to *M. incognita* in land-race germplasm from Papua New Guinea, Indonesia (Irian Jaya) and the Philippines is discussed. A lack of information on nematodes of sweet potato in Kenya, Uganda and Rwanda is noted.

PESTS

Insect pests of sweet potato are briefly reviewed through surveys reported from temperate and tropical regions. The complex of weevils, *Cylas* spp., is the key problem of sweet potato world-wide. In Indonesia, the Philippines, Thailand and Papua New Guinea, the only important pest of sweet potato is the weevil *C. formicarius*. In east Africa, *Cylas* spp. weevils are the most important pests; however, the sweet potato butterfly *Acraea acerata* and clear wing moths (*Synanthedon* spp.) can cause serious damage.

Weevil: Cylas spp. weevils are the most damaging pests of sweet potato world-wide. *Cylas formicarius* is the most widespread and is the only species occurring in south-east Asia and the Pacific. Three species are found in east Africa: *C. puncticollis* and *C. brunneus* in addition to *C. formicarius*. Weevils are generally more important under dry conditions and in traditional systems where tubers are harvested sequentially. Strategies for control include cultural practices, chemicals, biological control, resistance and IPM. The diversity of cultural control strategies is described. Although low-cost, effective chemical control strategies have been developed for small farmers in several countries, chemicals are rarely used (except by commercial producers in Thailand). Work on a sex pheromone for *C. formicarius* is reviewed. The somewhat controversial subject of resistance to *Cylas* weevils is discussed and recent findings of antibiosis described. Biological control for *Cylas* spp. weevils with the entomopathogenic fungi *Metarhizium anisopliae* and *Beauvaria* species has potential in several countries. IPM is the most appropriate control strategy for *Cylas* spp. weevils in developing countries. An IPM strategy developed by AVRDC for the control of *C. formicarius*, emphasizing cultural and chemical control, is described. The urgent need for development of IPM strategies for control of weevils in east Africa is stressed.

Clear wing moth, sweet potato butterfly: In east Africa, clear wing moths (*Synanthedon* spp.) and the sweet potato butterfly (*Acraea acerata*) can cause serious damage to sweet potato. Clear wing moth larvae tunnel through stems causing yield loss and plant death, while the sweet potato butterfly can cause complete destruction of stands under dry conditions. The need to develop low-cost control strategies applicable to small farmers is indicated.

ROLE OF WILD SPECIES OF IPOMOEA

That wild species of *Ipomoea* influence the importance of diseases and pests of sweet potato is discussed. There is growing interest in the potential of wild germplasm as a source of resistance to

Cylas spp. weevils, viruses and nematodes. Identification of stem resistance to *C. formicarius* in *I. trifida* and its incorporation into the crop is briefly described. The importance of *Ipomoea* spp. weeds as hosts of *C. formicarius*, LLM, fungal, bacterial and viral pathogens is documented. The present survey provides further information on the role of *Ipomoea* spp. as hosts of scab and of *Alternaria* spp. Reference is made to wild tuber-forming *Ipomoea* spp. as sources of food for indigenous cultures in east Africa and the Pacific.

Section 4: Research resources

Research resources including institutions, researchers, programmes and germplasm for sweet-potato research in south-east Asia, the Pacific and east Africa are reviewed.

SOUTH-EAST ASIA AND THE PACIFIC

In Indonesia, the Central Research Institute for Food Crops (CRIFC) at Bogor co-ordinates research activities for all food crops through six research institutions: BORIF, SURIF, MARIF, SARIF, BARIF and MORIF. BORIF and MARIF are the key root- and tuber-crop centres. Strong links with donor agencies and international centres of the CGIAR, especially CIP for sweet potato, are important to the implementation of CRIFC's agricultural research programme.

In the Philippines, the Philippines Root Crop Research and Training Centre (PRCRTC) at Visca, Leyte co-ordinates all research on sweet potato. Other important institutions working on sweet potato include the Northern PRCRTC, Baguio; the University of the Philippines, Los Baños; the Plant Breeding Institute, Los Baños; and Department of Agriculture Research Stations located in important sweet potato-growing areas. Research is partly supported by donor agencies and CIP, whose Region VII Programme for south-east Asia is based at Los Baños.

Responsibilities for research on sweet potato in Papua New Guinea are shared by Kuk Research Station in the highlands and Laloki Research Station in the lowlands. There is no national sweet potato programme. The importance of Papua New Guinea as a centre of diversity for sweet-potato germplasm and the implications for sweet-potato improvement are discussed.

In Thailand, research on sweet potato is carried out by the Horticultural Research Institute of the Department of Agriculture and Pichit Research Centre. Some research is supported by CIP.

EAST AFRICA

In Uganda, the National Root and Tuber Crops Improvement Programme, based at Namulonge Research Station near Kampala, directs most resources into its evaluation and breeding programme. Although IDRC has provided some support for research on root and tuber crops, the lack of support for sweet-potato research in Uganda is stressed.

The National Sweet Potato Improvement Programme of Rwanda is based at ISAR, Rubona and has an active breeding programme utilizing superior local and introduced germplasm for production of improved varieties. Multi-locational screening and on-farm testing are well developed. The high potential impact from international support for controlled screening for resistance to biotic factors limiting production in Rwanda is stressed. The well-organized system of multiplication plots, developed by the national programme, ensures that farmers have adequate supplies of planting material of improved varieties throughout the year, and is described as a model system for other countries facing the same problem.

In Kenya, sweet-potato research is carried out by KARI Research Stations located at Kisii, Kakamega, Katumani and Mtwapa. Kisii has recently been identified as the National Sweet Potato Germplasm Centre. The activities of the productive, long-term sweet potato-breeding programme at Katumani Research Station are described. International organizations including CIBC and CIP are also actively working on sweet-potato improvement in Kenya. CIBC co-ordinates an IDRC-funded project on integrated control of arthropod pests of root and tuber crops, including *Cylas* spp. weevils of sweet potato. CIP's Region III Programme for east and southern Africa is based in Nairobi.

Section 5: Recommendations

CULTIVATION AND AGRONOMY

Sweet potato production systems based on traditional land races and cultural practices in the highlands of Papua New Guinea, the Philippines, western Kenya and Rwanda have been developed over a long period. Such traditional systems are facing change from improved varieties and new cultural technologies. Characterization of traditional systems before major changes are made, and the development of new varieties and technologies applicable to traditional systems, are strongly recommended. There is also a need to determine the effect of complex traditional cultural practices on control strategies for diseases and pests.

The supply of planting material (especially disease- and pest-free material) to farmers was seen as a major problem in all countries visited except Rwanda. Although it is strongly recommended that the Rwandan system be used as a model, the system can be further improved by ensuring that initial stocks are disease- and pest-free and by locating multiplication plots in protected sites. Low soil fertility is an increasingly important problem: research on improved soil fertility management is needed. The possibility of applying traditional methods (or modifications of them) from country to country should be considered.

Simple storage and village-oriented processing technologies are needed to reduce the reliance of small farmers on sequential harvesting, which can result in increased problems with sweet potato weevils.

Research on varietal mixtures of crops has focussed on their role in disease control. Complex varietal mixtures are common in many traditional sweet potato production systems. Characterization of mixtures, especially for reactions to diseases and pests, would provide information on their contribution to disease and pest control and could lead to the wider application of mixtures as a control strategy.

DISEASES AND PESTS

International co-ordination would improve research already in progress on scab, the most important disease problem in south-east Asia and the Pacific. A standardized inoculation and evaluation methodology is needed, and the extent of pathogenic variation in *Elsinoe batatas* should be determined to support the development of scab-resistant varieties. Studies on the epidemiology of the pathogen, especially in complex cropping systems, would contribute to the development of control strategies.

Characterization of the complex of *Alternaria* species implicated in Alternaria stem blight, and development of standardized glasshouse and field methodologies, are needed to facilitate selection of resistant varieties. Research is needed to elucidate the apparent relationship between stem blight and less fertile soils.

Further definition of the restricted distribution of LLM throughout sweet potato-growing regions in the tropics would be worthwhile, especially to identify areas where sweet potato might escape LLM, such as the highlands of Papua New Guinea. Selection for resistance to leaf-hopper vectors, and the development of an IPM programme for LLM, are proposed.

Present problems with viruses could be reduced by cleaning up important varieties followed by rapid multiplication and dissemination of clean planting material. Results of the 6-year ACIAR project on the development of pathogen-tested varieties in selected countries of south-east Asia and the Pacific should provide important background. Systematic surveys and characterization of viruses are also needed in most countries. Basic support through virus indexing is needed for all countries with active breeding programmes which include selection for resistance to viruses.

The considerable amount of effort directed at *Cylas* spp. weevils, especially *C. formicarius*, has developed well-researched and widely recommended control strategies: there is an urgent need for the wide application of these strategies either individually as cultural or low-cost chemical controls or in an IPM programme, for both *C. formicarius* and *C. puncticollis*, before further research is done. Site-specific modifications could then be made. Further research on developing resistant varieties with emphasis on stem resistance and field application of biological control strategies is also recommended.

Studies on clear wing moth and sweet potato butterfly in east Africa are needed to develop low-cost control strategies applicable to small farmers.

RESEARCH RESOURCES

Most national sweet potato programmes depend on international support to implement their research objectives. Lack of manpower is an important limiting factor. Many national root- and tuber-crop programmes would benefit from having international scientists based at their centres to work on diseases and pests of sweet potato.

Access to tissue culture facilities is needed in most countries to develop stocks of disease- and pest-free sweet potato varieties. Support is needed for collection, characterization and, especially, maintenance of germplasm resources in most countries.

RESUME

Le bulletin passe en revue les informations disponibles concernant les facteurs biotiques affectant l'igname dans huit pays de trois importantes régions productrices tropicales, à savoir le Sud Est asiatique, le Pacifique et l'Afrique de l'Est. Les informations ont été tirées aussi bien de rapports publiés que directement de visites effectuées auprès d'organismes clés de recherche sur les cultures des racines et des tubercules et de discussions avec nombre de chercheurs aux Philippines, en Indonésie, en Thailande, en Papouasie Nouvelle Guinée, en Ouganda, au Rwanda et au Kenya. Les maladies et les parasites les plus importants sont identifiés; la situation actuelle des

recherches concernant l'igname est passée en revue et il est formulé des recommandations spécifiques quant aux recherches futures dans ces pays.

Structure

Le bulletin est divisé en cinq sections. La Section 1 schématise l'importance de l'igname dans les régions et les pays visités et place la culture dans une perspective mondiale. La Section 2 décrit les multiples méthodes agronomiques différentes employées par les agriculteurs dans la culture de l'igname dans toute le Sud Est asiatique, le Pacifique et l'Afrique de l'Est et souligne les implications en matière de stratégies de lutte contre les maladies. La Section 3 identifie et passe en revue les parasites et les maladies les plus importants de l'igname dans les régions tropicales. La Section 4 récapitule les ressources en matière de recherches disponibles concernant l'igname, y compris les organismes, les chercheurs, les programmes et les plasmas germinatifs disponibles dans les pays visités. La Section 5 comporte des recommandations spécifiques quant aux recherches futures. En conclusion, le bulletin présente une bibliographie complète.

Section 1: Importance de l'igname

L'igname constitue la deuxième plus importante culture mondiale de racines et de tubercules. Parmi la production mondiale, 97% provient des pays en voie de développement, dont 86% est cultivé en Chine, 7% dans le reste de l'Asie et 5% en Afrique. Les données en matière de productions et de rendements fournissent une évaluation comparative de l'importance de la culture parmi les pays et, dans chaque pays relativement aux autres principaux produits alimentaires. Il est décrit les utilisations aussi bien des tubercules que des tiges.

Section 2: Culture et agronomie

L'implantation, la diversité et la complexité des systèmes traditionnels de production de l'igname sont décrits et comparés pays par pays. L'igname est cultivé selon des systèmes de monoculture ou d'inter-culture ou encore de polyculture; en rotation avec des jachères ou une large gamme de cultures; et en tant que variétés uniques ou de mélanges variétals complexes. L'igname, dans le Sud Est asiatique, est fréquemment cultivé en rotation avec le riz; dans les régions montagneuses du Sud Est asiatique et du Pacifique il est généralement cultivé en rotation avec le système de jachères, tandis qu'en Afrique de l'Est, les rotations font intervenir une gamme de cultures. L'inter-culture avec le maïs, le sorgho, les légumineuses et le manioc est courante. Il est largement cultivé des mélanges variétals allant de simples à complexes dans les Philippines, la Papouasie Nouvelle Guignée, l'Irian Jaya, l'Ouganda et le Rwanda. Parmi les méthodes de culture, citons la mise en oeuvre d'une large variété de buttes dans toute la Papouasie Nouvelle Guinée, l'Irian Jaya, l'Ouganda et le Rwanda; les buttes de compost en Papouasie Nouvelle Guinée et en Irian Jaya; la technique "giu" de conservation des sols en Papouasie Nouvelle Guinée et la couverture de paille de riz à Java. Toutes ces pratiques agronomiques et de culture peuvent affecter l'incidence et la gravité des maladies ainsi que le succès des stratégies de lutte. Il est défini, répartis par chercheur clé dans chaque pays, les principaux problèmes de la production et les priorités au plan des recherches concernant les améliorations de l'igname.

Section 3: Maladies et parasites de l'igname

MALADIES

Les maladies de l'igname provoquées par les champignons, les bactéries, un mycoplasme, les virus et les nématodes sont passées en revue. A ce jour, d'importantes recherches ont été effectuées quant aux maladies de l'igname dans les pays développés tempérés. A l'exception de la gale (*Elsinoe batatas*), et du mycoplasme petite feuille (LLM) dans le Sud Est asiatique et le Pacifique et les virus en Afrique, il n'a été effectué en Afrique que des études restreintes. Les maladies les plus dévastatrices dans le régions à l'étude sont les virus, la gale, le LLM et les maladies *Alternaria*. Il est passé en revue les informations concernant l'importance, la répartition et les stratégies actuelles de lutte contre ces maladies.

Gale: La gale des feuilles et des tiges provoquées par le champignon *Elsinoe batatas* représente la maladie la plus grave de l'igname dans tout le Sud Est asiatique et le Pacifique. Parmi les stratégies de lutte citons les produits chimiques, les méthodes de culture, les systèmes sanitaires – et plus particulièrement l'emploi de semis exempts de gale – et les variétés résistantes.

Maladies Alternaria: Le complexe des maladies de l'igname, provoquées par au moins cinq espèces différentes d'*Alternaria*, fait l'objet d'une description. Parmi celles-ci, la gale des tiges prend une importance croîssante en Afrique de l'Est et en Papouasie Nouvelle Guinée. L'association de la gale des tiges avec les sols acides et infertiles au Rwanda et au Burundi fait l'objet d'une discussion. Les sources potentielles de résistance ont été identifiées.

Mycoplasme petite feuille: Il est passé en revue le LLM de l'igname, provoqué par des organismes de type mycoplasmes et dont la présence est signalée dans toute l'Asie et le Pacifique. Le LLM est plus sévère dans les conditions de sécheresse qui favorisent ses deux vecteurs de cicadelles, à savoir *Osorius lotophagorum* et *Nesophrosyne ryukyuensis*. Parmi les stratégies de lutte, citons les systèmes sanitaires et de quarantaine, les méthodes de culture, la lutte et la résistance aux produits chimiques qui sont décrits.

Virus: L'observation courante et répandue des symptômes de type virus sur l'igname mais généralement une médiocre compréhension des virus d'origine et des pathosystèmes des virus de l'igname sont mis en évidence. Il est signalé au moins 16 virus différents décrits sur l'igname dans le monde entier. Le virus le plus connu et le plus largement réparti est le virus moucheté plumeux de l'igname (SPFMV), un potyvirus, dont quatre souches ont été décrites. Un complexe de maladie virale de l'igname (SPVDC), un complexe de SPFMV et un agent de type virus de l'igname porté par l'aleurode (SPVLA), n'est connu qu'en Afrique et en Israel. Une complexe de SPFMV et du virus moucheté bénin de l'igname (SPMMV) est aussi présent en Afrique de l'Est, provoquant des symptômes similaires à SPVDC. Parmi les autres virus signalés en provenance d'Asie, du Pacifique et d'Afrique de l'Est, citons le SPMMV, qui est un potyvirus provenant d'Afrique, un virus de type caulimo de l'igname (SPCLV) provenant de Peurto Rico, de Pacifique et de l'Afrique de l'Est; un virus latent de l'igname (SPLV), un potyvirus; un virus nain jaune de l'igname (SPYDV) et un virus des feuilles bouclées de l'igname (SPLCV) provenant de Taiwan; un virus de tache annulaire de l'igname (SPRV) provenant de Papouasie Nouvelle Guinée; et un virus phytoréo de l'igname (SPRLV) provenant de Thailande. Les importantes stratégies applicables à la lutte incorporent la production et la dissémination de semis exempts de virus ainsi que des variétés résistantes.

Nématodes: Le nématode noeud de racine *Meloidogyne incognita* et le nématode réniforme *Rotylenchus reniformis* sont décrits comme étant les nématodes les plus importants affectant l'igname. *Meloidogyne incognita* est largement répandu et est fréquemment grave, tandis que *R. reniformis* est commun dans les régions tropicales. Dans de nombreux cas, les pertes graves sont provoquées par des méthodes médiocres de culture telles que la culture ininterrompue sur des sols infestés de nématodes. Parmi les stratégies de lutte contre les deux nématodes, citons des méthodes de culture telles que la rotation et la mise en oeuvre de semis exempts de nématodes; le traitement chimique des sols et les semis ainsi que la résistance. L'observation de niveaux élevés de résistance à *M. incognita* dans les plasmas germinatifs de races terrestres provenant de Papouasie Nouvelle Giunée, d'Indonésie (Irian Jaya) et des Philippines fait l'objet d'une discussion. Il est pris note de la pénurie d'informations concernant les nématodes de l'igname au Kenya, en Ouganda et au Rwanda.

PARASITES

Les insectes parasites de l'igname sont brièvement passés en revue grâce à des études effectuées dans des régions tempérées et tropicales. Le complexe des charançons, esp. *Cylas*, constitue le problème clé de l'igname dans le monde entier. Le seul parasite important de l'igname, en Indonésie, aux Philippines, en Thailande et en Papouasie Nouvelle Guinée, est le charançon *C. formicarius*. En Afrique de l'Est, les charançons des espèces *Cylas* sont les parasites les plus importants; néanmoins, le papillon de l'igname, à savoir *Acraea acerata* et les teignes à ailes transparentes (espèces *Synanthedon*) peuvent provoquer de grave dégâts.

Charançons. Les espèces de charançons *Cylas* sont les parasites les plus dévastateurs de l'igname dans le monde entier. *Cylas formicarius* est le plus répandu et est la seule espèce observée dans le Sud Est asiatique et le Pacifique. Il est observé trois espèces en Afrique de l'Est: *C. puncticollis* et *C. brunneus* en plus de *C. formicarius*. Les charançons sont en général plus nombreux dans les conditions de sécheresse et dans les systèmes traditionnels faisant intervenir la récolte séquentielle des tubercules. Les stratégies de lutte englobent les méthodes de culture, les produits chimiques, la lutte biologique, la résistance et la lutte intégrée anti-parasites (IPM). La diversité des stratégies en matière de lutte en faveur des cultures est décrite. Bien qu'il ait été mis au point des stratégies de lutte au moyen de produits chimiques aussi efficaces que peu onéreux pour les petits agriculteurs dans plusieurs pays, les produits chimiques ne sont que rarement utilisés (à l'exception de producteurs commerciaux en Thailande). Les travaux concernant une phéromone sexuelle pour *C. formicarius* sont passés en revue. Le sujet quelque peu controversé de la résistance aux charançons *Cylas* est étudié et les résultats récents de l'antibiose sont décrits. La lutte biologique contre les charançons des espèces *C. formicarius* avec le champignon entomopathogénique des espèces *Metarhizium anisopliae* et *Beauvaria* présente des possibilitiés dans plusieurs pays. IPM constitue la stratégie de lutte la mieux adaptée contre les charançons des espèces *Cylas* dans les pays en voie de développement. Une stratégie IPM mise au point par AVRDC pour la lutte contre *C. formicarius*, faisant ressortir la lutte au moyen des produits chimiques et les méthodes de culture est décrite. Il est fait ressortir le besoin urgent au plan de la mise au point de stratégies IPM pour la lutte contre les charançons dans l'Afrique de l'Est.

Teigne à ailes transparentes, papillon de l'igname. En Afrique de l'Est, les teignes à ailes transparentes (esp. *Synanthedon*) ainsi que le papillon de l'igname (*Acraea acerata*) peuvent provoquer des dégats importants à l'igname. Les larves de *Synanthedon* forent des tunnels dans les tiges, entraînant des pertes de rendements et la destruction de la plante, tandis que le papillon de l'igname peut provoquer la destruction totale des pieds pendant les conditions de sécheresse. Il est signalé la nécessité de mettre au point des stratégies de lutte peu onéreuses convenant aux petits agriculteurs.

RÔLE DES ESPÈCES SAUVAGES D'*IPOMOEA*

Il est discuté l'influence des espèces sauvages d'*Ipomoea* sur l'importance des maladies et des parasites de l'igname. On observe un intérêt croîssant dans le potentiel des plasmas germinatifs sauvages en tant que source de résistance aux charançons des espèces *Cylas*, des virus et des nématodes. L'identification de la résistance des tiges à *C. formicarius* dans *I. trifida* et son incorporation dans la culture font l'objet d'une description résumée. L'importance des mauvaises herbes des espèces *Ipomoea* en tant qu'hôtes de *C. formicarius*, et les pathogènes LLM, fongiques, bactériens et viraux sont documentés. La présente étude fournit d'autres renseignements concernant le rôle des espèces d'*Ipomoea* en tant qu'hôtes de la gale et des espèces d'*Alternaria*. Il est fait référence aux espèces sauvages d'*Ipomoea* formant des tubercules en tant que sources d'aliments dans les cultures indigènes en Afrique de l'Est et dans le Pacifique.

Section 4: Ressources en matière de recherche

Les ressources en matière de recherche, y compris les organismes, les chercheurs, les programmes et les plasmas germinatifs pour la recherche sur l'igname dans le Sud Est asiatique, le Pacifique et l'Afrique de l'Est sont passés en revue.

SUD EST ASIATIQUE ET PACIFIQUE

En Indonésie, l'Institut central de recherche pour les cultures vivrières (CRIFC) à Bogor, assure la coordination des activités de recherche pour toutes les cultures vivrières par le truchement de six organismes de recherche: BORIF, SURIF, MARIF, SARIF, BARIF, et MORIF. BORIF et MARIF sont les centres clés traitant des cultures de racines et de tubercules. Les rapports étroits existant avec les agences donatrices et les centres internationaux de CGIAR, et plus particulièrement CIP pour l'igname, sont importants dans la mise en oeuvre du programme de recherche agricole de CRIFC.

Aux Philippines, le Centre de recherche et de formation des cultures de racines aux Philippines (PRCRTC) à Visca, Leyte, assure la coordination de toutes les recherches concernant l'igname. Parmi les autres importants organismes travaillant sur l'igname, citons le PRCRTC Nord, Baguio, L'Université des Philippines, Los Baños, l'Institut d'élevage des plantes, Los Baños, et les stations de recherche du département de l'agriculture implantées dans d'importantes régions de culture de l'igname. Les recherches sont en partie prises en charge par les agences donatrices et CIP, dont le programme régional VII pour le Sud Est asiatique est basé à Los Baños.

La station de recherche de Kuk dans les régions montagneuses et la station de recherche de Laloki, dans les régions de plaines, partagent les responsabilités concernant les recherches sur l'igname en Papouasie Nouvelle Guinée. Il n'existe pas de programme national en faveur de l'igname. L'importance de la Papouasie Nouvelle Guinée en tant que centre de diversité de plasmas germinatifs d'igname ainsi que les implications quant aux améliorations de cette plante sont étudiées.

En Thailande, les recherches concernant l'igname sont effectuées par l'Institut de recherche d'horticulture du département de l'agriculture et du centre de recherche de Pichit. CIP finance une partie des recherches.

AFRIQUE DE L'EST

En Ouganda, le Programme national d'amélioration des cultures de racines et de tubercules, basé à la station de recherche de Namulonge près de Kampala, consacre la plupart de ses ressources à son évaluation et à son programme d'élevage. Bien qu'IDRC ait mis à disposition une certaine assistance en matière de recherche sur les cultures de racines et de tubercules, il est fait ressortir la pénurie de soutien quant aux recherches sur l'igname en Ouganda.

Le Programme national d'amélioration de l'igname au Rwanda est basé à ISAR, Rubona et dispose d'une programme actif d'élevage, faisant appel à des plasmas germinatifs locaux et introduits de haute qualité pour la production de variétés améliorées. La sélection multi-implantations et les essais sur les exploitations agricoles sont bien développés. Il est fait ressortir l'impact potentiel élevé de l'aide internationale en matière de sélection régulée pour la résistance aux facteurs biotiques restreignant la production au Rwanda. Le système bien organisé de parcelles de multiplication, mis au point par le Programme national, permit de s'assurer que les exploitants agricoles disposent d'approvisionnements suffisants de semis de variétés améliorées pendant toute l'année et est décrit en tant que système modèle pour les autres pays confrontés au même problème.

Au Kenya, les stations de recherche KARI, implantées à Kisii, Kakamega, Katumani et Mtwapa, effectuent des recherches sur l'igname. La station de Kisii a été récemment désignée en tant que Centre national de plasmas germinatifs de l'igname. Il est décrit les activités du programme productif et à long terme d'élevage de l'igname de la station de recherche de Katumani. Les organismes internationaux, y compris CIBC et CIP participent aussi activement à l'amélioration de l'igname au Kenya. CIBC assure la coordination d'un projet financé par IDRC portant sur la lutte intégrée contre les parasites arthropodes des cultures de racines et de tubercules, y compris les charançons des espèces *Cylas* de l'igname. Le programme régional III de CIP applicable à l'Afrique de l'Est et australe est basé à Nairobi.

Section 5: Recommandations

CULTURE ET AGRONOMIE

Le développement des systèmes de production de l'igname basés sur les races terrestres et les méthodes de culture traditionnelles des régions montagneuses de la Papouasie Nouvelle Guinée, des Philippines, du Kenya occidental et du Rwanda a nécessité de nombreuses années. De tels systèmes traditionnels sont confrontés à l'evolution découlant de l'introduction de variétés améliorées et de nouvelles technologies de culture. La caractérisation des systèmes traditionnels avant d'apporter d'importants changements et la mise au point de nouvelles variétés et technologies applicables aux systèmes traditionnels sont fortement recommandées. Il existe aussi un besoin de détermination des répercussions des méthodes de culture traditionnelles complexes sur les stratégies de lutte contre les maladies et les parasites.

La fourniture de semis (et plus particulièrement de semis exempts de maladies et de parasites) aux exploitants agricoles a été perçue comme constituant un problème majeur dans tous les pays visités, à l'exception du Rwanda. Bien qu'il soit fortement recommandé que le système de ce dernier pays soit employé à titre de modèle, ce système peut encore être amélioré en s'assurant que les stocks d'origine sont exempts de maladies et de parasites et en implantant les parcelles de multiplication dans des sites protégés. La faible fertilité des sols constitue un problème d'importance croîssante: il est nécessaire que des recherches concernant une gestion améliorée de la fertilité des sols soient effectuées. On devra aussi tenir compte de la possibilité d'appliquer les méthodes traditionnelles (ou des modifications de ces méthodes) d'un pays à l'autre.

Des installations simples d'entreposage et des technologies à vocation de villages sont exigées afin de réduire la nécessité des récoltes séquentielles effectuées par les petits exploitants agricoles, ces types de récoltes étant en effet susceptibles d'accroître les problèmes de charançons de l'igname.

Les recherches effectuées quant aux mélanges variétals de cultures se sont concentrées sur leur rôle dans la lutte contre les maladies. De complexes mélanges variétals sont courants dans nombre de systèmes traditionnels de production de l'igname. La caractérisation des mélanges, et tout spécialement en ce qui concerne les réactions aux maladies et aux parasites, fournirait des informations sur leur contribution à la lutte contre les maladies et les parasites et pourrait conduire à l'application plus large des mélanges en tant que stratégie de lutte.

MALADIES ET PARASITES

La coordination internationale permettrait d'améliorer les recherches actuellement en cours concernant la gale, qui constitue le plus important problème dans le Sud Est asiatique et le Pacifique. Une inoculation standardisée et une méthodologie dévaluation sont exigées et l'envergure de la variation pathogénique chez *Elsinoe batatas* devra être déterminée afin de soutenir la mise au point de variétés résistantes à la gale. L'exécution d'études portant sur l'épidémiologie du pathogène, et plus spécialement dans les systèmes complexes de culture, apporterait une contribution à la mise au point de stratégies de lutte.

La caractérisation du complexe des espèces d'*Alternaria* intervenant dans la rouille des tiges et la mise au point de méthodologies de terrain et de serres standardisées, sont nécessaires afin de faciliter la sélection de variétés résistantes. Des recherches sont exigées afin d'elucider les rapports apparents existant entre la rouille des tiges et les sols de médiocre fertilité.

Il serait digne d'intérêt d'avoir une définition complémentaire de la répartition restreinte de LLM dans toutes les zones de culture de l'igname dans les régions tropicales et plus particulièrement afin d'identifier les zones dans lesquelles l'igname pourrait échapper à LLM, par exemple les régions montagneuses de la Papouasie Nouvelle Guinée. Il est proposé la sélection en faveur de la résistance aux vecteurs d'aleurodes et la mise au point d'un programme IPM pour LLM.

Les problèmes actuels observés avec les virus pourraient être réduits en effectuant l'épuration des variétés importantes, suivie de la multiplication et de la dissémination rapide de semis sains. Les résultats du projet ACIAR de 6 ans concernant la mise au point de variétés testées aux pathogènes dans certains pays sélectionnés du Sud Est asiatique et du Pacifique devraient fournir d'importantes données de fond. Il est aussi exigé des études et caractérisations systématiques des virus dans la plupart des pays. Une assistance fondamentale, par l'intermédiaire de l'indexation des virus, est exigée pour tous les pays ayant des programmes actifs d'élevage, incorporant la sélection au plan de la résistance aux virus.

Les efforts considérables effectués en ce qui concerne les charançons des espèces *Cylas*, et plus particulièrement *C. formicarius*, ont permis de développer des stratégies de lutte bien documentées et largement préconisées: il existe un besoin urgent quant à l'élargissement de l'application de ces stratégies, soit à titre individuel en tant qu'agents de contrôle chimique à bon marché et des cultures, soit dans un programme IPM, aussi, bien pour *C. formicarius* que pour C. puncticollis, préalablement à l'exécution de recherches complémentaires. Des modifications spécifiques au site pourraient alors être effectuées. Il est par ailleurs préconisé d'exécuter des recherches complémentaires en matière d'élaboration de variétés résistantes, en faisant ressortir la résistance des tiges et l'application de terrain de stratégies de lutte biologique.

Des études concernant la teigne à ailes transparentes et le papillon de l'igname en Afrique de l'Est sont exigées afin de mettre au point des stratégies de lutte peu onéreuses et convenant aux petits exploitants.

RESSOURCES EN MATIÈRE DE RECHERCHES

La plupart des programmes nationaux concernant l'igname sont tributaires de l'aide internationale pour la mise en vigueur de leurs objectifs de recherche. Un important facteur limitatif est constitué par la pénurie de main-d'oeuvre. Nombre de programmes nationaux d'études sur les cultures de racines et de tubercules tireraient un grand parti de la présence de scientifiques internationaux basés dans leurs centres pour travailler sur les maladies et les parasites de l'igname.

L'accès à des aménagements de cultures tissulaires est exigé dans la plupart des pays afin de mettre au point des stocks de variétés d'ignames exempts de maladies et de parasites. Il est par ailleurs exigé de l'assistance en matière de rassemblement, de caractérisation et plus particulièrement de tenue à jour de ressources de plasmas germinatifs dans la plupart des pays.

RESUMEN

El boletin pasa revista a la información disponible sobre los factores bióticos que afectan al boniato en ocho países de tres importantes regiones tropicales, a saber, Sureste Asiático, zona del Pacifico y Africa Oriental. La información se obtuvo de informes publicados y, directamente, de las visitas realizadas a importantes instituciones de investigación sobre raíces comestibles y tubérculos, así como de conversaciones habidas con numerosos investigadores de Filipinas, Indonesia, Tailandia, Papúa Nueva Guinea, Uganda, Rwanda y Kenia. Además de las identificación de las enfermedades y plagas más importantes, se pasa revista al estado actual de las investigaciones sobre el boniato y se presentan recomendaciones especificas sobre futuros trabajos de investigación en los antedichos países.

Estructura

El boletin se encuentra dividido en cinco secciones. En la Sección 1, se pone de relieve la importancia del boniato en las regiones y países visitados, situándose este cultivo dentro de una perspectiva mundial. En las Sección 2, se describen las múltiples práticas agronómicas utilizadas por los agricultores en el cultivo del boniato por el Sureste Asiático, zona del Pacifico y Africa Oriental y se subrayan las consecuencias para una estrategia de control de las enfermedades. En las Sección 3, se identifica y pasa revista a las principales plagas y enfermedades del boniato en los Trópicos, mientras que, en la Sección 4, se presenta un resumen de los recursos de investigación disponibles para el boniato, incluyendo las instituciones, investigadores, programas y material genético disponible en los países visitados. En la Sección 5, se presentan recomendaciones específicas para futuros trabajos de investigación. El boletin acaba con una amplia bibliografia.

Sección 1: Importancia del boniato

A escala mundial, el boniato es el segundo tubérculo/raíz comestible más importante, procediendo el 97% de su producción mundial de países en desarrollo (China, 86%; otros países asiáticos 7% y Africa 5%). Los datos de producción y rendimiento proprocionan una evaluación comparativa de la importancia de este cultivo entre países y, dentro de cada país, en relación con otros alimentos de importancia. También se describen los usos de los tubérculos y vides.

Sección 2: Cultivo y agronomía

En esta sección se lleva a cabo una descripción y comparación, país por país, de la ubicación, diversidad y complejidad de los sistemas tradicionales de producción de boniatos. El boniato se cultiva a manera de monocultivo, como cultivo intermedio o como parte de sistemas de cultivos sucesivos; en rotación con barbechos o con una amplia gama de cultivos; y a manera de variedades únicas o de mezclas complejas de variedades. En el Sureste Asiático, el boniato se cultiva, generalmente, en rotación con el arroz. En las tierras altas del Sureste Asiático y en el Pacifico, su cultivo tiene lugar, generalmente, en rotación con barbechos, mientras que en la región oriental de Africa, se cultiva en rotación con productos diversos. También es frecuente su cultivo intermideo con maíz, sorgo, legumbres y mandioca. En Filipinas, Papúa Nueva Guinea, Irian Jaya, Uganda y Rwanda se cultivan, de manera generalizada, mezclas de variedades sencillas y complejas. Entre las prácticas de cultivo valga citar el empleo de una vasta variedad de montones en Papúa Nueva Guinea, Irian Jaya, Uganda y Rwanda; montones de compost en Papúa Nueva Guinea e Irian Jaya; la técnica 'giu' de conservación de suelos en Papúa Nueva Guinea y cubrición del suelo con paja de arroz, en Java. Todas estas prácticas agronómicas y de cultivo pueden ejercer cierta influencia sobre la incidencia e importancia de las enfermedades y sobre el éxito de las estrategias de control. Importantes investigadores de cada país definen los principales problemas de producción y las prioridades de investigación para la mejora del boniato.

Sección 3: Enfermedades y plagas del boniato

ENFERMEDADES

En esta sección, se pasa revista a las enfermedades del boniato causadas por mohos, bacterias, un micoplasma, virus y nematodos. Son considerables los trabajos de investigación realizados hasta la fecha sobre enfermedades del boniato en países desarrollados de clima templado. Si se exceptúa la roña (*Elsinoe batatas*) y el micoplasma de las hojas pequeñas (LLM) en el Sureste Asiático y en el Pacifico, y los virus en Africa, apenas si se ha llevado a cabo trabajo alguno de investigación en los Trópicos. Las enfermedades con mayor impacto en las zonas bajo estudio son los virus, la roña, el LLM y las enfermedades producidas por la *Alternaria*. En esta sección, se examina la información existente sobre la importancia, distribución y estrategias actuales de control de dichas enfermedades.

Roña: La roña del tallo y de las hojas, producida por el moho *Elsinoe batatas* es la más seria enfermedad del boniato por todo el Sureste Asiático y región del Pacifico. Entre las estrategias de control valga citar la aplicación de productos químicos, prácticas de cultivo, higiene — particularmente, el empleo de material de plantío libre de roña — y variedades resistentes.

Enfermedades de la Alternaria: Se describe aquí el complejo de enfermedades del boniato, causadas por un mínimo de cinco especies distintas de *Alternaria*. Una de ellas — el tizón del tallo — está adquiriendo una importancia cada vez mayor en la región oriental de Africa y en Papúa Nueva Guinea. También se examina la asociación del tizón del tallo con tierras ácidas e infértiles en Rwanda y Burundi. Se han identificado posibles fuentes de resistencia.

Micoplasma de la hojas pequeñas (LLM): Se estudia aquí el LLM del boniato, causado por organismos micoplasmoides observados por todo el Continente Asiático y región del Pacífico. El impacto del LLM es más serio bajo condiciones secas, que facorecen el desarrollo de sus dos vectores, las cigarras saltadoras *Orosius lotophagorum* y *Nesophrosyne ryukyuensis*. Entre las estrategias de control descritas se cuentan la higiene y cuarentena, prácticas de cultivo, control químico y resistencia.

Virus: Se pone de relieve la observación generalizada de síntomas virales en el boniato, si bien, en general, nuestra comprensión de los virus productores y de los patosistemas virales del boniato es pobre. A escala mundial, se han recibido informes de un mínimo de 16 virus distintos que afectan al boniato. Entre los más conocidos y de distribución más generalizada valga citar el virus productor de las manchas plumeadas del boniato (SPFMV) del que se describen cuatro varien-dades. El complejo morboso viral del boniato (SPVDC) es un complejo de SPFMV y de un agente viroide del boniato transmitido por las mosca blanca (SPVLA), conocido únicamente en Africa e Israel. En el Africa Oriental, un complejo del SPFMV y del virus productor de la mancha suave en el boniato (SPMMV) causan síntomas similares a los del SPVDC. Se han recibido asimismo informes de otros virus encontrados en Asia, región del Pacífico y Africa Oriental, entre los que se cuentan un SPMMV característico de Africa; el virus caulimoide del boniato (SPCLV) de Puerto Rico, región del Pacífico y Africa Oriental; el virus latente del boniato (SPLV); virus del enanismo amarillo del boniato (SPYDV) y el virus de la rizadura de las hojas del boniato (SPLCV), de Taiwan; el virus de la podredumbre anular del boniato (SPRV) de Papúa Nueva Guinea; y el fitorreovirus del boniato (SPRLV) de Tailandia. Son importantes estrategias de control la producción y diseminación de material de plantío libre de virus y el uso de variedades resistentes.

Nematodos: Se presenta una descripción de los dos nematodos más importantes que afectan al boniato, a saber, el nudo de la raíz *Meloidogyne incognita* y el nematodo reniforme *Rotylenchus reniformis*. El *Meloidogyne incognita* se encuentra muy propagado y, a menudo, constituye un problema serio, mientras que el *R. reniformis* es un nematodo común en las regiones tropicales. En muchos casos, se producen graves pérdidas debido a deficiencias en las prácticas de cultivo, tales como una recolección continua en tierras infectadas con nematodos. Entre las estrategias de control para ambos nematodos valga citar prácticas de cultivo tales como la rotación de cultivos y el empleo de material de plantío libre de nematodos; tratamiento químico de las tierras y del material de plantío; y resistencia. Se estudia el descubrimiento de altos niveles de resistencia a *M. incognita* en material genético nativo de Papúa Nueva Guinea, Indonesia (Irian Jaya) y Filipinas, apuntándose la carencia de información sobre nematodos del boniato en Kenia, Uganda y Rwanda.

PESTES

Se realiza un estudio breve de las plagas de insectos en el boniato, mediante estudios procedentes de regiones tropicales y templadas. A escala mundial, el problema clave del boniato es el complejo de gorgojos de la especie *Cylas*. En Indonesia, Filipinas, Tailandia y Papúa Nueva Guinea, la única plaga de importancia para el boniato es el gorgojo *C. formicarius*, mientras que en el Africa Oriental, la especie *Cylas* son la plaga de mayor importancia. Valga apuntar, sin embargo, que la mariposa del boniato *Acraea acerata* y las polillas de alas claras (especie *Synanthedon*) pueden causar serios problemas.

Gorgojos: Los gorgojos de la especie *Cylas* son la plaga más devastadora del boniato por todo el mundo. El *Cylas formicarius* se halla particularmente extendido, siendo la única especie presente en el Sureste Asiático y en la región del Pacífico. En el Africa Oriental se encuentran tres especies:

C. puncticollis y *C. brunneus*, además del *C. formicarius*. En general, los gorgojos poseen mayor importancia durante períodos secos y con sistemas tradicionales, cuando la recolección de los tubérculos se realiza secuencialmente. Entre las estrategias de control se cuentan las prácticas de cultivo, productos químicos, control biológico, resistencia y gestión integrada de plagas, describiéndose aquí la diversidad de estrategias de control de cultivos. Si bien se han desarrollado en diversos países estrategias eficaces y económicas de control químico para pequeños agricultores, los productos químicos apenas si se utilizan, dejando aparte los productores comerciales de Tailandia. Se pasa revista a la labor relativa a una feromona para el *C. formicarius*. También se examina el problema un tanto polémico de la resistencia a los gorgojos *Cylas*, describiéndose recientes observaciones de antibiosis. En diversos países, el control biológico de gorgojos de la especie *Cylas* con los mohos entomopatogénicos *Metarhizium anisopliae* y de la especie *Beauvaria* posee, sin duda, potencial. La gestión integrada de plagas es la estrategia de control más apropiada para la especie *Cylas* en países en desarrollo. Se describe aquí una estrategia de gestión integrada de plagas desarrollada por AVRDC para el control del *C. formicarius*, en la que se subraya el control químico y de cultivos, junto con la apremiante necesidad de desarrollo de estrategias de gestión integrada de plagas para el control de los gorgojos en el Africa Oriental.

Polilla de alas claras; Mariposa del boniato: En el Africa Oriental, las polillas de alas claras (especie *Synanthedon*) y la mariposa del boniato (*Acraea acerata*) puede producir grandes estragos en el boniato. Las larvas de la polilla de alas claras abren túneles en los tallos, causando pérdidas de rendimiento y agostamiento de las plantas, mientras que la mariposa del boniato puede producir, en épocas secas, una destrucción completa de los cultivos. Se pone de relieve la necesidad de desarrollar estrategias económicas de control, aplicables al pequeño agricultor.

PAPEL DE LA ESPECIE SILVESTRE DE *IPOMOEA*

El boletín estudia la influencia ejercida por la especie silvestre de *Ipomoea* sobre las enfermedades y plagas del boniato, existiendo creciente interés por el potencial del material genético silvestre como fuente de resistencia a los gorgojos de las especie *Cylas*, virus y nematodos. También se describe brevemente la identificación de resistencia del tallo al *C. formicarius* en *I. trifida* y su incorporación en el cultivo. También se presenta documentación sobre la importancia de las malas hierbas de la especie *Ipomoea*, huéspedes del *C. formicarius*, micoplasma de las hojas pequeñas y patógenos fungales, bacterianos y virales. En este estudio se proporciona información adicional sobre el papel de la especie *Ipomoea* como huésped de la roña y de la especie *Alternaria*, a la vez que se hace referencia a las especies de *Ipomoea* que forman tubérculos silvestres, como fuentes alimenticias para cultivos indígenas en el Africa Oriental y en el Pacífico.

Capítulo 4: Recursos experimentales

En este capítulo se pasa revista a los recursos de investigación en existencia, incluyendo instituciones, investigadores, programas y material genético para trabajos de investigación sobre el boniato en el Sureste Asiático, zona del Pacífico y Africa Oriental.

SURESTE ASIÁTICO Y ZONA DEL PACÍFICO

En Indonesia, el Instituto Central de Investigación para Cultivos Alimenticios (CRIFC), ubicado en Bogor, coordina las actividades de investigación para todos los productos alimenticios, por intermedio de seis instituciones de investigación: BORIF, SURIF, MARIF, SARIF, BARIF y MORIF. BORIF y MARIF son los dos centros clave para raíces comestibles y tubérculos. La existencia de fuertes vínculos con agencias donantes y centros internacionales del CGIAR — particualarmente, el CIP para el boniato — poseen importancia en la puesta en práctica del programa de investigación agrícola del CRIFC.

En Filipinas, el Centro de Investigación y Capacitación sobre Raíces Comestibles en Filipinas (PRCRTC), ubicado en Visca, Leyte, coordina todas las actividades de investigación sobre el boniato. Valga citar asimismo, entre otras instituciones de importancia interesadas en el boniato, el PRCRTC septentrional, Baguio; la Universidad de las Filipinas, Los Baños; el Instituto de Fitogenética, Los Baños; y las granjas experimentales del Ministerio de Agricultura, ubicadas en importantes zonas para el cultivo del boniato. Los trabajos de investigación reciben, en parte, el apoyo de agencias donantes y del CIP, cuyo Programa Región VII para el Sureste Asiático tiene su base en Los Baños.

En Papúa Nueva Guinea, la labor de investigación sobre el boniato cae bajo la responsabilidad de la Granja Experimental de Kuk, en las tierras altas, y de la Granja Experimental de Laloki en las tierras bajas, sin que exista un programa nacional para el boniato. En este capítulo, se estudia también la importancia de Papúa Nueva Guinea como centro de diversidad para el material genético del boniato y las consecuencias para la mejora del boniato.

Las investigaciones sobre el boniato en Tailandia corren a cargo del Instituto de Investigaciones Hortícolas del Ministerio de Agricultura y del Centro de Investigaciones Pichit. Ciertos trabajos de investigación reciben el apoyo del CIP.

AFRICA ORIENTAL

En Uganda, el Programa Nacional para la Mejora de Raíces Comestibles y Tubérculos, con base en la Granja Experimental de Namulonge, cerca de Kampala, dirige la mayor parte de los recursos hacia su programa de evaluación y cría. Y aunque el IDRC ha proporcionado cierto apoyo a la labor de investigación sobre raíces comestibles y tubérculos, se subraya aquí la falta de apoyo a la labor de investigación sobre el boniato en Uganda.

En Rwanda, el Programa Nacional para la Mejora del Boniato tiene su base en ISAR, Rubona, en donde existe un activo programa de cría en el que se utiliza material genético local e introducido de alta calidad para la producción de mejores variedades. Las técnicas de selección multilocacional y prueba en explotación se hallan bien desarrolladas. Se subraya el impacto potencialimente elevado del apoyo internacional para el estudio controlado de resistencia a los factores bióticos, que limitan la producción en Rwanda. El sistema bien organizado de parcelas de multiplicación, desarrollado por el programa nacional, hace que el agricultor cuente, durante todo el año, con un suministro adecuado de material de plantío de variedades mejoradas, describiéndose como sistema modelo para otros países con problemas similares.

En Kenia, los trabajos de investigación sobre el boniato se realizan en las granjas experimentales KARI, ubicadas en Kisii, Kakamega, Katumani y Mtwapa, habiéndose establecido recientemente en Kisii el Centro Nacional de Material Genético para el Boniato. También se describen las actividades del programa productivo de cultivo de boniatos a largo plazo desarrollado en la Granja Experimental de Katumani. Entre las organizaciones internacionales el CIBC y CIP están trabajando activamente en la mejora del boniato en Kenia. El CIBC coordina un proyecto costeado por el IDRC sobre el control integrado de artrópodos de tubérculos y raíces comestibles, incluyendo los gorgojos de la especie *Cylas* del boniato. El Programa Región III del CIP para el Africa Oriental y Meridional tiene su base en Nairobi.

Capítulo 5: Recomendaciones

CULTIVO Y AGRONOMÍA

A lo largo de muchos años, se han venido desarrollando sistemas de producción de boniatos basados en prácticas de cultivo y en razas nativas tradicionales en las tierras altas de Papúa Nueva Guinea, Filipinas, región occidental de Kenia y Rwanda. Dichos sistemas tradicionales están experimentando los cambios procedentes de mejores variedades y nuevas tecnologías de cultivo. Se recomienda encarecidamente la caracterización de los sistemas tradicionales, antes de la realización de cambios de importancia, junto con el desarrollo de nuevas variedades y tecnologías aplicables a los sistemas tradicionales. Existe asimismo la necesidad de determinar el efecto de complejas prácticas tradicionales de cultivo sobre las estrategias de control de plagas y enfermedades.

Se consideró que el suministro al agricultor de material de plantío — en particular, de material libre de enfermedades y de plagas — constituía un importante problema en todos los países visitados, excepto en Rwanda. Y, aunque se recomienda encarecidamente el empleo del sistema de Rwanda como modelo a seguir, dicho sistema podrá mejorarse todavía más haciendo que el material inicial se halle libre de plagas y enfermedades y ubicando las parcelas de multiplicación en zonas protegidas. Dado que un problema de creciente importancia es la baja fertilidad de los suelos, se requerirá la realización de trabajos de investigación sobre una gestión más adecuada de la fertilidad do los suelos, debiendo tomarse en consideración la posibilidad de aplicar métodos tradicionales (o modificaciones de los mismos) de un país a otro.

A fin de reducir la dependencia del pequeño agricultor de la recolección secuencial, que puede resultar en mayores problemas con los gorgojos del boniato, se necesitan sencillas tecnologías de almacenamiento y de elaboración con base en las aldeas mismas.

Los trabajos de investigación sobre mezclas de variedades de cultivos han girado en torno a su papel en el control de las enfermedades. Complejas mezclas de variedades son comunes en muchos sistemas tradicionales de producción de boniatos. La caracterización de las mezclas — particularmente por cuanto respecta a reacciones a enfermedades y plagas — proporcionaría información sobre su aportación al control de plagas y enfermedades y podría llevar a una aplicación más amplia de las mezclas como estrategia de control.

ENFERMEDADES Y PLAGAS

Una coordinación internacional contribuiría a mejorar los trabajos de investigación ya en progreso sobre la roña, principal enfermedad en la región del Sureste Asiático y del Pacífico. Se requiere una metodología normalizada de inoculación y evaluación, debiendo determinarse asimismo la importancia de la variación patogénica en el *Elsinoe batatas*, en apoyo del desarrollo de variedades resistentes a la roña. La realización de estudios sobre la epidemiología del patógeno — particularmente, en complejos sistemas de recolección — contribuiría al desarrollo de estrategias de control.

Se requiere una caracterización del complejo de especies *Alternaria* relacionado con el tizón del tallo, así como el desarrollo de metodologías normalizadas de invernadero y sobre el terreno, para facilitar la selección de variedades resistentes. También se necesitan trabajos de investigación para elucidar la aparente relación existente entre el tizón del tallo y los suelos menos fértiles.

Valdría asimismo la pena conseguir una definición más exacta de la distribución restringida del micoplasma de las hojas pequeñas por todas las regiones dedicadas al cultivo del boniato en los Trópicos, particularmente, para identificar zonas en donde el boniato pudiera escapar al ataque del antedicho micoplasma, tal como las tierras altas de Papúa Nueva Guinea. También se propone una selección para resistencia a los vectores de la cigarra saltadora, así como el desarrollo de un programa de gestión integrada de plagas para el micoplasma de las hojas pequeñas.

Los problemas hoy día encontrados con los virus podrían reducirse mediante limpieza de importantes variedades, seguida de rápida multiplicación y diseminación de material limpio de plantío. Poseen importancia a este respecto los resultados del proyecto ACIAR de seis años sobre el desarrollo de variedades probadas contra patógenos en países seleccionados del Sureste Asiático y del Pacífico. También se hacen necesarios en muchos países estudios sistemáticos y caracterización de los virus, junto con apoyo básico, mediante clasificación de los virus para todos los países con programas activos de fitogenética, que incluyen selección para resistencia a los virus.

La considerable cantidad de esfuerzo dirigido hacia los gorgojos de la especie *Cylas* — especialmente, el *C. formicarius* — ha llevado a la recomendación generalizada de estrategias de control bien estudiadas. Antes de que se lleven a cabo estudios adicionales de investigación, existe una necesidad apremiante de que estas estrategias se apliquen de forma generalizada, bien individualmente como controles de cultivo o controles químicos de bajo coste, o dentro de un program de gestión integrada de plagas para el *C. formicarius* y *C. puncticollis*. Subsiguientemente, sería posible realizar modificaciones específicas para cada emplazamiento. Se recomienda asimismo la realización de nuevos trabajos de investigación sobre el desarrollo de variedades resistentes, con un énfasis particular en la resistencia del tallo y aplicación sobre el terreno de estrategias de control biológico.

Con objeto do poder desarrollar estrategias económicas de control, que tengan aplicación al pequeño agricultor, se hace necesaria la realización de estudios sobre la polilla de alas claras y sobre la mariposa del boniato en el Africa Oriental.

RECURSOS DE INVESTIGACIÓN

La mayor parte de los programas nacionales sobre el boniato dependen del apoyo internacional, para llevar a cabo sus objetivos de investigación. Un importante factor límite es la carencia de mano de obra. Son numerosos los programas nacionales de raíces comestibles y tubérculos que se beneficiarían de la presencia de científicos internacionales en sus centros, que trabajaran con aspectos relacionados con las enfermedades y plagas del boniato.

En muchos países, se necesita acceso a instalaciones de cultivo tisular para el desarrollo de variedades de boniato libres de enfermedades y plagas. Se require asimismo en muchos países apoyo para las actividades de recolección y caracterización y, de manera particular, para el mantenimiento de recursos de material genético.

Introduction

Sweet potato, *Ipomoea batatas* (L.) Lam., is the only important economic plant of the family Convolvulaceae (Purseglove, 1968). It is thought to have originated in north-western South America about 8000 to 6000 BC (Austin, 1988). The primary centre of diversity occurs in Colombia, Ecuador and northern Peru, while secondary centres are found in Central America, particularly Guatemala, China, south-east Asia, Papua New Guinea and east Africa (Yen, 1982).

Sweet potato is widely cultivated throughout the tropics for its edible storage tubers, an important source of food in many countries. A wide range of varieties exists. On the basis of tuber texture after cooking, there are three types: firm, dry, mealy flesh, preferred in most countries of south-east Asia, the Pacific and east Africa; soft, moist, gelatinous flesh, preferred in developed countries; and coarse, fibrous tubers for industrial uses as starch, snack foods and alcohol, and for animal feed (Onwueme, 1978). Sweet potato is also eaten as a leafy vegetable, like spinach, especially in the Philippines, although water spinach, *Ipomoea aquatica*, is preferred in south-east Asia where water is available for its cultivation. Interest in vines for forage is increasing in east Africa where zero-grazing initiatives are responding to pressure for land.

Sweet potato is very widely adapted throughout temperate and tropical zones over almost 80 degrees of latitude and from sea level to over 2000 m altitude (Purseglove, 1968). It is tolerant of a wide range of climatic and edaphic conditions, and is a low-input crop. Sweet potato has high nutritional value, being a good source of energy, vitamins A and C, thiamin, niacin, riboflavin and minerals (Purseglove, 1968; Onwueme, 1978). The leaves contain 27% crude protein on a dry weight basis (Onwueme, 1978).

International research on sweet potato began in the early 1970s through the Asian Vegetable Research and Development Centre (AVRDC) based in Taiwan, and the International Institute of Tropical Agriculture (IITA) in Africa. IITA emphasized sweet potato improvement through breeding for high yield, resistance to weevils and viruses, and quality characters (Hahn *et al.*, 1989). Field screening in sites with high biotic pressures was emphasized rather than controlled screening. This approach has been followed by most African countries (see pages 64 and 74 ff.).

AVRDC also initiated an improvement programme through breeding, particularly focused on minimum-input varieties to be used in the intensive cropping systems typical of Asia (Villareal and Griggs, 1982). The most important biotic constraint to sweet potato improvement was identified as the weevil, *Cylas formicarius*. As extensive field screening for resistance to weevil was not sufficiently successful (Talekar, 1982; 1987c), AVRDC developed an integrated pest management (IPM) approach to weevil control (Talekar, 1988a,b) which is being widely adopted by Asian countries (see pages 76 ff.).

The involvement of Centro Internacional de la Papa (CIP) in research on sweet potato began in 1985, and in 1986 CIP was officially given the world mandate for sweet potato research (CIP, 1988c, 1989b). CIP's research on biotic factors affecting sweet potato is presently focussed on viruses, nematodes and weevils (CIP, 1988a,b; 1989a,b,c); however, its research expansion on some important and potentially important biotic factors is severely restricted at headquarters because these problems do not occur in Peru. These include many viruses, little leaf mycoplasma, scab (*Elsinoe batatas*), Alternaria diseases and *Cylas* spp.

weevils. Although CIP plans to develop a global research network to address *Cylas* spp. weevils (CIP, 1989c), no plans appear to have been made regarding other important biotic factors affecting sweet potato.

Sweet potato has been widely described as the world's most important subsistence crop. Apart from recent work on several viruses, diseases as constraints to sweet-potato production in developing countries of south-east Asia, the Pacific and east Africa have largely been neglected by international funding. Sweet potato has considerable unrealized potential.

The first objective of the mission reported here was to identify the most important and potentially important diseases and pests of sweet potato (including their geographic distribution, current control practices and the magnitude of losses caused) in diverse production systems throughout south-east Asia, the Pacific and east Africa. This was achieved by visiting key scientists in major root- and tuber-crop institutions throughout the regions, and by reviewing available published and unpublished literature. Particular emphasis was placed on assessing the role of Integrated Pest Management (IPM) of diseases and arthropod pests. The second important objective of the report was to identify and recommend research needs both on country- and problem-specific bases.

The survey focussed on south-east Asia, the Pacific and east Africa because, outside China, these regions are the most important sweet-potato producers. International efforts on biotic constraints to sweet potato production have so far been limited in these regions. The choice of countries was related to the importance of sweet potato and to the known activities of national sweet potato research programmes. In the south-east Asia/Pacific region, Indonesia, the Philippines, Thailand, Papua New Guinea and Australia were visited; in east Africa, Kenya, Rwanda and Uganda.

Plate 1

Sweet potato may be used for erosion control on terraces in Indonesia. (Source: Jillian Lenné.)

Plate 2

Rice-straw mulch increases sweet potato yields and reduces weevil infestation in Indonesia. (Source: Jillian Lenné.)

Plate 3

Sweet potato is commonly grown in monoculture on flat beds in the Philippines. (Source: Jillian Lenné.)

Plate 4

Shade-tolerant varieties of sweet potato are grown under coconuts in the Philippines. (Source: Jillian Lenné.)

Plate 5

Compost mounding is a common practice for sweet potato cultivation in the highlands of Papua New Guinea. (Source: Jillian Lenné.)

Plate 6

Sweet potato is frequently grown on mounds in Uganda. (Source: Jillian Lenné.)

Plate 7

Sweet potato is commonly cultivated on large mounds in flooded valleys in Rwanda. (Source: Jillian Lenné.)

Plate 8

Sweet potato is widely intercropped with maize in Kenya. (Source: Jillian Lenné.)


Plate 1


Plate 2


Plate 3


Plate 4


Plate 5


Plate 6


Plate 7


Plate 8

Plate 9

Plate 10

Plate 11

Plate 12


Plate 13


Plate 14

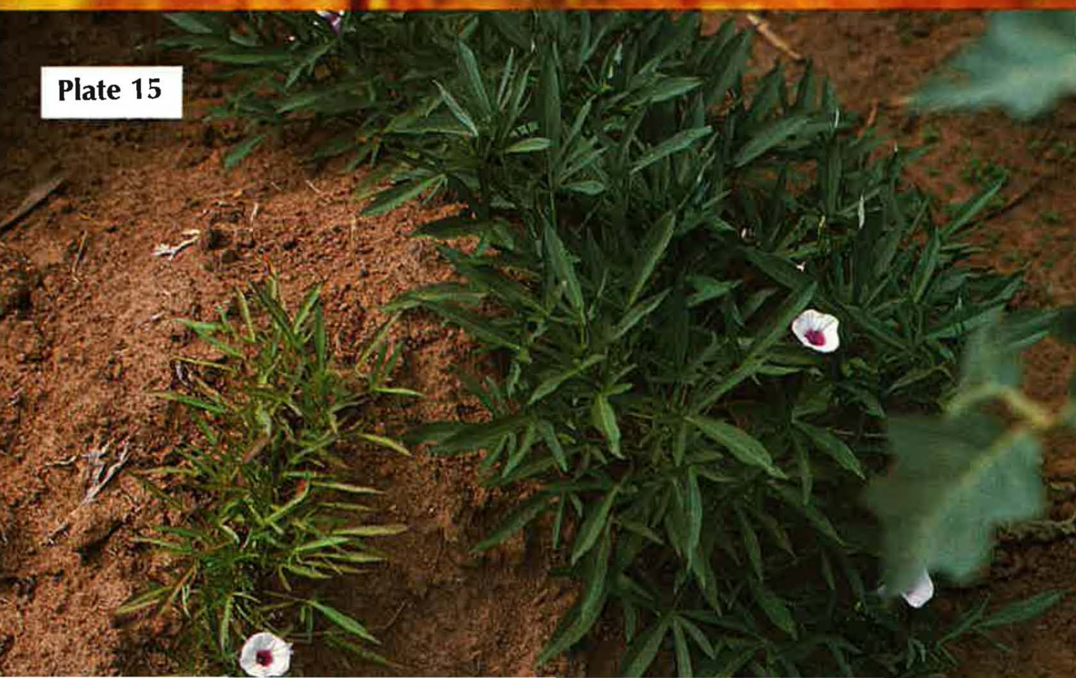


Plate 15


Plate 16

Plate 9

Cercospora leaf spot (*Pseudocerocospora timorensis*), a widespread foliar disease of sweet potato in the tropics. (Source: Jillian Lenné.)

Plate 10

Scab (*Elsinoe batatas*), the most important disease of sweet potato in south-east Asia and the Pacific. (Source: Jillian Lenné.)

Plate 11

Alternaria stem blight (*Alternaria* spp.), a disease of increasing importance for sweet potato in east Africa. (Source: Jillian Lenné.)

Plate 12

Larvae of the sweet potato butterfly *Acraea acerata*, a serious pest of sweet potato under dry conditions in east Africa. (Source: Jillian Lenné.)

Plate 13

Sweet potato weevil (*Cylas formicarius*), the most important pest of sweet potato world-wide. (Source: Barbara Pembroke, Reading University.)

Plate 14

Virus symptoms on sweet potato in east Africa: vein chlorosis. (Source: Richard Gibson, NRI.)

Plate 15

Virus symptoms on sweet potato in east Africa: stunting. (Source: Richard Gibson, NRI.)

Plate 16

Virus symptoms on sweet potato in east Africa. (Source: Richard Gibson, NRI.)

Section 1

Importance of sweet potato

Of the world's root and tuber crops, sweet potato is second in importance only to white potato. Ninety-seven percent of world production is from developing countries, with 86% being grown in China (FAO, 1989) (see Table 1). About 7% of the world's production is from the rest of Asia, particularly Indonesia, Vietnam and India, while Africa produces 5% of the total, Uganda, Kenya, Rwanda and Burundi being the highest producers (FAO, 1989). In terms of production, sweet potato is basically an Asian crop (see Table 2).

Table 1

Leaders in sweet potato production (FAO, 1989)

Country	Production (1,000 MT)
China	114,000
Indonesia	2,106
Vietnam	2,000
Uganda	1,800
India	1,350
Japan	1,330
Rwanda	810
Brazil	750
Philippines	661
Korea (Rep.)	600
Kenya	550
Bangladesh	545
USA	542
Korea (DPR)	500
Papua New Guinea	475
Madagascar	475

Table 2

Sweet-potato production by region (FAO, 1989)

Country	Production (1,000 MT)
Asia	123,600
Africa	6,105
South America	1,549
Central America	1,324
Oceania	571
Europe	86
Total world	133,235

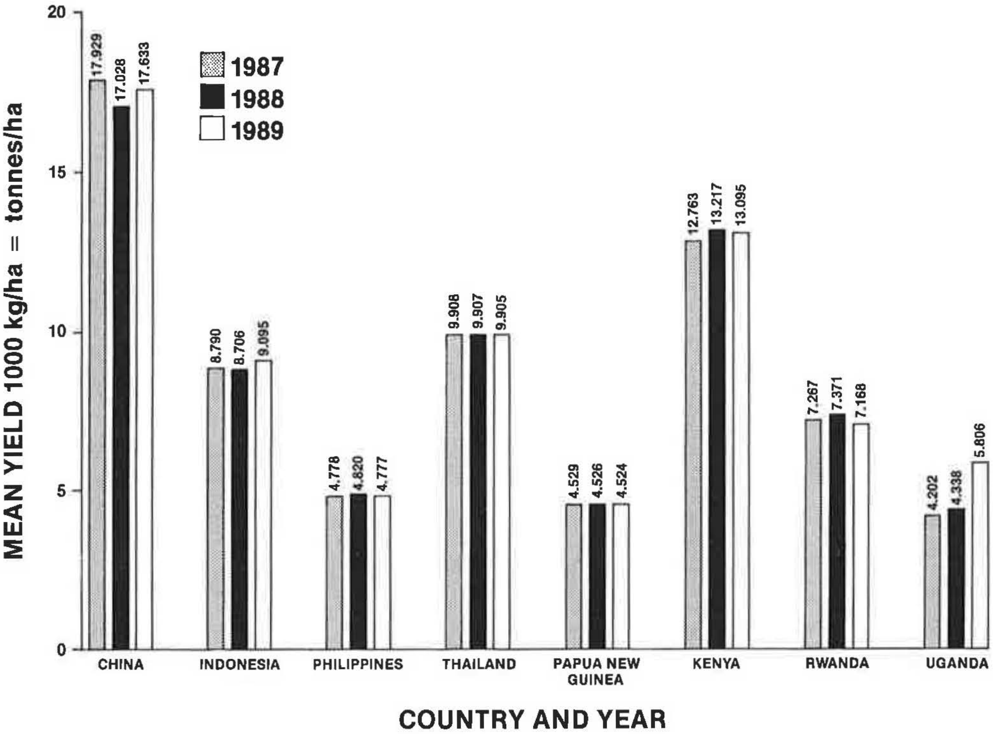
SOUTH-EAST ASIA/PACIFIC

Indonesia

After China, Indonesia and Vietnam share the position as the world's second most important sweet potato producer (FAO, 1989; CIP, 1989b). Indonesia's annual production is 2,100,000 tonnes with mean production of 9.0 t/ha (FAO, 1989) (see Figure 1). Sweet potato (ubi jalar) is the second most important root crop in Indonesia (cassava is first) (Manwan and Dimyati, 1989), and is ranked third after maize and cassava as a source of carbohydrates.

Figure 1

Annual sweet potato production (1987–1989) of selected countries in south-east Asia, the Pacific and East Africa. (From *FAO Yearbook*, 1989.)



Current production figures, however, reflect the diminishing importance of the crop (Manwan and Dimyati, 1989). From 1968 to 1986, the harvested area declined from approximately 400,000 to 250,000 ha, and overall production decreased slightly from 2,365,000 to 2,050,000 t. Yield, however, increased from 6 to 8.5 t/ha (Manwan and Dimyati, 1989). Sweet potato is a staple in Irian Jaya with *per capita* consumption of 170 kg/year.

Approximately 90% of production is consumed by humans as tubers and leaves (Manwan and Dimyati, 1989). Although the importance of sweet potato as livestock feed is low, some varieties are grown specifically for pigs. Commercial farmers in Java consider sweet potato an attractive crop as it is easy to maintain, does not require much input, is less risky than most other vegetables, and is easily marketed (Manwan and Dimyati, 1989). In Irian Jaya, sweet potato is significant both as a food source and in rituals and ceremonies.

Philippines

The Philippine sweet potato (camote) annual harvest is approximately 660,000 tonnes with mean production of 4.8 t/ha (FAO, 1989) (see Figure 1). Yields range from 2–8 t/ha (Palomar *et al.*, 1989). Root crops, especially sweet potato, play a major role in the diet of Filipinos (Palomar *et al.*, 1989) They are the staple food in dry, hilly and marginal areas. Both tubers and leaves are eaten. High dry-matter, low water-content varieties are preferred. *Per capita* consumption is 18.7 kg. Sweet potato is increasingly used commercially as flour, starch and snack foods (Palomar *et al.*, 1989). About 5% of the total production is used as animal feed.

Papua New Guinea

Sweet potato is the most important subsistence crop in Papua New Guinea (Hadfield, 1989). Annual production is documented at between 500,000 (FAO, 1989) and 2,000,000 t (Hadfield, 1989), with mean yields of 4.5 t/ha (FAO, 1989) (see Figure 1). In the highlands, pigs, man and sweet potato form a system in which sweet potato is the basic human staple (80% of calorific intake) and the surplus is fed to pigs (Hadfield, 1989). Approximately 43% is consumed by humans, 46% is fed to pigs, and only a small proportion is formally marketed (Joughin, 1987). Although attempts have been made in industrial processing of sweet potato, none have yet become commercially viable (Hadfield, 1989).

A recent economic study looked at the implications of increased production of sweet potato in Papua New Guinea (Joughin, 1987). Because prices of imported cereals are falling while prices of fresh tuber crops such as sweet potato are increasing, inevitably there will be a shift away from consumption of roots and tubers to cereals. If yields are increased, the excess will be fed to pigs.

Thailand

Sweet potato is the second most important root crop to cassava in Thailand (Thongjiem and Piriyathamrong, 1989). Annual production is 360,000 t with mean yield of 9.9 t/ha (FAO, 1989). Sweet potato is grown commercially and also by small farmers for domestic consumption and starch production. Vines and unmarketable roots are fed to animals. Commercial production is a relatively recent expansion, servicing an industry exporting starch to Korea and Japan.

EAST AFRICA

Uganda

The largest producer in Africa, Uganda produces approximately 1,800,000 t of sweet potato annually (FAO, 1989). Present mean yields of 5.8 t/ha (FAO, 1989) show an improvement on previous yields of 4.2 to 4.3 t/ha (1987/88) (see Figure 1). Sweet potato (lumonde) ranks third behind cassava and bananas in calorie contribution (Mwanga and Wanyera, 1988). It is the most widely cultivated and widespread food crop in Uganda and is grown as a major staple or as a supplement to banana, Eleusine millet and cassava. During the past ten years, it has increased in importance due to population pressure and to the progressive unsuitability of land previously used for banana, caused by reduced soil fertility and increased pressure from banana weevil and nematodes.

Rwanda

Among the seven developing countries described in this report, Rwanda is the most reliant on sweet potato as a staple food. Sweet potato is the most important root and tuber crop and the most significant source of carbohydrate (Ndamage, 1989). In 1986, of a total of 1,500,000 t of roots and tubers, sweet potato, cassava and potato provided 58.5, 24.6 and 16.4%, respectively. Sweet potato and beans constitute the common diet of Rwandans (Ndamage, 1988).

Uganda, Rwanda and Burundi together produce about half the total African sweet-potato crop (FAO, 1989). Annual production in Rwanda is second to Uganda with 800,000 t and mean yield of about 7 t/ha (FAO, 1989). The level of sweet-potato production in Rwanda grew remarkably between 1966 and 1983, with an annual increase of 7% in area and 9% in production (Ndamage, 1989). In 1987, the population density of Rwanda was 230 per km^2 in total and 500 per km^2 of arable land. Food self-sufficiency is a high priority and sweet-potato production is an important component of this (Mulindangabo, 1989).

Kenya

Annual production of sweet potato (viazi tamu or viazi vitamu) in Kenya is 550,000 t with mean yield of over 13 t/ha (FAO, 1989). Sweet potato is consumed by humans and used for forage in Kenya. Marketing is unreliable as root and tuber crops are not staple food crops in Kenya. Sweet potato is still treated as a famine food, and in the Coast Province it is a preferred food during Ramadan.

Section 2

Cultivation and agronomy

Methods of sweet-potato cultivation in tropical developing countries are extremely variable. Although three basic systems are used: monocropping, rotation and intercropping, considerable variability exists within these methods due to topography, soil fertility, climate, and farmer tradition. For example, monocroppping of sweet potato can range from single varieties, to more than 20 component varietal mixtures in the highlands of Papua New Guinea, to 60 component mixtures in Irian Jaya. Varietal mixtures with fewer components are used in east Africa. Rotations are made with a wide range of crops or with fallows of up to 20 years. Intercropping is common with maize, grain legumes and vegetables in often very complex systems, for example in central Java. In addition, farmers use a wide range of cultural practices before, at and after planting which can have a considerable effect on the incidence and severity of pests and diseases. These include flat beds, ridges, mounds and compost mounds; irrigation; wilting or non-wilted cuttings; different depths of planting; hilling-up; weeding; mulching; and single or sequential, progressive harvests. As all of these cultural practices can affect the incidence and severity of diseases and pests, recommendations for research on pests and diseases affecting sweet potato should take into account the complexity of the sweet potato-growing systems.

SOUTH-EAST ASIA/PACIFIC

Indonesia

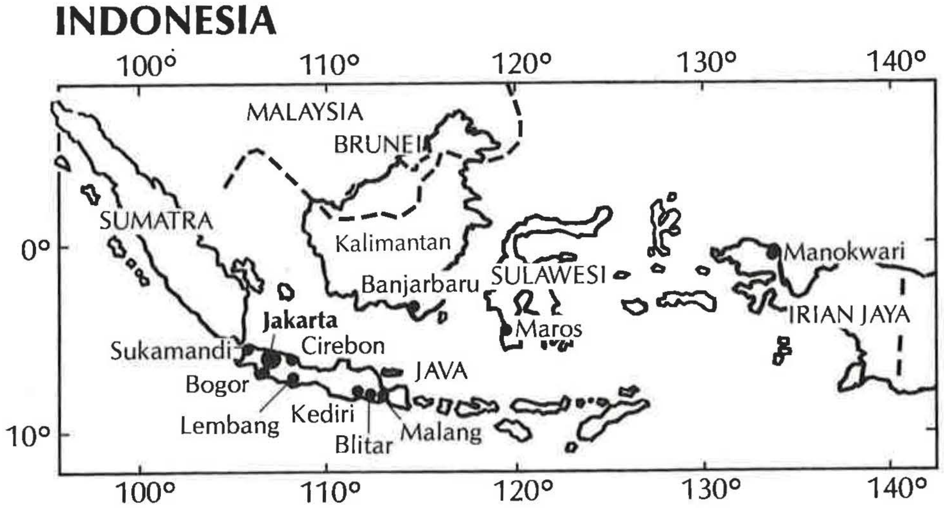
Java is the most important sweet potato production region in Indonesia with 1,000,000 t annually, about three times the production of any other region (Manwan and Dimyati, 1989). The major production areas in Java include the north coast east of Cirebon, in rotation with rice; Bogor (western Java), with sweetcorn/sweet potato intercropping usually in rotation with rice; Lembang (central Java), with maize/sweet potato rotation; and Malang, Kediri, Blitar and further east (the dry eastern region of Java), where sweet potato is often the only crop grown (see Figure 2). Most sweet potato is grown at low altitudes in Indonesia, with the exception of Irian Jaya.

Cultural practices vary widely from region to region (Manwan and Dimyati, 1989). Soil and water management are emphasized. In Java, most farmers plant sweet potato on single-row ridges of varying height depending on soil depth. Many farmers do not use fertilizers, fertility being maintained by treatments applied to the rotation crop, most commonly rice and maize, and by intercropping with legumes. Sometimes several crops will be grown before rice is again planted. Rice residues are usually kept for the next rice crop and are not incorporated into the soil for the sweet-potato crop. In central Java, sweet potato is grown in small gardens on ridged beds, on terraces and on the edges of terraces where it may give some erosion control (see Plate 1: Plate section opp. p.16). A complexity of crops including maize, tobacco, sweet potato and vegetables are grown on terraces. Hilling-up and deep planting are recommended to farmers for weevil control.

In Irian Jaya, sweet potato is grown throughout the highlands and lowlands, with more production in the highlands. Farmers' practices are diverse and often highly developed. They include sophisticated drainage systems, cultural practices and mounding. Compost mounding to maintain soil fertility is a common practice throughout the highlands of south-east Asia and the Pacific.

Figure 2

Indonesia



Farmers use their own planting material, either from the previous crop or from conserved roots planted in nursery gardens. In Irian Jaya, the continuous cropping system to meet food needs provides a constant supply of planting material, from which most farmers try to select clean material.

Varieties vary greatly from region to region (Manwan and Dimyati, 1989), locally adapted varieties being most commonly used. In Java, farmers grow one or two popular varieties in a large area and a few others on smaller plots. In Irian Jaya, however, farmers grow mixtures of many varieties and harvest sequentially; for example, in one district 65 varieties are grown in the valley and 16 on the hillsides. Where mounds are used, different varieties may be planted in the same mound, their location being determined by the water table and time of maturity. In the lowlands, sweet potato is harvested at 4 to 5 months; at 700 m and above, crops require more than 5 months to mature. This often leads to weevil problems. As there is a trend towards early-maturing varieties, probably to escape weevil damage, later-maturing varieties are in danger of being lost.

Rice is the principal crop in Indonesia: all others are called 'paliwija' (non-rice or secondary) crops. In Java, the predominantly commercial farmers rotate sweet potato with rice on paddy fields which may be irrigated or rain-fed. Irrigation is very important to agriculture in Indonesia. In Java also, sweet potato is often intercropped with maize. The spacing of the maize is determined by how well it grows in the region and by the comparative prices of sweet potato and maize. As sweet potato is sensitive to shading, agronomic trials have compared the effect of different planting densities of maize on the growth and yield of sweet potato. At all levels, maize intercropping decreased the leaf-area index and yield of sweet potato, demonstrating a need for shade-tolerant varieties. Studies on the effect of intercropping sweet potato with various grain legumes such as soya bean, peanut and mung bean, as well as maize, are being conducted in eastern Java by the Malang Research Institute for Food Crops (MARIF) (see page 80). In intercroppings with sweetcorn or maize, sweet potato will benefit from fertilizer used for maize. This is important as most farmers do not apply fertilizer. Leuwilang, near Bogor, is an exception as commercial production for the Jakarta market makes the use of inorganic fertilizers profitable.

In eastern Java (Malang – Blitar – Kediri), sweet potato is a dry-season crop after rice and is often intercropped with maize. Grain legumes, especially soya bean, are also important in the rotation. Planting material is commonly maintained in small plots near houses. Farmers in this region usually plant on ridges and hill up after one month. Experiments have found that rice-straw mulch significantly increases yield and reduces weevil infestation (see Plate 2: Plate section opp. p.16) (Y. Widodo, MARIF, Malang, personal communication). Use of rice-straw mulch is a viable cultural practice in this region because farmers do not incorporate it into the paddies for the rice crop.

The major problems faced in growing sweet potato in Indonesia are the low fertility of marginal soils, weevil, scab, little leaf mycoplasma, viruses and marketing-related problems of a bulky perishable product (Manwan and Dimyati, 1989). Recommendations for sweet potato improvement are specific to production systems. For subsistence systems, important priorities are improved varieties for use in mixtures; maintenance of better soil fertility by rotations with leguminous crops; better soil conservation techniques; and development of storage techniques. For commercial systems, the main requirements are improved varieties suitable for food, feed and processing; and development of processing and utilization technologies together with marketing and adoption studies. Recommendations common to both systems include improved characterization of production systems; collection and evaluation of local germplasm; improvement of basic breeding material; and development of IPM procedures. As no single institution has the resources to handle such a programme, international collaboration is needed to fulfil these plans (Manwan and Dimyati, 1989).

Philippines

Sweet potato is grown widely throughout the Philippines, ranging from climatically and edaphically favourable areas to marginal lands. Although in some highland regions both white potato and sweet potato grow together, poor farmers tend to grow only sweet potato. It is commonly grown in rotation with rice and maize, and on flat beds (see Plate 3: Plate section opp. p.16) or ridges.

The Bicol and Eastern Visayas regions produce about 30 and 20%, respectively, of the national total (see Figure 3). Tarlac, Central Luzon, is an important sweet potato-producing area. Rice is the primary crop grown from June to March, and sweet potato the secondary crop from November to April. At Panique (within the Tarlac area), 1833 farmers plant 2750 ha, with average farm size being 1–2 ha. Yields range from 14 to 16 t/ha. The most common variety in the region is 'Bureau', thought to originate from the Bureau of Plant Industry. Several varieties have been released by the Philippine Root Crop Research and Training Centre (PRCRTC), Visca, Leyte. Although these varieties are high yielding at 14 to 21 t/ha, usually early-maturing (90 to 110 days) with high dry-matter (26 to 39%), protein (1.4 to 2.7%) and sugar (6 to 14%) contents and are recommended for food, animal feed and starch, they are not yet widely grown.

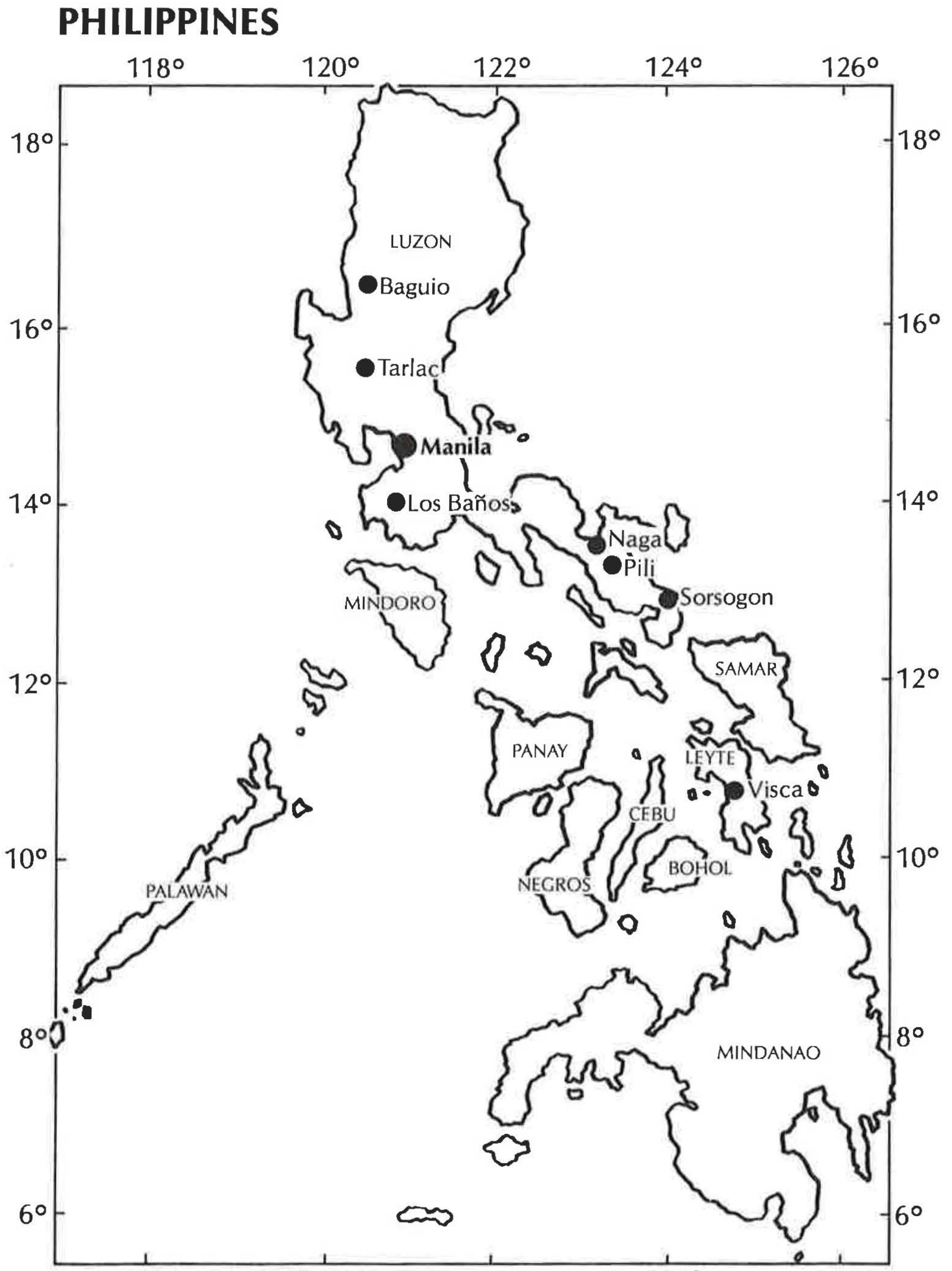
In Tiaong Quezon, near Los Baños, Southern Luzon, a major coconut-producing area in the Philippines, sweet potato is grown under coconuts (see Plate 4: Plate section opp. p.16). Although local shade-adapted varieties are mainly used, improved varieties with shade tolerance are being sought. Farmers in the highland Dolores region (near Los Baños) grow two major varieties: 'Sinuksuk', a local, late-maturing variety (8–9 months) and 'Miracle', an early-maturing variety (3–4 months in the lowlands, 5 months in the highlands).

In Sorsogon, Southern Luzon, farmers grow mixtures of at least two early-maturing varieties. Nurseries of planting material are usually maintained for new crops. Rotations with maize and peanut are commonly practised. Around Naga and Pili, Southern Luzon, sweet potato is grown year-round. Monoculture, rotation with maize and peanut and relay cropping with maize are practised. Local indeterminate varieties producing runners which bind the soil, in contrast to improved lines which are bushy and determinate, are used as an erosion control on slopes.

In the highlands around Baguio, Northern Luzon, rice and vegetables are the main crops where water, terracing and reasonable areas of flat land are available. On steep hillsides in the highlands, however, sweet potato is the staple crop, grown in a sweet potato-fallow rotation. After 3 to 5 years, the fallow regrowth is burnt and sweet potato planted, ash being the only fertilizer. The sustainability of

Figure 3

Philippines



this traditional highland system is presently threatened by pressure for land which may shorten the fallow. Most farmers grow small plantings of individual varieties, but, in a few locations, mixtures are traditionally grown. Farmers usually use their own planting material or that from nearby farmers. Local varieties predominate as, until recently, no improved varieties were available. Clean planting material is strongly selected for at planting. Farmers progressively harvest (piecemeal harvest or priming) over about a year. Most sweet potato is grown for home consumption, but some may be bartered. Both tubers and leaves are eaten, while vines are cooked for pigs and peelings for poultry. Weevil is a problem in later harvests. In warmer, lower areas of the highlands, sweet potato is rotated with rice and various legumes including pigeon pea and common, lima and winged beans.

In the Visca area of Leyte, most small farmers grow several local varieties of sweet potato for home consumption and to sell in local markets. The improved variety 'Miracle,' however, is becoming more common. Farmers with more than 0.5 ha of sweet potato are classed as commercial and often sell to a trader pre-harvest. The trader then has responsibility for harvesting and marketing. Farmers prefer varieties for different reasons: 'Miracle' is preferred because it is resistant to weevil; 'Siete Flores' because it is sweet; while 'Visca 4' is early-maturing and escapes weevil damage. Some farmers have formed commercial co-operatives which benefit from technical assistance, training and especially with setting up processing initiatives from the PRCRTC at Visca. Most farmers do not directly fertilize sweet potato. In a rotation, however, the following sweet potato crop often benefits from fertilizers applied to maize and other cash crops.

Farmers are stimulated by breeders from the PRCRTC to play a role in varietal selection. Innovative farmers select new varieties together with PRCRTC scientists which are then disseminated to other growers. Farmers also grow and select their own planting material which can lead to build-up of diseases, especially viruses; their symptoms, however, are often confused with scab. Some recommended cultural practices are being implemented for weevil control including hilling up, deep planting and selecting clean planting material. The principal problems of sweet potato in the Philippines are production and supply of planting material; poor agronomic practices; pests and diseases (important insect pests, fungi, viruses, bacteria and nematodes can cause yield losses as high as 50%); and inadequate distribution and marketing systems (Palomar *et al.*, 1989).

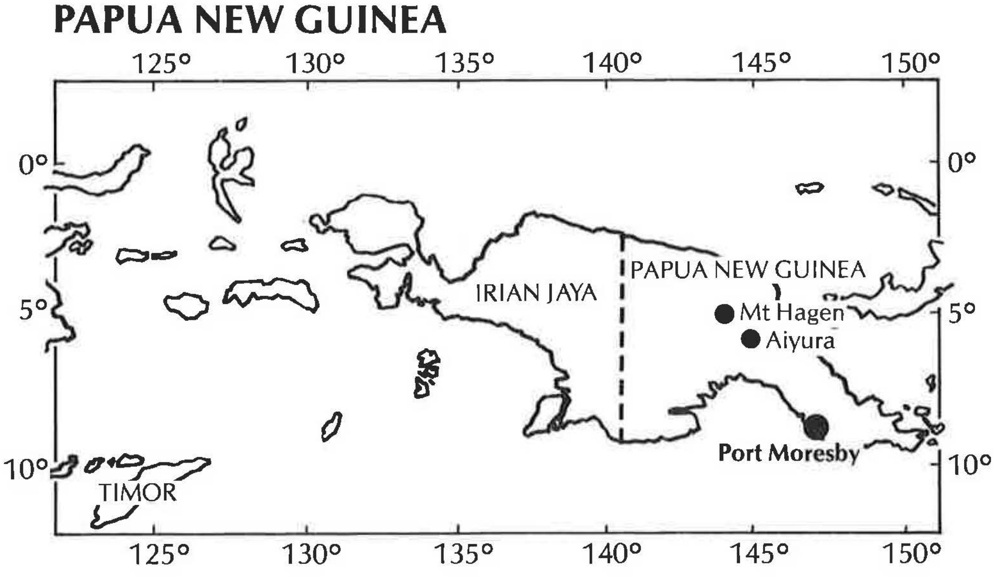
Papua New Guinea

Sweet potato is cultivated extensively in Papua New Guinea on a wide range of soil types, in many agro-ecological zones from sea level to over 2800 m, and in climatic regimes from 1000 to 8000 mm annual rainfall (Bourke, 1982; Rangaii and Kanua, 1988) (see Figure 4). Considerable research has been done on crop agronomy and farming systems by the Department of Primary Industry (Bourke, 1982). Unfortunately this appears to have had little impact on improving production in traditional systems (Hadfield, 1989).

Traditional production technologies in contrasting lowland and highland regions are diverse and complex. They include fallow rotation; varied planting systems from flat beds to mounds (mounds vary greatly in size and form: mounding is common in the highlands while flat beds are used in the lowlands

Figure 4

Papua New Guinea



especially for commercial production) (see Plate 5: Plate section, opp. p.16); and soil fertility and conservation techniques (Rangaii and Kanua, 1988). The latter range from composting on low-fertility soils to the extreme of the unique "Giu" technique of erecting horizontal soil-retention fences; use of ash from burnt, cleared fallow regrowth (slash and burn); application of ash from other sources; use of animal dung either through collection or tethering animals on plots after harvest; alley cropping; and planting leguminous and other nitrogen-fixing trees such as casuarina in the fallow.

Declining soil fertility is a major problem in some areas of the highlands and is potentially important in many areas as the population increases. Compost mounding, involving the incorporation of grass into the mound, shows great potential in alleviating fertility problems in areas where this is not currently practised (see Plate 5). Mounds vary in size and composting type: mounds containing up to 27 kg of composted material have been observed in the Western Highlands (Rangaii and Kanua, 1988). Where production is as low as 5 t/ha, preliminary trials with compost mounding have increased yields by 100%. The large-mound composting technique common in the Southern Highlands is presently being tested for introduction into other highland areas (Rangaii and Kanua, 1988). Fallows vary from region to region, tending to be longer in the lowlands (up to 15 years) than the highlands (1 to 7 years). Land shortages and increasing population pressure are contributing to shortening of fallows in the highlands. In some highland areas, soil fertility is maintained by sweet potato/legume (winged bean and peanut) rotations.

Farmers, mostly women, employ sequential or progressive harvesting of mature tubers using a digging stick. Progressive harvests may continue for 6 months after the first harvest, and total tuber yields are significantly greater than for single harvests. Although progressive harvesting alleviates the problem of storage, it allows pests such as weevil (and probably diseases) to multiply.

Papua New Guinea is considered an important secondary centre of diversity for sweet potato and varieties are numerous (Bourke, 1982). Farmers have selected sweet potato for many years and recognize the potential of new cultivars developed from chance seedlings. They change varieties constantly. Up to 40 varieties may be grown in a single village and more than 20 in a single garden, all chosen for particular characters. Some varieties are village-specific. Approximately 2000 varieties have been assembled into germplasm collections, yet these collections are largely under-utilized (Hadfield, 1989). To date, research has focussed on varietal characterization and selection rather than breeding (Rangaii and Kanua, 1988).

Each region tends to grow the same base group of varieties to facilitate supplies of planting material. The mix of other varieties grown depends largely on the availability of planting material from the farmer's previous planting and from neighbours' fields. The movement of planting material from farmer to farmer is very fluid. Selection of clean planting material is practised as much as possible. Farmers' variety preferences are complex and include visual appearance, colour, taste, texture, sweetness and yield. White to cream flesh is preferred. Farmers emphasize different characters depending on the destination of the tubers whether it be human consumption, pig feed or trading. Unfortunately, improved varieties are presently being selected mainly on the basis of yield, dry matter and protein content, with limited concern for farmers' preferences (Rangaii and Kanua, 1988).

In the highlands, sweet potato flowers profusely and seeds well every year. Some out-crossing does occur. Volunteer plants from seed commonly appear in gardens and vigorous, productive volunteers are often selected for the next planting. This is probably how the wealth of varieties arose in the highlands and throughout other secondary centres of diversity (Yen, 1982). The traditional use of mixtures probably indirectly benefits disease control. Previous crop residues can act as a source of inoculum for subsequent crops. Sanitation could also be improved by better selection of disease-free planting material but often availability of planting material is a limiting factor.

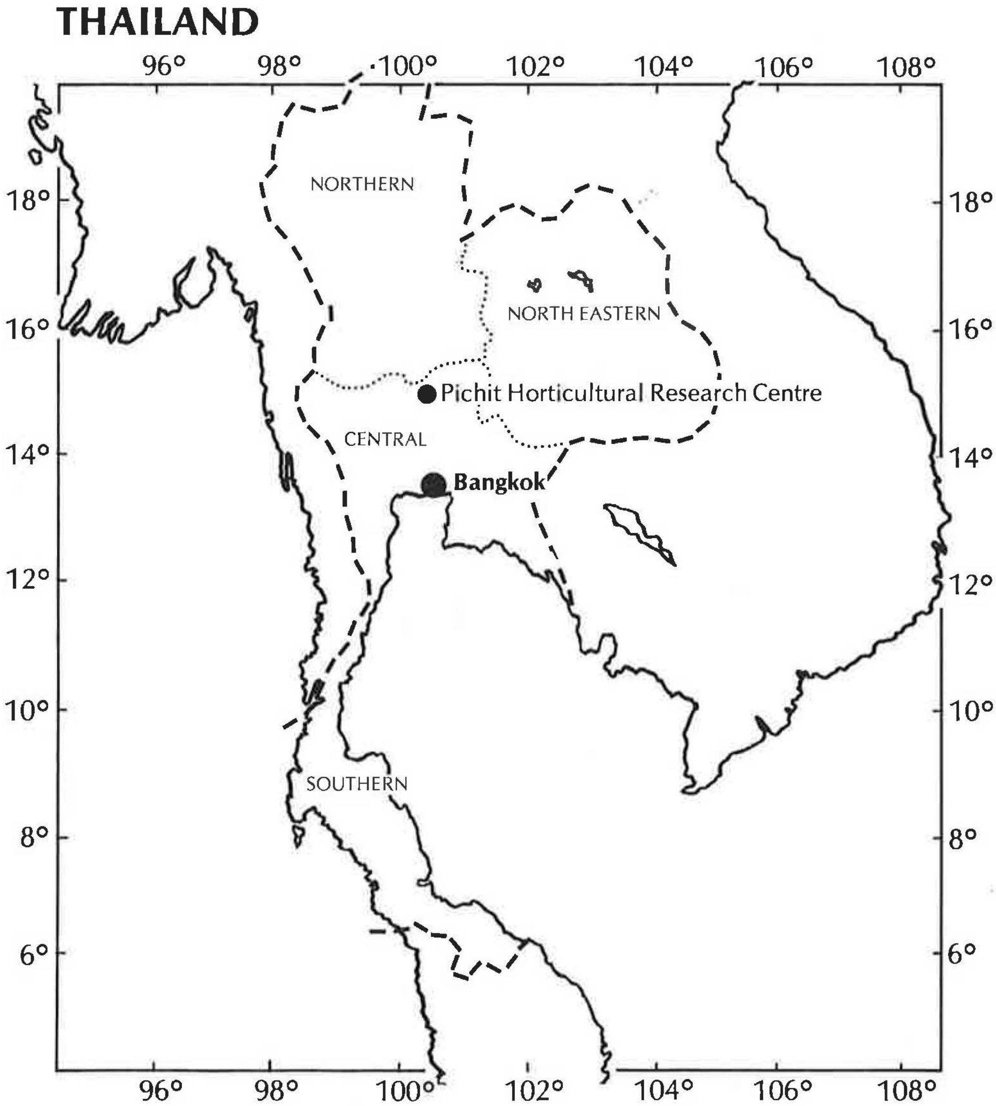
Traditional subsistence sweet potato production is experiencing drastic changes promoted by mounting population pressure and increasing socio-economic expectations. Recent advances in the introduction and adoption of new technologies such as intensive crop rotation, alley cropping, new cultivars and improved cultural practices have displaced many subsistence techniques (Rangaii and Kanua, 1988). Without any planning, this could be a risky development in such traditional areas.

Thailand

In the past, sweet potato was grown as a small-farmer crop for domestic consumption; now it is grown commercially in all regions of Thailand (Thongjiem and Piriyathamarong, 1989). Most sweet potato is grown in central Thailand (35.8%), followed by the southern (27.1%), north-eastern (26.5%), and northern (10.7%) regions (Thongjiem and Piriyathamrong, 1989) (see Figure 5). Although sweet potato can be grown year-round in Thailand because of good access to irrigation, the main growing season is late May to August. Commercial producers usually grow two crops per year, each requiring three months (Keinmeesuke and Vattanatangum, 1988). Sweet potato is grown commercially for both human consumption and processing to starch which is exported to Korea and Japan. Vines and unmarketable roots are used for animal feed. Small farmers grow sweet potato as a secondary and rotation crop with rice. They may also grow cassava,

Figure 5

Thailand



maize and mung bean. Such rotations aid in weevil control. Many farmers, especially small farmers, grow traditional local varieties, generally using planting material from their own fields or purchased from other, often large commercial farmers. There is no system in Thailand to provide farmers with good quality planting material (Thongjiem and Piriyathamarong, 1989). Sweet potato is generally cultivated on ridges in rice paddies, after the rice crop. Some research has been carried out on improved cultural practices and attempts have been made to transfer results to farmers. In general, commercial farmers have adopted some practices (Thongjiem and Piriyathamarong, 1989).

Although sweet potato is considered an important root crop in Thailand, it has been neglected in terms of research and development (Thongjiem and Piriyathamarong, 1989). The major areas where further agronomic research is needed include improvements in yield; specific location adaptation; improved soil and water management; plant protection; and improved post-harvest technology and utilization at the village and industrial levels.

EAST AFRICA

Uganda

Sweet potato is generally planted as a secondary crop to cereals in Uganda (Mwanga and Wanyera, 1988). It is grown whenever there is sufficient water for establishment. It is also usually grown outside the normal arable crops rotation, sometimes as a closing crop in the rotation or as an opening crop after clearing (Mwanga and Wanyera, 1988). In areas with year-round rainfall, such as the Lake Victoria region (see Figure 6), sweet potato is planted throughout the year. In dryer regions such as Serere, it is planted in the wet season only. In swampy areas, however, sweet potato may be cultivated in the dry season on huge mounds in swamps or at swamp edges (see Plate 6: see plate section opp. p.16). These often provide planting material and food until the end of the dry season (Jana, 1982).

Sweet potato is cultivated as an annual from vegetative cuttings which are usually left in a shaded, humid place for two or more days before planting. This treatment reduces initial extraction of soil moisture during establishment (Aldrich, 1963). Cuttings are planted in deeply-worked soil. Most sweet potato varieties flower and seed freely: volunteer plants from seed commonly appear in gardens and vigorous productive volunteers are often selected for the next planting (Mwanga and Wanyera, 1988).

There is great variation in foliage and root characters among sweet potato varieties in Uganda. In addition, varieties vary in taste, food value, consumer acceptance and maturity period (Jana, 1982). Most varieties mature within 4 to 6 months depending on climate, variety and local customs (Mwanga and Wanyera, 1988).

In Uganda, sweet potato is grown on mounds or, less commonly, on ridges of varying size (Aldrich, 1963). It is rarely grown on flat beds. Although varying from region to region (Jana, 1982), mounds are usually small, often 3 feet apart from centre to centre, and usually 2 to 6 cuttings are inserted into each mound. Deep cultivation is practised for ideal root growth and to reduce weevil damage (Jana, 1982; Mwanga and Wanyera, 1988). Sweet potato is grown most frequently in small, mixed varietal plantings in monoculture or in association with beans and maize. It is usually harvested piecemeal (Jana, 1982).

Although sweet potato is one of the most important food crops in Uganda, it has received little research attention. Research priorities include the development of improved high-yielding varieties of wide adaptability and consumer acceptance and techniques for improving soil fertility.

Rwanda

Sweet potato is widely cultivated year-round in Rwanda (Ndamage, 1984a). The major production areas are Butare, Ruhengeri, Gikongoro and Gitarama (see

Figure 6

Uganda

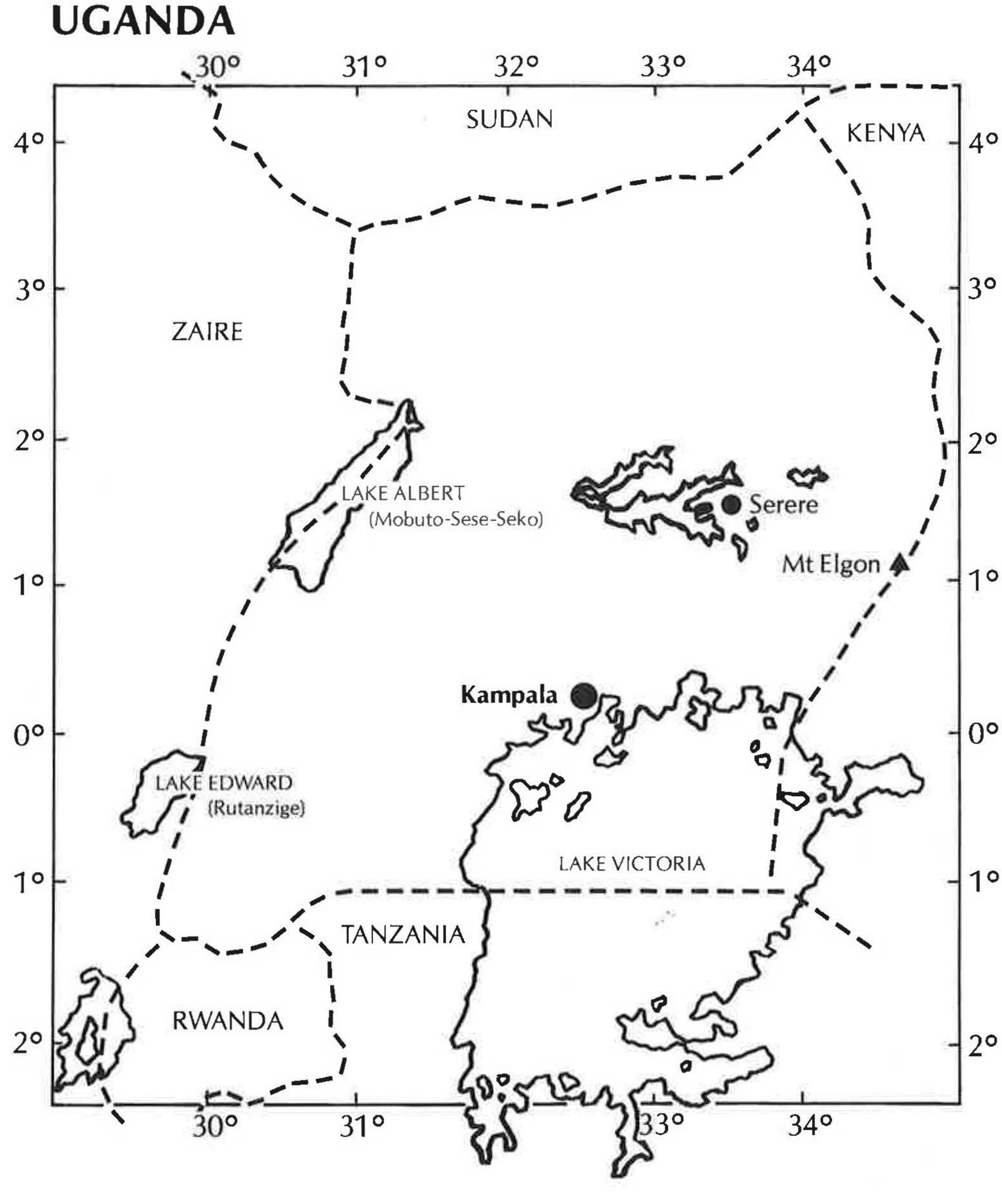
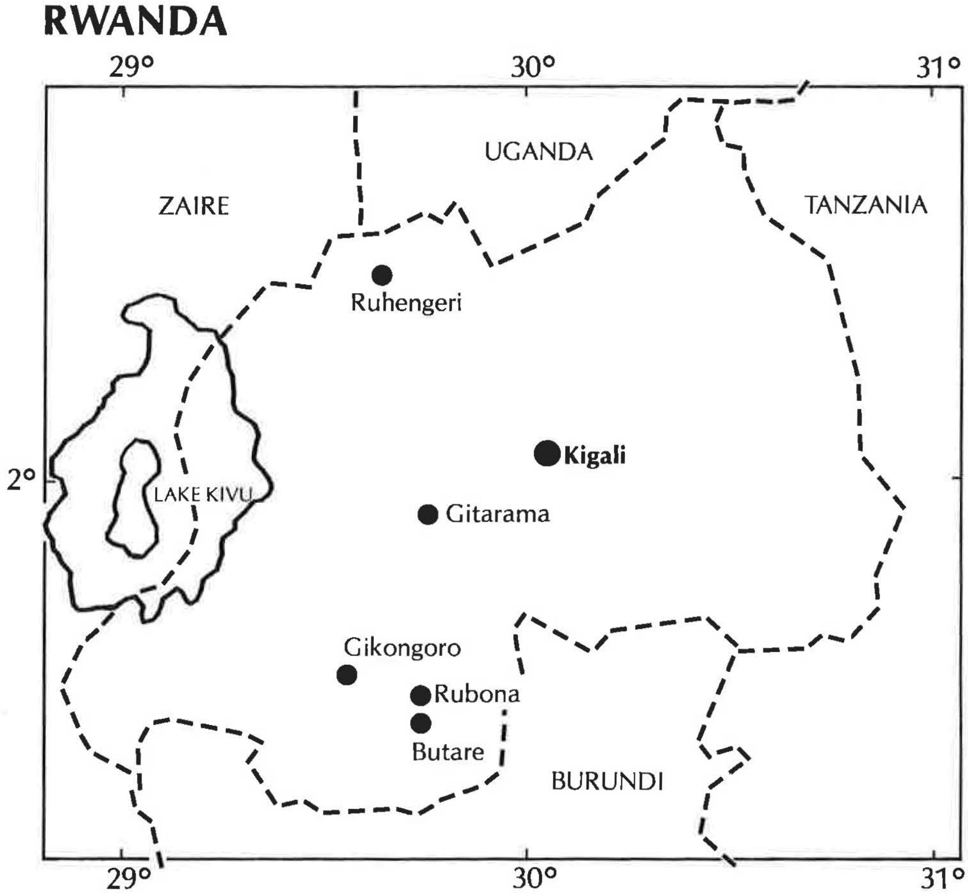


Figure 7) (Ndamage, 1988). It is grown up to 2300 m altitude, alone or in association with beans, sorghum or cassava, from September to April (wet season) on hill slopes and from May to July (dry season) in valleys which are often flooded during the wet season (Ndamage, 1984a). On hill slopes, sweet potato is grown on ridges or mounds, while in the flooded valleys it is grown on large mounds (see Plate 7: see Plate section opp. p.16). Cultural practices are very diverse and need to be better understood both agronomically and economically (Janssens, 1980). Some agronomic research has been done on planting methods, planting density and fertilizers. A comparison of ridges, mounds and flat beds showed no significant yield differences among treatments (Ndamage, 1989). In the future, improving sweet potato production by further intensifying production will become more important because of increasing population growth.

Considerable emphasis is being placed on the development of adequate supplies of clean planting material, especially for the end of the dry season, so that new crops can be planted as early as possible in the wet season. After the last severe famine, the government supported the initiation of multiplication plots in each community to supply planting material at the end of the dry season. A simple, efficient, rapid multiplication scheme has been developed which sup-

Figure 7

Rwanda



plies almost all of more than 140 communities growing sweet potato (see page 86).

Mixtures are most commonly planted, although mixing varieties with different maturity times can be a problem when farmers use single harvests. Most farmers, however, harvest progressively over a period of several months. Although not common, in some regions, sweet potato is grown commercially : for example, in Gitarama about 30% of production goes to market. This contrasts with cassava where about 50% of the national production is sold commercially for processing.

Although farmers' plantings on more fertile soils achieve similar yields to research station plots, lack of vigour and productivity is obvious in plantings on poor soils. Farmers often compost with grass about 2 to 3 months before planting, but do not use fertilizers. Application of manure as a mulch is recommended (Ndamage, 1989). Poor soils are either very low in organic matter and/or acid (pH 3 to 5) with a high aluminium content. Lime may be applied to reduce aluminium and acidity. Such land is mainly used for forestry but sweet potato may be grown when the trees are young. Farmers own their own land on hillsides but usually swampy valleys are owned by the government. Farmers can use this land as needed, but it can be taken for government use without warning. During the dry season, most valleys throughout Rwanda are used for sweet potato production.

In the Rubona region, sweet potato is continuously cultivated, on hillsides during the wet season and in valleys during the dry season. Plantings on hillsides are often associated with beans, while dry-season valley plantings are usually monocultures of varietal mixtures. These mixtures are striking: often ten or more varieties are grown in small patches, ISAR varieties being mixed with local lines. Planting material of traditional local varieties is commonly grown in small plots near farmers' houses. Around Kigali, sweet potato is also grown on hillsides and in flooded valleys and taro is also often grown on large mounds in flooded valleys.

Kenya

Sweet potato culture in Kenya varies from region to region. The crop is grown in association with cereals (see Plate 8: see Plate section: opp. p.16) and grain legumes, or mono-cropped on ridges and mounds. Traditional local varieties are both late-maturing and low-yielding, characters which generally make them more susceptible to pests and diseases (Shakoor *et al.*, 1988). Sweet potato was traditionally grown as a perennial crop in Kenya, each planting being harvested progressively over a long period. In the mid-1960s, noticeable pest build-up occurred, due either to increased planting of sweet potato exacerbating pest and disease problems, or to increased use of insecticides in plantation crops such as coffee causing the death of natural biological control agents of sweet potato pests (Kibata, 1976). These factors, together with declining soil fertility, have shortened the growth cycle of the crop.

About 90% of Kenya's sweet potato is produced in Nyanza, Western, Central and Eastern provinces (Shakoor *et al.*, 1988) (see Figure 8). The most important sweet potato production zone in Kenya is South Nyanza in Western Kenya, which is serviced by Kisii Research Station, the National Sweet Potato Germplasm Centre. Production from this region is distributed throughout Kenya, including to the Nairobi and Mombasa markets. Although most sweet potato is grown in Western Kenya, there are also important production regions in Kiambu, Machakos, and on the coast and throughout the coastal hinterland.

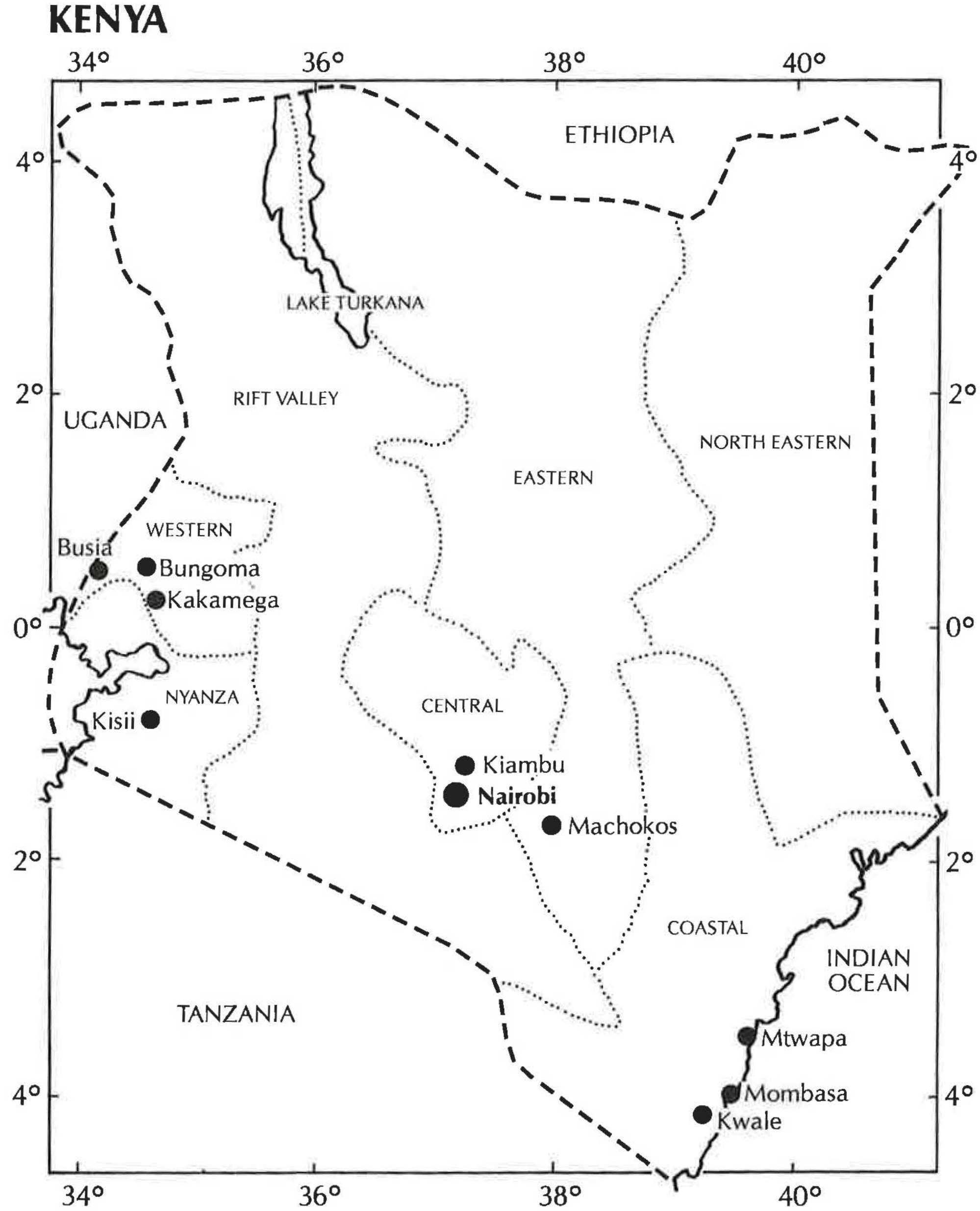
Although sweet potato is grown year-round in Western Kenya, there are peaks related to the extent and severity of the dry season. Much is planted during October to December as food for the dry season, because other crops will not mature in time. Sweet potato is mostly grown as small plots of pure stands. Commercial farmers tend to plant single varieties, but small farmers usually plant mixtures. Traditionally the crop is harvested piecemeal. Sweet potato is becoming more important as supplies of cereals decrease.

An informal quarantine system for sweet potato exists between regions in Kenya. This is very important because there are three major, largely geographically isolated, production regions. Certain pests and diseases may be restricted to specific areas. Even in Western Kenya, the Kisii area is isolated from the Kakamega area by a valley producing sugar cane. Despite this, farmers still tend to move vegetative material around the country. As sweet potato is grown throughout the year in Western Kenya, planting material is always available and some moves to other parts of Kenya, especially dryer regions. It is also brought into Kenya from nearby countries such as Uganda and Tanzania. There is a risk in moving germplasm from region to region in Kenya before disease and pest constraints in each region are adequately identified.

Cultural practices are diverse in Western Kenya. Commercial farmers hill up to facilitate an early single harvest, concentrating root development in time as well as giving protection from weevil. As most small farmers harvest progressively for home consumption, they tend to plant on flat beds as this allows root maturation over time. Tubers remain in the ground until needed, and there is no above-ground storage. Three types of variety are grown, based on maturity: 3-month, 3–4-month, and 5–6-month. Early-maturing varieties allow only one harvest and are mainly grown by commercial producers, whereas late-maturing varieties allow progressive harvesting and are grown on small farms. Medium-sized tubers and sweet, yellow, high dry-matter varieties are preferred. Leaves are used for forage and are only eaten as a vegetable in times of food shortage. Most commonly, forage is offered to animals only at the final harvest. There is, however, increasing interest in forage and dual-purpose (tuber and forage-producing) varieties, and the latter are being multiplied at Kakamega Research Station. This is related to a zero-grazing initiative in areas with increasing pressure for land such as in Western Kenya.

Figure 8

Kenya



In the dry Eastern Province (annual rainfall 500–800 mm), rainfall is bimodally distributed with the main wet season from March to May, and a shorter wet season from October to December. There are potentially two cropping seasons, but most small farmers plant in March and do not harvest until October to December, or harvest piecemeal. As the crop is often left in the soil for 7 to 8 months, weevils are very important pests in this region. In contrast, commercial farmers grow early-maturing varieties and harvest after 3 months. Potential yields of the best varieties are about 20 t/ha in comparison to 45 t/ha in well-watered regions. As in Western Kenya, there is increasing interest in dual-purpose varieties as pressure for land is making the role of sweet potato forage more important.

An adequate supply of clean planting material, especially at the beginning of the wet season, is a major problem in the Eastern Province, as only some farmers have access to irrigation. IITA has provided courses in rapid multiplication and tissue culture facilities are available at Muguga; however a Kenya-wide rapid propagation scheme is needed to facilitate supplies of healthy planting material to farmers.

Intercropping sweet potato with maize (see Plate 8) and pigeon pea is common, and agronomic research is in progress on spacing for pure and intercropped plantings. The choice between mounds, ridges and flat beds is complex and determined by many factors including the scale of operation, the tradition of the farmer and region, and the type of harvest planned. Commercial farmers will often use flat beds with hilling up at 1 month to make harvesting easier. Small farmers will use either flat beds for piecemeal harvesting or mounds for ease of tuber location. Strict rotation is not common as sweet potato is usually grown on marginal lands where other crops cannot be grown.

In the Coastal Province, the crucial problem is lack of planting material at the beginning of the wet season. Improved technology for rapid multiplication of planting material is being developed at Mtwapa Research Station to try to alleviate this (T. Munga, personal communication). Nursery beds are constructed under shelters of coconut fronds, and cuttings with 2 to 3 nodes are planted and watered twice daily for 2 weeks. Cuttings are dipped in carbofuran before planting. Shelters are then removed and the material is watered once daily. After 3 weeks, each square metre can yield 100 to 300 cuttings, depending on whether cuttings are harvested basally or apically. However, as high humidity in these nurseries facilitates disease development, Benlate is commonly applied for leaf spot (probably *Cercospora* leaf spot) control, and insecticides are also used. The need for pesticides may discourage some farmers from using this technology.

At Mtwapa Research Station, CIP collaborative agronomic trials are looking at the effect of leaf removal on cutting establishment and tuber yield, and the effects of method of planting (angle of cuttings) and of plant density on yield. These trials include one locally bred variety (MTW 8) and one IITA variety, selected for high yield, dry matter and resistance to weevil. Most local coastal varieties are early-maturing (3–4 months).

On the coast, planting method depends on soil type. Where the soil has structure, ridges are most common, but on sandy, structureless soils, farmers plant on flat beds because ridges readily wash away. But farmers who use ridges believe that yields are better than on flat beds. This may be due to increased weevil control with ridges.

The main commercial production area on the coast is Shimba Hills in Kwale province. Three main varieties are grown – MTW 8, Rwanda, and a local, traditional variety. MTW 8 is preferred because of its yellow flesh, lack of fibre, medium sweetness and high dry matter. The other two varieties are white to cream-coloured. Ridging is used frequently. Farmers, especially commercial ones, use rotation usually with maize and sometimes pigeon pea, to control weevil. Some farmers also grow mixtures. Commercial farmers may use insecticides to control weevil.

The potential impact of sweet potato improvement on traditional production systems such as those in Western Kenya needs to be evaluated before major cultural changes and new varieties are introduced. Farmers have developed their own systems, cultural practices and varieties in, until recently, an isolated situation. They are successfully managing many production constraints. Studies of these traditional systems and of the complex interactions with pests and diseases should be carried out before major changes are made.

Section 3

Diseases and pests of sweet potato

SUMMARY

Diseases

Sweet potato is affected by a wide range of diseases caused by fungi, bacteria, a mycoplasma, viruses and nematodes. Most published information, however, relates to temperate, developed countries (Harter and Weimer, 1929; Clark and Moyer, 1988). Major diseases of sweet potato mentioned in this literature include bacterial pox (*Streptomyces ipomoea*), soft rot (*Erwinia chrysanthemi*), black rot (*Ceratocystis fimbriata*), dry rot (*Diaporthe batatas*), Java black rot (*Botryodiplodia theobromae*), wilt or stem rot (*Fusarium oxysporum* f. sp. *batatas*), scurf (*Monilochaetes infuscans*), foot rot (*Plenodomus destruens*), soft rot (*Rhizopus stolonifer*), and circular spot (*Sclerotium rolfsii*) (Clark, 1988; Clark and Moyer, 1988; Collins, 1988). Few of these diseases are presently regarded as important in the tropics.

Most of the published information on diseases of sweet potato in tropical developing countries is restricted to surveys of their distribution. Important exceptions are research on scab and, to a lesser extent, little leaf mycoplasma (LLM) in south-east Asia and the Pacific and on viruses in Africa. This will be reported in the following pages. A comprehensive list of pathogenic fungi recorded on sweet potato, with emphasis on diseases observed during the survey and containing published and unpublished (International Mycological Institute) records from Africa, Asia and the Pacific is included (Table 3). In addition, diseases on specimens in the Herbarium Bogoriense, Indonesia and the National Herbarium, Nairobi, Kenya are listed (Table 4). Information about mycoplasmas, viruses, bacteria and nematodes affecting sweet potato is also given in Tables 5–8, respectively.

Although both Cercospora leaf spots and Phomopsis (Phyllosticta) leaf spot are common in south-east Asia, the Pacific and east Africa, they were found to be of minor importance in the present survey. Two species of *Cercospora* have been commonly described as leaf-spotting pathogens of sweet potato, *Cercospora ipomoeae* and *Pseudocercospora timorensis* (syn. *C. timorensis*); however, they are not easy to distinguish. Both fungi cause circular to irregular brownish lesions and may cause severe damage and defoliation under humid conditions. They can be distinguished by conidial morphology (see Figure 9; Plate 9, see Plate section opp. p. 17). Further work on symptom characterization could be worthwhile. Yield losses of 10% have been recorded in the Philippines (de la Cruz *et al.*, 1981). Phomopsis leaf spot (*Phomopsis ipomoeae-batatas*, syn. *Phyllosticta batatas*) is widespread on sweet potato throughout south-east Asia, the Pacific and east Africa as well as in other sweet potato-growing regions. It is manifest as usually small, greyish to light brown spots with purplish brown margins. It is classed as a minor disease and my own observations support this. It has apparently been confused with scab in some African countries.

The most important diseases recognized in south-east Asia, the Pacific and east Africa were viruses, scab (*Elsinoe batatas*) (see Plate 10: see Plate section opp. p. 17), little leaf mycoplasma (LLM) and Alternaria stem blight (*Alternaria* spp.) (see Plate 11: see Plate section opp. p. 17). All of these diseases are restricted geographically. Scab and LLM are presently known only from south-east Asia and the Pacific; Alternaria stem blight has been reported from east Africa and Papua New Guinea only; while specific viruses are restricted to

Table 3

Fungal pathogens recorded* on sweet potato with emphasis on records from Africa, Asia and the Pacific regions.

Fungus	Disease	Distribution
Albugo ipomoeae-panduratae (Schwein.) Swingle	White blister rust	Widespread in Africa, Asia, Australasia, Oceania, Europe, North, Central and South America and West Indies on a wide range of species and genera of the Convolvulaceae (CMI Distribution Map No. 568 [1986]); Bangladesh (Ahmed, 1952), Cuba (IMI, 1967), Fiji (Morwood, 1955), Guyana (IMI, 1944), Nepal, Paraguay, Trinidad (IMI, 1968, 1945, 1944), Vietnam (Anon.), Venezuela (IMI, 1927)
Albugo sp.	White blister rust	Bolivia (IMI, 1968)
Alternaria alternata (Fr.) Keissler	Leaf and stem blight	India, Malaysia, Papua New Guinea, Senegal (IMI, 1975, 1985, 1987, 1982)
Alternaria bataticola Yamamoto	Leaf spot	Papua New Guinea (Waller, 1984)
A. capsici-annui Savul. and Sandu-ville	Leaf and stem blight	India (IMI 1985; Sivapraksam *et al.* 1977)
A. solani Soraurer	Leaf and stem blight	Burundi (Buyckx, 1962), New Caledonia (Bugnicourt and Marty, 1961), Papua New Guinea (Kokoa pers. comm), Rwanda (Buyckx, 1962)
A. tenuissima (Pers.) Wilts.	Leaf and stem blight	India (IMI, 1958), South Africa (Gorter, 1977)
Alternaria sp.	Leaf and stem blight	Gabon (Manser, 1982), Kenya (Gatumbi *et al.*, 1990) Africa (IMI, 1982), Ethiopia (IMI, 1963†; Van Bruggen, 1984), Togo (Steiner, 1976), Uganda (IMI, 1963), Zambia (Angus, 1963; Riley, 1956; IMI, 1954), Zimbabwe (Whiteside, 1966)
Ascochyta bataticola Cochr. and Djurin	Leaf spot	Papua New Guinea (Muthappa, 1987), Rwanda (IMI, 1985)
A. convolvuli Fautrey	Leaf spot	Ghana (Piening, 1962), Papua New Guinea (IMI, 1984; Waller, 1984)
A. hortorum (Speg.) C. O. Sm.	Leaf blight	Ethiopia (Stewart and Yirgou, 1967)
Ascochyta sp.	Black leaf spot	Indonesia (Gattani and Oka, 1964), Kenya (IMI, 1967; Ondieki, 1973), Malaysia (Singh, 1980), Uganda (IMI)
Botryosphaeria ribis Grossenb. and Dugg.	Tuber rot	Malaysia (IMI, 1970†)

Fungus	Disease	Distribution
Botryodiplodia theobromae Pat. (syn. *Diplodia tubericola; D. gossypina*)	Tuber rot/Java black rot	Argentina (IMI, 1978), Burundi (Buyckx, 1962), Ghana (Leather, 1959), Indonesia (Gattani and Oka, 1964), Kenya (IMI; Nattrass, 1961), New Zealand, Nigeria (IMI, 1965, 1985), Niue (Dingley *et al.*, 1981), Papua New Guinea (IMI, 1975; Muthappa, 1987), Philippines (IMI, 1983; Reinking, 1919), Rwanda (Buyckx, 1962), Solomon Islands (IMI, 1988), Uganda (Emechebe, 1975), Vietnam (Anon., 1966)
Capnodium sp.	Sooty mould	Pakistan (Ghafoor and Khan, 1976)
Ceratocystis fimbriata Ellis and Halst.	Black rot	India (Rangaswami, 1975), Papua New Guinea (IMI, 1984; Shaw, 1985), Trinidad, USA (IMI, 1927), Vietnam (Anon., 1966)
C. paradoxa (Dade) C. Moreau	Tuber rot	Malaysia (IMI, 1956; Singh, 1973), Papua New Guinea (Waller, 1984)
Ceratocystis sp.	Tuber rot	Malaysia (IMI, 1961; Singh, 1973)
Cercospora ipomoeae Wint.	Leaf spot	Antigua, Cuba, India, (IMI, 1972, 1967, 1967†), Malaysia (IMI, 1960; Singh, 1973), Netherlands New Guinea‡ (IMI, 1959), Senegal (IMI, 1982), Sudan (IMI, 1944; Tarr, 1963), Tanzania (IMI; Riley, 1960)
Cercospora sp.	Leaf spot	India (IMI, 1968), Kenya (Gatumbi *et al.*, 1990), Nigeria (IMI, 1989), Uganda (Emechebe, 1975)
Cochliobolus cynodontis Nelson	Leaf spot	New Zealand (IMI, 1968)
C. geniculatus Nelson	Leaf spot	Cuba, India (IMI, 1966, 1958), Malawi (Wiehe, 1953)
C. lunatus Nelson and Haasis	Leaf spot	India (IMI, 1958†), Vietnam (Anon., 1966)
C. pallescens (Tsuda and Uyemoto) Sivan.	Leaf spot	India (IMI, 1958)
C. spicifera Nelson	Leaf spot	India (IMI, 1986)
Coleosporium ipomoeae (Schwein.) Burr.	Red rust	Present throughout Africa, Asia, North, Central and South America and West Indies on *Pinus* spp. and *I. batatas* (CMI Distribution Map No. 484 [1971]); Grenada, Jamaica, St. Vincent, Uganda (IMI, 1954, 1949, 1971, 1954)
Colletotrichum capsici (Sydow) Butl. & Bisby	Leaf spot	India, Nigeria (IMI, 1978, 1973)
C. phomoides (Sacc.) Chester	Anthracnose	Philippines (Quimio and Capilit, 1981)
Colletotrichum sp.	Leaf spot	Fiji (Dingley *et al.*, 1981), Kenya (Gatumbi *et al.*, 1990), Mauritius (Wiehe, 1948)

Fungus	Disease	Distribution
Corticium rolfsii (syn. *Sclerotium rolfsii* Sacc.)	Collar rot/wilt	Burundi (Buyckx, 1962), Fiji (Morwood, 1955), India (Anon, 1950), Indonesia (Anon, 1975), Malawi (Wiehe, 1948), Malaysia (IMI, 1966; Singh, 1973), Papua New Guinea (Shaw, 1985), Philippines (Reinking, 1919), Rwanda (Buyckx, 1962), Solomon Islands (IMI, 1976), Thailand (Chantarasrikul, 1962), Vietnam (Anon., 1966), Zimbabwe (Whiteside, 1966)
Corticium sp.	Collar rot	Cameroon, Ghana, Nigeria, Sierra Leone (IMI, 1979, 1951, 1957, 1928)
Corynespora cassiicola (Berk. and Curt.) Wei	Large leaf spot	Indonesia (Gattani and Oka, 1964), Papua New Guinea (IMI, 1984), Solomon Islands (Brown, 1973)
Curvularia sp.	Leaf spot	India (IMI, 1980)
Cylindrocarpon destructans (Zins.) Scholten	Leaf spot	Papua New Guinea (IMI, 1984; Waller, 1984)
Diplodia sp.	Leaf spot	Ghana (IMI, 1951)
Elsinoe batatas Sawada	Scab	**ASIA** : Brunei (Peregrine and Kassim Bin Ahmad, 1982), China (Ling and Jenkins, 1951), Hong Kong (IMI, 1962), Indonesia (IMI; Gattani and Oka, 1964), Japan (Wilson *et al.* 1989), Malaysia (IMI, 1960†; Singh, 1973), Philippines (Nayga and Gasapin, 1986), Taiwan (IMI, 1933), Vietnam (Anon, 1966); **PACIFIC** : Australia (Ramsey *et al.*, 1988), Cook Islands (Dingley *et al.*, 1981), Fiji (IMI, 1961; Firman, 1972), French Polynesia, Hawaii (Wilson *et al.*, 1989), Guam (IMI, 1975; Adair, 1971), New Caledonia (IMI, 1961), Niue (Dingley *et al.*, 1981), Papua New Guinea (IMI, 1960; Shaw, 1985), Solomon Islands (IMI, 1975), Palau, Pohnpei, Rota, Saipa, Tinian, Truk (Wilson *et al.* 1989), Tonga, Vanuatu, Yap (IMI, 1964, 1960; Wilson *et al.* 1989), **AMERICAS** : Brazil (Jenkins and Viegas, 1943), Mexico
Elsinoe sp.	Scab	Netherlands New Guinea‡ (IMI, 1959)
Exserohilum sp.	Leaf spot	Brunei (IMI, 1988)
Fomes lignosus	White root disease	Malaysia (Singh, 1973)
Fusarium avenaceum (Fr.) Sacc.	Diseases caused by *Fusarium* spp. include wilt, root rot, stem canker, and surface rot	Solomon Islands (IMI, 1975)
F. graminearum Schwabe		Malaysia (IMI, 1985)
F. moniliforme Sheldon		India (IMI, 1976)
F. moniliforme var. *subglutinans* Wr. and Reink.		Malaysia (IMI, 1985)

Fungus	Disease	Distribution
F. oxysporum Schlecht.		Africa (IMI, 1982), Kenya (Gatumbi *et al.*, 1990), Papua New Guinea (IMI, 1984†; Shaw, 1985), Solomon Islands (IMI, 1975), South Africa (Gorter, 1977)
F. oxysporum f. *batatas* (Wr.) Snyd. and Hans.		India (Anon., 1950)
F. pallidoroseum (Cke.) Sacc.		Ethiopia (Peregrine, 1988), India, Papua New Guinea (IMI, 1975, 1986)
F. solani (Mart.) Appel. and Wr.		Argentina, Papua New Guinea, Solomon Islands (IMI, 1978, 1984†, 1985)
Fusarium sp.	Storage rot	Uganda (IMI, 1985; Emechebe, 1975)
Glomerella cingulata (Stonem.) Spauld. and Schrenk.	Leaf spot	India (IMI, 1976), Ethiopia (IMI, 1977; Peregrine, 1988), Papua New Guinea (IMI, 1984; Waller, 1984), Tanzania (IMI, 1961; Riley, 1960), Uganda (IMI, 1961)
Helicobasidium compactum	Root rot	South Africa (Gorter, 1977)
H. purpureum Pat.	Violet root rot	Ethiopia (IMI, 1977)
Khuksia oryzae Hudson	Leaf spot	Brunei (IMI, 1988)
Leptosphaeria sp.	Leaf spot	Papua New Guinea (IMI, 1984; Waller, 1984)
Leptospherulina trifolii (Rostr.) Petrak	Leaf spot	Brunei (Peregrine and Kassim Bin Ahmad, 1982), Papua New Guinea (Waller, 1984)
Macrophomina phaseolina (Tassi) Goid.	Charcoal rot	Burundi (Buyckx, 1962), India, Nigeria (IMI, 1974), Pakistan (Ghafoor and Khan, 1976), Papua New Guinea (Muthappa, 1987), Philippines (IMI, 1983), Rwanda (Buyckx, 1962), South Africa (Gorter, 1977), Sudan (IMI), Tanzania (IMI, 1943; Riley, 1960), USA, Venezuela (IMI, 1923, 1969), Vietnam (Anon., 1966), Zimbabwe (Hopkins, 1950)
Meliola clavulata Wint.	Sooty mould	Dominican Republic, Guyana (IMI, 1930, 1960)
M. malacotricha Speg.	Sooty mould	Puerto Rico (IMI, 1936)
M. quadrifurcata Rehm.	Sooty mould	Philippines (Welles)
Monilochaetes infuscans Harter	Scurf	Australia (Simmonds, 1966), Cook Is. (Dingley *et al.*, 1981), Papua New Guinea (Muthappa, 1987), Sierra Leone (Deighton, 1936), Vietnam (Anon., 1966), Zimbabwe (Whiteside, 1966); CMI Distribution Map No. 246 (1981)
Mycosphaerella sp.	Leaf spot	Bolivia, Ethiopia (IMI, 1968, 1980), Malaysia (IMI, 1959; Singh, 1980), Nepal (IMI, 1965), Solomon Islands (IMI, 1971; Brown, 1973)
Myrothecium roridum Fr.	Leaf spot	India (Ravichandran and Sullia, 1983)
Nigrospora sphaerica (Sacc.) Mason	Leaf spot	Papua New Guinea (IMI, 1972)

Fungus	Disease	Distribution
Periconia byssoides Pers.	Leaf spot, storage rot	Cuba (IMI, 1966), Malaysia (IMI; Singh, 1973), Mauritius (IMI, 1958; Orieux and Felix, 1968), Nigeria (IMI, 1960), Singapore (Tan and Lin, 1970), Sudan (IMI, 1949), Zambia (Angus, 1963)
Pestalotiopsis versicola (Ell. and Everh.) Stayaert	Leaf spot	Papua New Guinea (IMI, 1984)
P. royenae (Sacc.) Stayaert	Leaf spot	Papua New Guinea (IMI, 1984)
Phoma glomerata (Corda) Wollenw. and Hochapf.	Leaf spot	India (IMI, 1971*)
P. exigua Desm.	Leaf spot	Papua New Guinea (Waller, 1984)
P. leveilleri	Leaf spot	Papua New Guinea (Waller, 1984)
P. sorghina (Sacc.) Boerem., Dorenb. and van Kest.	Leaf spot	Papua New Guinea (Muthappa, 1987)
Phoma sp.	Leaf spot	Rwanda (IMI, 1985), Venezuela (IMI, 1969), Zimbabwe (IMI, 1963; Whiteside, 1966)
Phomopsis ipomoeae Petrak	Leaf spot	Brazil (IMI, 1988), Brunei (IMI, 1972; Peregrine and Kassim Bin Ahmad, 1982), Central Africa (IMI, 1982), Ivory Coast (Resplandy *et al.*, 1954), Papua New Guinea (IMI, 1984; Waller, 1984)
P. ipomoeae-batatas Punith. (syn. *Phyllosticta batatas*)	Leaf spot, dry tuber rot, vine dieback	Brazil (IMI, 1988), Burundi (Buyckx, 1962), Cuba (IMI, 1967), Ghana (IMI, 1963; Leather, 1959), Guinea, Haiti, Hong Kong (IMI, 1962), Ivory Coast (Resplandy *et al.*, 1954), Kenya (Ondieki, 1973), Nigeria (IMI, 1958; Bailey, 1943), Papua New Guinea (IMI, 1964†; Shaw, 1985), Rwanda (Buyckx, 1962), Sierra Leone (IMI, 1936†; Deighton, 1936), St. Vincent, Sudan (IMI, 1971, 1944†), Tanzania (IMI, 1964†; Ebbels and Allen, 1979), USA, Uganda (IMI, 1923, 1960), Zambia (IMI, 1960; Angus, 1963)
Phomopsis sp.	Leaf spot	Bolivia, Ghana, Kenya, Tanzania (IMI, 1968, 1951, 1944, 1964)
Phyllosticta sp.	Leaf spot	Papua New Guinea (Muthappa, 1987)
Phyllostictina sp.	Leaf spot	Bolivia (IMI, 1968)
Phytophthora infestans (Mont.) de Bary	Wilt	Philippines (Quimio and Capilit, 1981)
Phytophthora sp.	Tuber rot	Australia (Simmonds, 1966)
Plenodomus destruens Harter	Stem blight, tuber rot	Burundi (Buyckx, 1962), Niue (Dingley *et al.*, 1981), Rwanda (Buyckx, 1962), South Africa (Gorter, 1977), Tanzania (Riley, 1960)
Pleospora herbarum (Fr.) Rabh.	Leaf spot	Senegal (Bohout and Mallamaire, 1965), South Africa (Gorter, 1977)

Fungus	Disease	Distribution
Pseudocercospora timorensis (Cooke) Deighton (syn. *C. timorensis; C. batatae*)	Leaf spot	Bangladesh (Ahmed, 1952; Ishaque and Talukdar, 1967), Brunei (Peregrine and Kassim Bin Ahmad, 1982), Cambodia (Hanson, 1963a), Fiji (Morwood, 1955), Hong Kong (IMI, 1966), India (IMI, 1981†), Indonesia (Gattani and Oka, 1964), Laos (Hanson, 1963a), Malaysia (IMI, 1959†; Singh, 1973), Mauritius (IMI, 1959), Nepal, Nigeria (IMI, 1985), Papua New Guinea (IMI, 1984; Muthappa, 1987), Philippines (de la Cruz *et al.* 1981), Sierra Leone, St. Lucia (IMI, 1936, 1934), Solomon Islands (IMI; Brown, 1973), Tanzania (IMI, 1981; Wallace and Wallace, 1948), Thailand (Puckdeedindan, 1966), Vanuatu (IMI, 1961), Vietnam (Hanson, 1963a), Western Somoa (Dingley *et al.*, 1981)
Puccinia holosericea Cke.	Rust	Uganda (IMI, 1966)
Pyrenochaeta sp.	Leaf spot	Brunei (IMI, 1978; Peregrine and Kassim Bin Khan, 1982), Nigeria (IMI, 1972)
Pythium ultimum Trow	Wilt	South Africa (Gorter, 1977), Uganda (Hansford, 1937)
Ramularia batatas Rac.	Leaf spot/rot	Indonesia (Gattani and Oka, 1964)
Ramularia sp.	Leaf spot	Papua New Guinea (Muthappa, 1987)
Rhizopus oryzae Went. and Prisen. Geerl.	Storage rot/tuber rot	Fiji, Nigeria (IMI)
R. stolonifera (Fr.) Lind.	Tuber rot/storage rot	Australia (Simmonds, 1966), Cuba (IMI, 1967), Ethiopia (Peregrine, 1988), Fiji (Morwood, 1955), India (IMI, 1977), Indonesia (Gattani and Oka, 1964), Kenya (Gatumbi *et al.*, 1990), Malawi (Wiehe, 1948), Malaysia (Singh, 1973), Papua New Guinea (IMI; Waller, 1984), Philippines (Reinking, 1919), South Africa (Gorter, 1977), Uganda (Emechebe, 1975), Zimbabwe (Hopkins, 1950)
Septoria bataticola Taub. (syn. *Rhizoctonia bataticola* (Taub.) Butl.	Foliage blight	Indonesia (Anon., 1975), Uganda (IMI, Hansford, 1937), USA (IMI)
Septoria sp.	Foliage blight	Ghana (IMI, 1958)
Sporodesmium bakeri Syd.	Leaf spot	Philippines (Welles)
Stemphyllium botryosum Wallr.	Leaf spot	India (Anon., 1950)
S. lycopersicum (Enjoji) Yamamoto	Leaf spot	Senegal (IMI, 1982)

Fungus	Disease	Distribution
Thanatephorus cucumeris (Frank) Donk.	Foliage blight, black rot	India (Anon., 1950), Philippines (Anon., 1962), Solomon Islands (IMI, 1976), Thailand (Piya Giatong, 1980)

Notes:
* Published records and unpublished herbarium records from the CAB International Mycological Institute (IMI). This list complements Moyer and Clark (1988).
† More than one sample for the specific country exists in the IMI herbarium; date of accession of the first sample only is given.
‡ This material relates to Netherlands New Guinea, which is now part of Indonesia.

Table 4a

Diseases recorded on herbarium specimens of *Ipomoea* spp. in the Herbarium Bogoriense (H.H.B.), Bogor, Java, Indonesia (Backer and Bakhuizen van der Brink, 1962).

Location (No. from each location)	H.H.B. Number and date	Diseases
Species: *I. batatas*		
Indonesia:		
Celebes (8)	175165/?	Scab*, CLS†
Java (25)	175144/1943	CLS
	175146/1944	CLS
	175141/1904	CLS
	175150/1899	CLS
Sunda Island Flores (4)	122819/1939	CLS
Ambon (2)	175156/1914	CLS
	175157/1900	CLS
Moluccas	175158/1917	CLS
Buluceram (4)	175157/1917	CLS
Sumatra (10)	175173/1915	Scab
Papua New Guinea		
Enarobali	09339/1939	Scab
	09340/1939	Scab, CLS
	09341/1939	Scab
Philippines		
Luzon (3)	175162/1915	CLS
Guadalcanal	175180/1944	Scab
Hawaii		
Niikau	175182/1912	CLS
Species: *I. triloba*		
Indonesia :		
Java (60)	177386/1903	CLS
	177389/1903	Scab
	177421/1922	Scab
	177400/1893	Scab
	177402/1902	CLS
	177403/1903	CLS
	177405/1903	Scab
	177309/1918	Scab, CLS
	177407/1913	Scab
	177408/1913	Scab
	177409/1911	Scab, CLS
	177422/1917	Scab
	177429/1914	Scab
	177424/1910	CLS
	177416/1921	Scab
	177431/1919	Scab

Location (No. from each location)	H.H.B. Number and date	Diseases
Sunda Islands Lombok (4)	09533/1939	Scab
Subawa (2)	18185/1961	CLS
Ambon (1)	177436/1913	CLS
Sumatra (6)	S 40/1971	CLS
	177445/1941	Scab
	177446/1914	Scab
	54443/1938	Scab
Philippines	177438/1908	CLS
	177437/1914	CLS
Species: *I. aquatica*		
Indonesia:		
Borneo (5)	175057/1926	Black leaf spot
Java (45)	1233/1973	CLS
	?/1927	CLS
	175084/1912	Brown zonate leaf spot
	175086/1912	CLS
Sumatra (17)	175110/1918	CLS
	175113/1925	CLS
New Guinea (7)	10.347/1966	CLS
	09344/1941	Scab (severe)
	175098/1904	Scab (severe)
Philippines (2)	175100/1906	Black leaf spot
Species: *I. gracilis*		
Java (19)	177560/1912	Scab
	177572/1931	Rust
	177569/1952	Rust
	177570/1911	CLS

Notes: * Scab = *Elsinoe batatas.*
† CLS = Cercospora leaf spot, *Pseudocercospora timorensis.*
Note : Most specimens of *I. pes-caprae* were affected by CLS but no scab was detected.

Table 4b

Diseases recorded on herbarium specimens of *Ipomoea* spp.† at the National Herbarium, Nairobi, Kenya.

Origin	Number of Specimens	Diseases
Species: *I. batatas*		
Tanzania	8	CLS*
Tanzania	6	CLS
Zaire	1	CLS
Species: *I. longituba*†		
Uganda	5	CLS Rust/Synchytrium?‡
Kenya	29	CLS Rust/Synchytrium?
Species: *I. oenantherae*†		
South Africa	8	Rust
Zambia	2	CLS
Uganda	3	CLS
Kenya	26	Rust‡
Species: *I. aquatica*		
Ethiopia	5	CLS
Somalia	2	CLS
Kenya	11	CLS Tarspot
Zambia	2	CLS
Malawi	3	CLS
Tanzania	26	CLS Sooty mold Virus-like symptoms
Uganda	4	CLS

Notes:

* CLS = Cercospora leaf spot, *Pseudocercospora timorensis.*

† Specimens of *I. batatas, I. aquatica,* the two indigenous tuber-forming species, *I. longituba* and *I. oenantherae,* and several 'morning glory' weed species were observed. Damage to herbarium specimens of *I. oenantherae* suggests that it could be a host of sweet potato weevils. Various 'morning glory' weeds, common in Kenya including *I. purpurea, I. tricolor* and *I. nil* and the common beach colonizer *I. pes-caprae,* were examined. Specimens of *I. purpurea* from throughout Kenya (Nairobi, Thika, Kisii, virus plots at Muguga, Kitui), Tanzania, Ethiopia and Transvaal were affected by rust, CLS and Sooty mold. *Ipomoea nil* from Tanzania had rust, white rust and possible Synchytrium pustules on leaves. The most common disease observed on *I. pes-caprae* specimens was CLS.

‡ It was not possible to identify the rust. Some specimens showed hairiness indicative of mite attack (Erinose) but it could also have been a morphological character.

Table 5

Records of little leaf mycoplasma on sweet potato*.

Country	Reference
China	Chen *et al.* (1985)
Indonesia	Johnston (1961)
Korea	So (1973)
Malaysia	Johnston (1960a)
New Caledonia	Pole (1987)
Niue	Pole (1987)
Palau	Pole (1987)
Papua New Guinea	Pearson *et al.* (1984)
Ryukyu Islands (Japan)	Summers (1951)
Solomon Islands	Johnston (1960c)
Taiwan	Yang (1969)
Vanuatu	Jackson (1963)

Note: * Widespread in Asia, South-east Asia and the Pacific but never recorded outside this region.

Table 6

Characterized and partly characterized viruses recorded on sweet potato worldwide*.

Virus	Size (nm) and group	Known Distribution	Transmission†
Sweet Potato Feathery Mottle Virus (SPFMV)	Potyvirus		
Strains: 1. Feathery Mottle (FMV)‡	830±30 nm	Africa, Asia, Australia, South Pacific, Taiwan, USA	I=*Aphis gossypii, A. craccivora, Liphaphis erysimi, Myzus persicae, A. appi*; M=Occasionally to *Chenopodium quinoa* and *C. amaranticolor, Ipomoea setosa, I. nil* (best subcultured from grafted *I. setosa*); G=Restricted to the Convolvulaceae with *I. setosa* being the best species.
2. Russett Crack (RCV)	845±30 nm	USA	
3. Internal Cork (ICV)	845±30 nm	USA	
4. Chlorotic Leaf Spot (CLSV)	845±30 nm	USA	
Sweet Potato Mild Mottle Virus (SPMMV)‡	850–950 nm Potyvirus	East Africa	I=*Bemisia tabaci*; M=*Nicotiana tabacum, N. glutinosa, N. clevelandii, N. benthamiana*; G=Restricted to the Convolvulaceae with *I. setosa* being the best species.
Sweet Potato Latent Virus (SPLV; also called SPV-N)¶	750 nm Potyvirus	Taiwan	I=*Bemisia tabaci*; M=Best to *N. clevelandii*; G=Restricted to the Convolvulaceae with *I. setosa* being the best species.
Sweet Potato Caulimo-like Virus (SPCLV)‡	50 nm sphere Caulimovirus	Australia, Papua New Guinea, Togo, Puerto Rico, East Africa	I=not known; M=not known; G=Best to *I. setosa*
Sweet Potato Chlorotic Stunt Virus (SPCSV)¶	850–900 nm Rod	Puerto Rico	I=not known; M=Best to *N. tabacum* and *N. benthamiana*; G=*I. setosa* and *I. nil*.
Sweet Potato Ring Spot Virus (SPRV; also called SPV-B)	25 nm Nepovirus	Papua New Guinea	I=not known; M=not known; G=*I. setosa*.
Sweet Potato Yellow Dwarf Virus (SPYDV)	750 nm Potyvirus	Taiwan	I=*Bemisia tabaci*; M=*Chenopodium* spp., Solanaceae, Amaranthaceae, Compositae; G=*I. setosa*.

Virus	Size (nm) and group	Known Distribution	Transmission†
Sweet Potato Virus Disease Complex (SPVDC)	850 nm rod (SPFMV) and a whitefly transmitted agent (SPVLA)	Africa	I=Rod by *Myzus persicae* and *Aphis gossypii*; other component by *Bemisia tabaci*; M=TIB 8 sweet potato clone, subclone 9A of clone TIB9 with SPFMV; G=not known.
Cucumber Mosaic Virus (CMV)	30 nm sphere	Worldwide but not common on sweet potato	I=Various aphids; M and G=Wide range including Chenopodiaceae and Solanaceae.
Sweet Potato Vein Mosaic	760 nm Potyvirus	Argentina	I=*Myzus persicae*; M=Restricted to Convolvulaceae; G=*I. setosa*, *I. nil* and *I. hederaceae*.
Sweet Potato Phytoreo Virus	70 nm Reovirus	Thailand	
Sweet Potato Virus II (SPV-II)	750 nm Potyvirus	Taiwan	I=Various aphids; M=*N. benthamiana*; G=*I. setosa*.
Sweet Potato Leaf Curl Virus (SPLCV)	Badnavirus	Indonesia (Gattani and Oka 1964), Japan, Papua New Guinea (Muthappa, 1987; Shaw, 1985), Nigeria, Taiwan	I=*Bemisia tabaci*; M=not known; G=*I. setosa*.
Sweet Potato Mosaic Virus	?	Taiwan	I and M=not known; G=*I. setosa*.
Ilar-like Virus	?	Guatemala	I and M=not known; G=*I. setosa*.

Notes:
* After Beetham and Mason (unpublished data). This list complements Moyer and Salazar (1989).
† Transmission by insects (I); by mechanical means (M); and by grafting (G).
‡ Serological indexing by ELISA (The assay is performed on *I. setosa* leaf material which has been grafted with sweet potato tips).
¶ Serological indexing by ISEM (The assay is performed on *I. batatas* leaf material and *I. setosa* material [as for ELISA]).

Table 6b

Virus-like symptoms recorded on sweet potato with emphasis on records from Africa, Asia and the Pacific regions*.

Country	Record and source
Asia	
India	Mosaic (Anon, 1950)
Indonesia	Mosaic (Anon, 1975)
Philippines	Chlorotic spotting (Gapasin and Suico, 1984)
Australia/Pacific	
Australia	Mosaic (Simmonds, 1966)
New Caledonia	Virus-like symptoms (Dumbleton, 1954)
Africa	
Benin	Sweet potato virus (SPVDC)? (IMI)
Burundi	SPVDC?‡ (Buyckx, 1962)
Congo	SPVDC? (Sheffield, 1957)
Gabon	Virus (Manser, 1982)
Ghana	SPVDC? (IMI), mosaic (Leather, 1959)
Kenya	SPVDC? (Sheffield, 1953, 1957)
Malawi	Mosaic, SPVDC? (Weihe, 1948)
Nigeria	Mosaic and vein clearing (Bailey, 1943); SPVDC (Tottapilly and Rossell, 1988)
Rwanda	SPVDC? (Buyckx, 1962)
Sierra Leone	Mosaic (Deighton, 1936)
Tanzania	SPVDC? (Sheffield, 1957)
Togo	SPVDC? (Steiner, 1976)
Uganda	SPVDC? (Hansford, 1945; Sheffield, 1957)
Zimbabwe	Mosaic (Rothwell, 1983)

Notes:
* This list complements Beetham and Mason (unpublished data).
‡ SPVDC? could refer to either the complex of SPFMV and SPVLA or the complex of SPFMV and SPMMV.

Table 7

Bacterial pathogens recorded* on sweet potato with emphasis on records from Africa, Asia and the Pacific regions.

Bacterium	Disease	Distribution
Agrobacterium tumefaciens (Smith and Townsend) Conn	Crown gall	Not given (Bradbury, 1986)
Erwinia chrysanthemi Burkholder pv. *zeae* (Sabet) Victoria	Bacterial soft rot	Widespread throughout sweet-potato growing regions but not a major problem in many regions (Bradbury 1986; Clark 1988)
Pseudomonas solanacearum (Smith) Smith	Bacterial wilt	Although the pathogen is widespread, sweet potato wilt has only been reported in China where it causes serious losses (Clark, 1988)
P. syringae van Hall pv. *syringae*	Leaf spot, blight	Not given (Bradbury, 1986)
Streptomyces ipomoeae (Pearson and Martin) Waksman and Henrici	Soil rot or pox	Widely reported from the USA and Japan. Causes serious losses under cooler conditions (Clark, 1988)

Notes: *Rhodococcus fascians* (Tilford) Goodfellow may cause fasciation,leafy gall and distortion in East Africa and Asia.
* This list complements Moyer and Clark (1988).

Table 8

Pathogenic nematodes recorded on sweet potato with emphasis on records from Africa, Asia and the Pacific regions*.

Nematode	Distribution and source
Root-knot nematode	
Meloidogyne incognita (Kofoid and White) Chitwood	Most important, serious and widespread nematode attacking sweet potato (Jatala, 1989). May interact with *Fusarium* spp. causing severe wilting and premature death.
M. javanica (Trueb.) Chitwood *M. arenaria* (Neal) Chitwood	Both species readily attack the root system of sweet potato but cannot complete their life cycle on this plant (Jatala, 1989).
M. hapla Chitwood	Recorded on sweet potato in cooler, temperate regions.
Other nematodes	
Rotylenchulus reniformis	A widespread nematode in warm temperate and tropical regions which can limit sweet potato production (Jatala, 1989). Also interacts with *Fusarium* spp. causing plant death. Limited information is available on the importance of this nematode.
Pratylenchus spp.	Widely distributed in warm tropical regions and can seriously affect sweet potato (Jatala, 1989). Limited information is available on their importance.
Ditylenchus destructor	Potato rot nematode may also attack sweet potato, especially in China (Jatala, 1989).
Helicotylenchus sp.	Papua New Guinea (Bridge and Page, 1982); Thailand (Piya Giatong, 1980)
Heterodera marioni	Nigeria (West, 1938)
H. radicicola	Indonesia (Anon, 1975)

Note: * This list complements Moyer and Clark (1988).

specific regions and even countries (see Table 6). Although future extensive surveys may further clarify this picture, research on presently recognized important and potentially important sweet-potato diseases would be most efficient on a regional basis. This could create a logistical problem for international organizations.

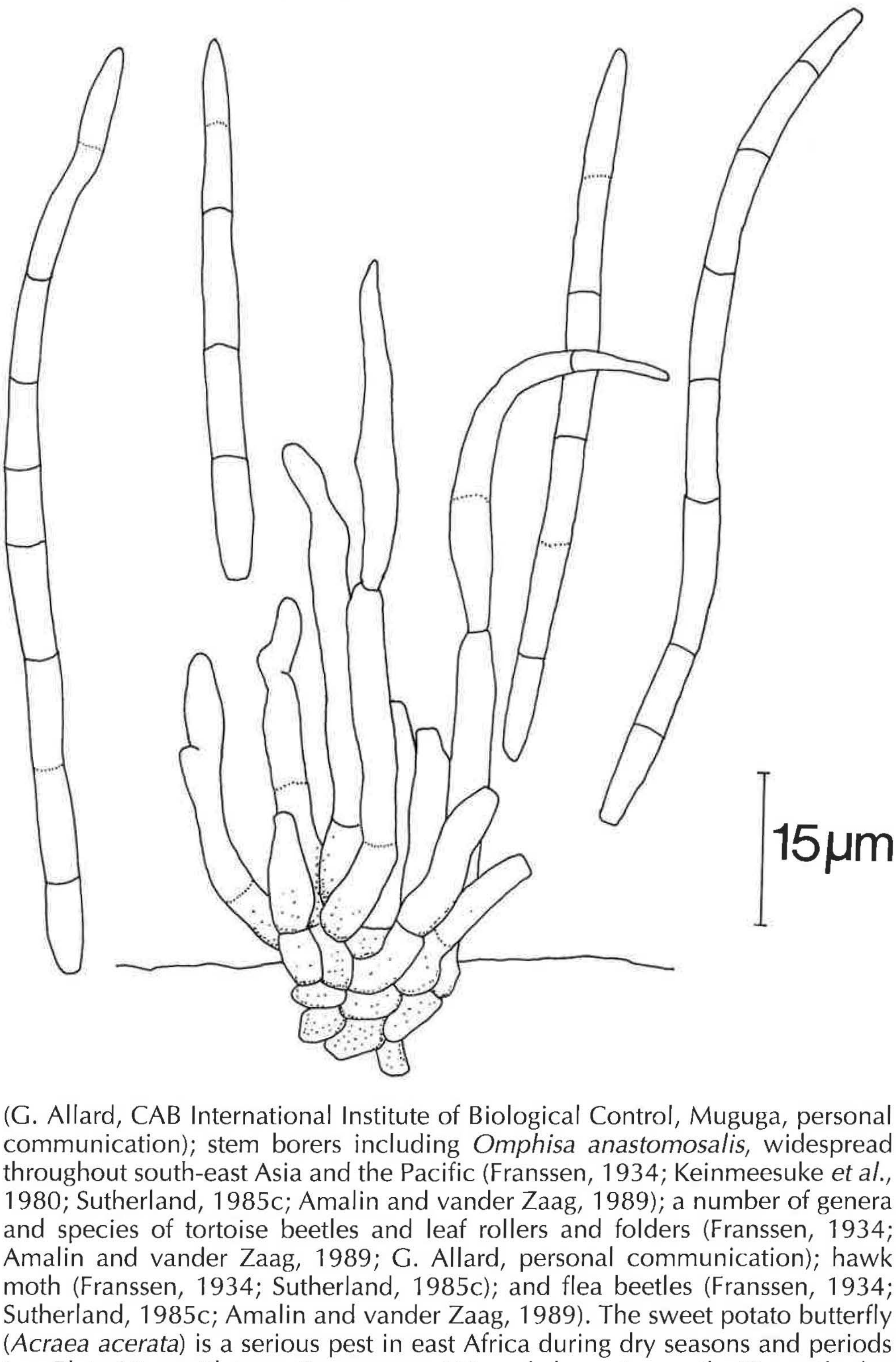
It should be borne in mind that the relative importance of sweet-potato diseases depends on the production system and the intended utilization of the crop (Clark, 1988). In the tropics, sweet potato may be grown year-round and is usually propagated by stem cuttings. In sub-tropical and temperate areas, with marked growing seasons, storage tubers are preserved through the cool season for propagation. Many important bacterial and fungal diseases affect storage roots, and their relative importance increases if roots are involved in the propagation cycle. As tubers are rarely stored in the tropics, storage diseases such as rots are generally of little importance. Also, in some countries (such as the Philippines) where sweet potato is an important source of vegetable leaves as well as tubers, foliar diseases, usually of minor importance, are potentially more destructive.

Pests

Insect pests of sweet potato have been extensively reviewed in both temperate and tropical regions (Franssen, 1934; Maitai, 1958; Wheatley, 1961; Terry, 1976; West, 1977; Sutherland, 1985c; Talekar, 1988b; Raman, 1988a,b; Amalin and vander Zaag, 1989; Chalfant *et al.*, 1990). Pests include leaf, stem, vine, tuber and flower feeders. Insect pests of interest include sweet potato weevils: *Cylas* spp., the most widespread and damaging genus (Talekar, 1982; Raman, 1988a,b; Chalfant *et al.*, 1990); *Euscepes postfasciatus*, important throughout the Caribbean and the Americas (Raman, 1988a,b; Chalfant *et al.*, 1990); striped weevils, *Alcidodes* spp. (Wheatley, 1961) and *Blosyrus* spp., common in east Africa

Figure 9

Conidia of *Pseudocercospora timorensis*. (Source: Deighton (1976) reproduced with permission from *Mycological Papers*, **140**: 154.)



(G. Allard, CAB International Institute of Biological Control, Muguga, personal communication); stem borers including *Omphisa anastomosalis*, widespread throughout south-east Asia and the Pacific (Franssen, 1934; Keinmeesuke *et al.*, 1980; Sutherland, 1985c; Amalin and vander Zaag, 1989); a number of genera and species of tortoise beetles and leaf rollers and folders (Franssen, 1934; Amalin and vander Zaag, 1989; G. Allard, personal communication); hawk moth (Franssen, 1934; Sutherland, 1985c); and flea beetles (Franssen, 1934; Sutherland, 1985c; Amalin and vander Zaag, 1989). The sweet potato butterfly (*Acraea acerata*) is a serious pest in east Africa during dry seasons and periods (see Plate 12: see Plate section, opp. p. 17), and clear wing moths (*Synanthedon* spp.) are also regarded as important pests in parts of east Africa (Wheatley, 1961; Bradley, 1968).

It is widely agreed that the most important insect pest affecting sweet potato world-wide is the complex of sweet potato weevils, *Cylas* spp. (see Plate 13: see Plate section, opp. p. 17). *Cylas formicarius* is widely distributed throughout the tropics, including the regions surveyed, while other *Cylas* spp., *C. puncticollis* and *C. brunneus*, are found in Africa. *Cylas* spp. weevils were the most important pests of sweet potato encountered during the present survey.

South-East Asia/Pacific

INDONESIA

The sweet potato weevil (*Cyclas formicarius*) and scab (*Esinoe batatas*) are the two most important biotic factors affecting sweet potato in Indonesia. Contaminated planting material is often the major source of scab. Other biotic factors of potential importance include LLM, viruses, hawk moth, and leaf folders and rollers.

PHILIPPINES

The sweet potato weevil (*C. formicarius*) is the most damaging pest. Other pests include leaf folders, mealy bugs, flea beetles and mites (Amalin and vander Zaag, 1989). Scab is the most prevalent disease and is common in the wetter parts of the Philippines. The existence of viruses is acknowledged but their importance has not been quantified. Although Java black rot (*Botryodiplodia theobromae*) has not been shown to be a major disease in the Philippines, it has been commonly observed in some highland areas.

PAPUA NEW GUINEA

The most important problem for sweet potato production in Papua New Guinea is widely believed to be declining soil fertility. This problem will increase in the future as pressure for land, especially in the highlands, increases. Important diseases and pests are location-specific in Papua New Guinea. The sweet potato weevil (*C. formicarius*) and LLM are the most important problems in the lowlands, while scab and Alternaria stem blight cause more damage in the highlands. Vine dry rot caused by *Fusarium oxysporum* is common in the Southern Highlands in locations where continuous planting has built up inoculum in the soil. Other pests include hawk moth, tortoise beetles and vine borers (Sutherland, 1985c).

THAILAND

Sweet potato weevil, *C. formicarius*, is the most important biotic factor affecting sweet potato in Thailand. Commercial producers depend on insecticides for control. Other pests include stem borer and the leaf miner. The most common diseases are scab, leaf spots caused by *Phaeoisariopsis bataticola*, *Pseudocercospora timorensis* and *Cercospora ipomoeae*, and root-knot nematode *Meloidogyne incognita* (P. Nilmanee, Dept of Agriculture, University of Bangkok, personal communication). Scab is found in all growing regions and is more severe in the cool, wet season (June to October).

East Africa

UGANDA

Viruses are the most serious diseases of sweet potato in Uganda. Sweet potato virus disease complex (SPVDC) has been known since the late 1930s (Hansford, 1945; MacDonald, 1963; 1967; Mukiibi, 1976a,b; Sheffield, 1957). Other viruses may also be present. Losses, however, have not been quantified. Other diseases are considered to be of minor economic importance, yet no country-wide surveys have yet been done. Stem blight, caused by *Plenodomus destruens*, has been reported (Hansford, 1944). The most serious pests are *Cylas* spp. weevils, including both *C. puncticollis* and *C. formicarius*. The smaller *C. formicarius* is commoner and more serious (Mwanga and Wanyera, 1988). Sweet potato butterfly is an important pest in the dry season.

RWANDA

SPVDC is the most important disease of sweet potato in Rwanda (Ndamage, 1989). As in Uganda, other viruses may also be present. Surveys have shown that

Alternaria stem blight, probably caused by *Alternaria solani*, is the second most important disease (Ndamage, 1989). No basic studies of either of these diseases have been done. Sweet potato weevils (*Cylas* spp.) are the most serious pests. Larvae of the sweet potato butterfly, *Acraea acerata*, severely defoliate sweet potato in the dry season (Ndamage, 1989). Erinose, caused by mites (*Aceria* spp.), is a minor problem and has not been reported outside east Africa (Sheffield, 1954).

KENYA

Viruses, including SPVDC, are also the major diseases of sweet potato in Kenya. Although other diseases are not presently considered to be important (Shakoor *et al.*, 1988), development of diagnostic tools, epidemiological studies and determination of the relative importance of diseases are considered necessary (Matata, 1988). An old germplasm collection at Mtwapa Research Station on the Kenya coast was moderately affected by *Pseudocercospora timorensis*. The major pests recorded on sweet potato in Kenya are *Cylas* spp. weevils (Maitai, 1958; Wheatley, 1961; Bradley, 1968; Kibata, 1976; G. Allard, personal communication). Three *Cylas* spp. occur in Kenya but *C. puncticollis* is regarded as the worst pest (G. Allard, personal communication). Other pests include tortoise beetles, striped weevils (*Alcidodes* spp.), *Blosyrus* spp. weevils, and clear wing moths (*Synanthedon* spp.) (Wheatley, 1961; Bradley, 1968). Erinose has also been reported (Sheffield, 1954). Nematodes can be a problem in fields under continuous cultivation.

IMPORTANT DISEASES AND PESTS IN THE TROPICS

Scab

Leaf and stem scab is the most severe fungal foliar disease of sweet potato throughout south-east Asia and the Pacific. It is caused by the fungus *Elsinoe batatas* (anamorph *Sphaceloma batatas*).

SYMPTOMS

Small brown lesions on leaf veins become corky, causing vein shrinkage and leaf curling (Clark and Moyer, 1988). Stem and petiole lesions are raised with brown centres and lighter brown margins. Lesions coalesce, forming scab-like structures; stems and petioles may be twisted and distorted (see Plate 10).

LOSSES

In the Philippines, yield losses of 50% have been measured in the field (Divinagracia and Mailum, 1976). Under controlled conditions, plants inoculated at 2–4 weeks of age showed 28% loss, while plants inoculated at 8 weeks suffered only 4% yield loss (Gapasin, 1984a). Further trials have indicated that infection within the first 2 to 4 weeks after planting causes greater loss of marketable tubers than later infection (Nayga and Gapasin, 1986). In Papua New Guinea, scab has been reported to reduce yields by 57% (Goodbody, 1983), 19% (34% marketable yield; Floyd, 1988) and 27% (P. Kokoa, Kuk Agricultural Research Station, unpublished data). Tuber number was the most severely affected yield parameter. In Tonga, a significant positive correlation was found between yield of marketable roots and percentage of leaf area not affected by scab (Stier and van Wijmeersch, 1984) while in Australia, Ramsey *et al.* (1988) showed that a negative correlation between yield and scab severity was significant at 55 and 82 days from planting, but not later.

DISTRIBUTION

Although scab was first reported from Brazil in the 1940s (Jenkins and Viegas, 1943), it is not widespread in the Americas. It has since been reported only from

Mexico. Scab is, however, very widespread and serious in the Pacific, Asia and south-east Asia, being reported from 29 countries (J. E. Wilson *et al.*, 1989). Unconfirmed, doubtful reports have been made from Nigeria and Sierra Leone. The disease is probably native to south-east Asia and the Pacific and spread from wild *Ipomoea* species to sweet potato in this region. Scab has been observed on *I. aquatica* in Cambodia (Hanson, 1963a) and Indonesia, and *I. gracilis* and *I. triloba* in Indonesia (Table 4a). Although it has not been found on other *Ipomoea* species, no extensive survey has yet been done.

Scab is most severe under wet or humid, cool-to-warm conditions such as in the highlands of Papua New Guinea, the Baguio region of the Philippines, moderate elevations in Indonesia and Malaysia, and many Pacific islands. It causes most damage during wet seasons. No studies on the epidemiology of the disease have been reported. There is also a need to look at the effect of varietal mixtures and intercropping with maize and legumes on scab incidence and severity. For example, in Papua New Guinea most farmers use tolerant or resistant varieties within mixtures of up to 25 different varieties. It is believed that scab is kept at low levels by the use of mixtures in Irian Jaya (Y. Widodo, MARIF, Malang, personal communication).

CONTROL

Strategies include chemicals, sanitation, selection of disease-free planting material, rotation and resistant varieties.

Cultural control

Sanitation by destroying residues from infected crops, and rotation with other crops or fallow are methods readily applicable to controlling disease in subsistence farming systems. Provided there is an adequate supply of material, selection of disease-free planting material is also relatively easy, as scab symptoms are obvious on young growth. Disease incidence has been kept low in Java, for example, by selection of clean planting material and crop rotation (see page 21).

Chemical control

Several studies have evaluated the effect of chemicals on scab (Divinagracia and Mailum, 1976; Floyd, 1988; Ramsey *et al.*, 1988; Smit, 1988). In Papua New Guinea, weekly applications of benomyl reduced scab incidence on infected plants from 55 to 15% (Floyd, 1988). In Australia, both benomyl and chlorothalonil reduced scab severity (Ramsey *et al.*, 1988). In Tonga and other Pacific islands, dipping of planting material with various fungicides including benlate, and weekly or biweekly spraying regimes with benlate or mancozeb, have also been useful in reducing scab severity (MAFF, 1978; Van Wijmeersch, 1986). However, resistance to benlate has been observed in some areas (J. E. Wilson *et al.*, 1989). Spray applications of chemicals are costly and will probably not be used by farmers with the exception of commercial producers. Pre-planting dips with systemic fungicides are cheap and may provide sufficient protection early. This is of particular importance for scab as, if plants are not infected early, yield loss is minimal. Further investigation is warranted.

Resistance

The most practical and economic approach to controlling scab is through use of resistant varieties. In areas where scab is widespread and severe, germplasm and breeding lines are systematically screened both in the field and under glasshouse conditions. Field screening has been carried out in Australia, Fiji, Indonesia, Papua New Guinea, the Philippines, Solomon Islands, Thailand, Tonga and Vanuatu (Goodbody, 1982; Gapasin, 1984a; FAO, 1987; Jackson, 1988; Ramsey *et al.*, 1988; J. E. Wilson *et al.*, 1989). In most cases, natural inoculum is used for field screening. In the Philippines, in a collection of 300 varieties, moderately high additive genetic variance for scab rating and dry matter content suggested that resistance to scab could be improved by selection within the population (Mariscal and Carpena, 1988). A technique has been developed in Tonga for rapidly testing sweet potato seedlings for resistance to scab (Smit *et al.*, 1991), which is accurate enough to be used for screening progeny from a breeding programme. In Papua New Guinea, the highlands germplasm collection (approximately 1000 varieties) at Kuk Research Station (see page 81), was evaluated for field reaction to scab using natural inoculum under ideal conditions for disease development. Approximately 60% of varieties were resistant, with 20% being severely affected (P. Kokoa, personal communication). Field resistance to scab has not been difficult to find in germplasm collections and breeding lines in south-east Asia and the Pacific. Resistant varieties have been identified at AVRDC and in Australia, Fiji, Indonesia, Papua New Guinea, the Philippines, the Solomon Islands, Tonga and Vanuatu (Sudjadi *et al.*, 1977; AVRDC, 1985; Kumar *et al.*, 1985; FAO, 1987; Bajit and Gapasin, 1987; Anggiani and Mukelar, 1988; Kanua and Floyd, 1988; Ramsey *et al.*, 1988; J. E. Wilson *et al.*, 1989).

Many different methods of controlled resistance screening have been used. Isolation, multiplication and inoculation techniques for *Sphaceloma batatas* have been developed in Australia, Taiwan (AVRDC), Indonesia, Philippines, Papua New Guinea and Tonga (Lao and Divinagracia, 1979; Nayga and Gapasin, 1986; Paningbatan, 1987; Anggiani and Mukelar, 1988; Ramsey *et al.*, 1988; J. E. Wilson *et al.*, 1989).

At the PRCRTC, Visca (see page 80), germplasm and breeding plots are inoculated with spores of *Sphaceloma batatas* in the early morning, several times during the growing period, to create severe epidemics and achieve an effective screen. Germplasm and progeny from the breeding programme are evaluated in the field using a 1 to 9 scale. Resistant varieties are selected for glasshouse tests. Cuttings are grown for 1 month, and stems are rubbed with carborundum and washed with distilled water. Inoculum is obtained from infected field plots. No consideration is made, however, for variability in the quality and age of inoculum and/or the existence of races. Field-collected stem pieces with scab, approximately 3 cm long, are held under conditions of high temperature and humidity for 24 h to stimulate sporulation and are then taped onto cuttings to be screened. Inoculated plants are placed in a mister and evaluated several days later. Only isolates from Visca are used. Selected resistant lines are further screened in the glasshouse and in the field. At this stage, a more detailed evaluation of morphological characters and resistance is made.

Preliminary work at PRCRTC has identified pathogenic variation among eight isolates of *S. batatas* obtained from various trials at Visca. Six differentials were used, including several widely-distributed Visca lines. Two-week-old cuttings were inoculated to run-off with 5×10^4 spores/ml and inoculated cuttings were enclosed in plastic bags for 2 days. Scab development, measured as relative lesion density, was rated for the top 30 cm of cuttings according to a 1–9 scale. Although the rating of relative density of lesions is probably too subjective for clear-cut race definition, results suggested the occurrence of three different races. Further work with isolates from different regions of the Philippines, and from other countries, would be worthwhile.

At the Institute of Plant Breeding (IPB), Los Baños, promising varieties are screened for scab reaction in the glasshouse. Inoculum is grown in sweet potato decoction (made from sweet potato vines) for 2 to 3 weeks, being agitated daily. Three-week-old cuttings are used and inoculum is sprayed until run-off. Inoculated plants are placed under high humidity and evaluated after 5 days.

In Indonesia, work has been in progress on sweet potato scab since the mid-1970s. The fungus has been isolated, cultured artificially, multiplied and inoculated successfully under glasshouse conditions (Mukelar, 1988; Anggiani and Mukelar, 1988). Potato dextrose agar is used for isolation of the fungus, while soya bean meal agar (SMA) is a superior medium for spore multiplication.

Inoculum, prepared by homogenizing colonies and streaking out on SMA, is applied to 2-week-old cuttings in pathogenicity tests. As glasshouse inoculation studies are highly correlated with field results, selection for resistance in Indonesia could be carried out in the glasshouse. Although no strain comparisons have been made, variation in cultural characters and agar pigmentation among isolates from different parts of the Indonesia have been observed (A. Mukelar, personal communication).

Many different isolation, multiplication, inoculation and evaluation techniques are being used for glasshouse and field screening of sweet potato for resistance to scab. This makes comparisons both within and between countries and regions difficult. It would be useful to summarize all the available information and develop standardized methodologies. An international workshop involving pathologists and breeders working on scab could achieve this.

The value of scab resistance outside the location where it was selected is beginning to be questioned. AVRDC varieties, resistant to scab in Taiwan, are susceptible in the Philippines, and PRCRTC varieties from Visca are susceptible in other locations in the Philippines (J. Lenné, personal observation). CIP has recommended that resistant varieties from Tonga and AVRDC be cleaned up and distributed throughout south-east Asia and the Pacific. As there is no indication that such material will be resistant outside the locations in which it was selected, more information should be sought on pathogenic variation within *S. batatas* and results from multi-locational screening trials of selected varieties before this is implemented.

There has been limited consideration of the basis of resistance to scab. Bajit and Gapasin (1987) noted that resistant varieties had thicker cuticles and fewer stomata. Studies on the basis of resistance to scab would be worthwhile in aiding the identification of potentially useful germplasm.

Alternaria diseases

A complex of diseases caused by *Alternaria* species, known variously as leaf spot, stem blight, alternariosis and anthracnose, have been widely reported on sweet potato. Four *Alternaria* species have also been reported on three other *Ipomoea* species (Table 9). At least five different *Alternaria* species, including *A. alternata, A. capsici-annui, A. solani, A. tenuissima and Alternaria* tax. sp. IV, have been implicated as causal agents. Although some reports regard leaf spots caused by *Alternaria* species as minor diseases (Clark and Moyer, 1988), stem blight is becoming increasingly important in east Africa, including Burundi, Ethiopia, Rwanda, Uganda and Zambia, and also in Papua New Guinea (Van Bruggen, 1984; Simbashizweko and Perreaux, 1988; Ndamage, 1988). In these countries, the causal agents have been identified as *A. alternata, A. bataticola, A. solani, Alternaria* tax. sp. IV and *Alternaria* spp. As yet, Alternaria diseases of sweet potato have received minimal research effort.

SYMPTOMS

Alternaria stem blight first appears as small, grey to black oval lesions with a lighter centre on stems and petioles (Van Bruggen, 1984). Under humid conditions, lesions enlarge as black areas, which may involve expanses of stem and petiole, and result in petiole and stem girdling (see Plate 11). Leaves above the affected parts become chlorotic and dry. If the main stem is affected when the plant is young, the plant will die. Stress due to drought and infertile or acid soils may also result in plant death.

LOSSES

No quantitative information is available on the economic impact of this disease complex.

Table 9

Specific diseases recorded on wild *Ipomoea* species* which may affect sweet potato.

Pathogen	Wild species	Distribution
Fungi		
Aecidium distinguendum Syd.	*I. crassicoulis*	Cuba (IMI, 1967)†
	I. sp.	Ecuador (IMI, 1954)
A. kaerbachii Henn.	*I. aquatica*	Pakistan (Ghafoor and Khan, 1976)
	I. biloba	Pakistan (Ghafoor and Khan, 1976)
	I. congesta	Papua New Guinea (IMI, 1986)
	I. hederacea	Pakistan (Ghafoor and Khan, 1976)
	I. hispida	Sudan (IMI,1954)
	I. mombassana	Sudan (IMI,1954)
	I. pes-caprae	Indonesia (IMI, 1954), Papua New Guinea (IMI; Shaw, 1985), Western Samoa (Dingley *et al.*, 1981)
	Ipomoea sp.	Burma, East Indies (IMI, 1972, 1954), Papua New Guinea (IMI; Shaw, 1985), Sudan (IMI, 1955)
Aecidium sp.	*I. trifolia*	Venezuela (IMI, 1969)
	Ipomoea sp.	Hong Kong, Tanzania (IMI, 1966, 1945)
Albugo ipomoeae-panduratae Sawada	*I. angulata*	Trinidad (IMI, 1944)
	I. aquatica	Borneo (IMI, 1962), Brunei (IMI, 1971; Peregrine and Kassim Bin Ahmad, 1982), Burma (IMI, 1971‡), Cambodia (Hanson, 1963a), Hong Kong (IMI, 1962), Malaysia (Singh, 1980), Pakistan (Ghafoor and Khan, 1976), Taiwan (IMI, 1909), Thailand (Piya Giatong, 1980), Trinidad (IMI, 1970)
	I. cardiosepala	Sudan (IMI)
	I. digitata	Sierra Leone (Deighton, 1936)
	I. hederacea	India (IMI, 1953), Pakistan (Ghafoor and Khan, 1976), USA (IMI, 1934)
	I. leptophylla	USA (IMI, 1927)
	I. mauritiana	Sierra Leone (IMI, 1944)
	I. plebeia	Australia (Simmonds, 1966)
	I. phillonega	Trinidad (IMI, 1944)
	I. pilosa	Sudan (IMI, 1950)
	I. reniformis	Burma (Ravichandran and Sullia, 1983)
	I. sindica	Pakistan (Ghafoor and Khan, 1976)
	I. tiliarea	Trinidad (IMI, 1944)
	I. trifolia	Venezuela (IMI, 1969)
	I. triloba	Cuba, Philippines (IMI, 1966, 1940)
	Ipomoea sp.	Dominican Republic, India (IMI, 1944, 1933), Jamaica (IMI, 1949), Kenya (IMI, 1950; Nattrass, 1961), Nigeria (Bailey, 1943), Papua New Guinea (IMI, 1947; Shaw, 1985), South Africa (Gorter, 1977), Tanzania (IMI, 1945), Tonga (Dingley *et al.*, 1981), Uganda (Hansford, 1937), Zambia (IMI, 1964; Angus, 1963), Zimbabwe (Whiteside, 1966)
A. ipomoeae-pes-caprae Ciferri	*I. pes-caprae*	Barbados, Dominican Republic, Grenada, Jamaica, St. Vincent, Trinidad (IMI, 1944, 1960, 1946, 1960, 1946, 1944)
A. minor (Speg.) Ciferri	*I. pestigrindes*	India (IMI, 1977)
A. mysorensis Safee and Thirum	*I. hederacea*	India (Anon, 1950)
A. portulacae (DC) O. Kuntze	*Ipomoea* sp.	Sudan (IMI, 1947)

Pathogen	Wild species	Distribution
Albugo sp.	*I. reptans*	Cuba (IMI, 1967)
	Ipomoea sp.	India (IMI, 1978)
Alternaria alternata (Fr.) Keissler	*I. aquatica*	India (IMI, 1967‡)
	I. alba	India (IMI, 1972)
	I. fistula	India (IMI, 1976)
	I. indica	India (IMI, 1988)
	I. tridentata	India (IMI, 1982)
A. bataticola Yamamoto — No wild species hosts listed		
A. capsici-annui Savul and Sandu-ville — No wild species hosts listed		
A. sesami (Kaw.) Moh. and Beh.	*I. purpurea*	Kenya (Nattrass, 1961)
A. solani Soraurer	*I. purpurea*	Kenya (IMI, 1960)
	Ipomoea sp.	Sudan, 1949‡, Uganda (IMI, 1944)
A. tenuissima (Pers.) Wilts.	*I. aquatica*	Hong Kong (IMI, 1966)
	I. carnea sp.	Pakistan (IMI, 1964
	Ipomoea sp.	Venezuela (IMI, 1970)
Alternaria sp.	*I. aquatica*	Hong Kong (IMI, 1966)
	I. fistulosa	India (IMI, 1977)
	I. purpurea	Mozambique (Carvalho and Mendes, 1958)
	Ipomoea sp.	Uganda (Hansford, 1937)
Ascochyta bataticola Cochr. and Djurin — No wild species hosts listed		
A. convolvuli Fautrey — No wild species hosts listed		
Cercospora ipomoeae Wint.	*I. alba*	Sierra Leone (IMI, 1934)
	I. aquatica	India, Hong Kong (IMI, 1968, 1966)
	I. asarifolia	Cuba (IMI, 1967)
	I. biloba	Pakistan (IMI, 1951; Ghafoor and Khan, 1976)
	I. bona nox	Burma (IMI, 1971), Brunei (IMI, 1971; Peregrine and Kassim Bin Ahmad, 1982)
	I. cairica	Sudan (IMI, 1949)
	I. campanulata	Bengal (IMI, 1984)
	I. cardiflora	Sudan (IMI, 1957)
	I. carnea	India (IMI, 1965)
	I. eriocarpa	Sudan (IMI, 1949‡)
	I. fistulosa	India (IMI, 1970‡)
	I. hederacea	Pakistan (Ghafoor and Khan, 1976)
	I. hildebrantii	Kenya (IMI, 1956; Nattrass, 1961)
	I. kentrocarpa	Guinea (IMI, 1962)
	I. leoni	Sierra Leone (IMI, 1936)
	I. muricata	India (IMI, 1967)
	I. nil	India (IMI, 1967‡)
	I. obscura	India (IMI, 1967)
	I. pes-caprae	Papua New Guinea, Seychelles, Sierra Leone (IMI, 1956, 1982, 1935)
	I. pestigridis	India (IMI)
	I. purpurea	Sierra Leone (Deighton, 1936)
	I. sepiaria	Burma (IMI, 1971)
	I. turpethum	India (IMI, 1975)
	Ipomoea sp.	Australia (Simmonds, 1966), India (IMI, 1974‡), Kenya (Nattrass, 1961), Uganda (Hansford, 1937), Zambia (Whiteside, 1966)
C. ipomoeae-illustris Chiddarwar	*I. illustris*	Hong Kong (IMI, 1957), India (Anon, 1950)
C. ipomoeae-stoloniferae Yen and Gilles	*I. asarifolia*	Brazil (IMI, 1977)
	I. stolonifera	Gabon (IMI, 1970)
C. varanasiana Pavgi and U. P. Singh	*Ipomoea* sp.	India (IMI, 1962)
C. viridula	*Ipomoea* sp.	Kenya (Hansford, 1937), Mauritius (Orieux and Felix, 1968)
Cercospora sp.	*I. hederacea*	Brunei (Peregrine and Kassim Bin Ahmad, 1982)

Pathogen	Wild species	Distribution
Cochliobolus geniculatus Nelson	*I. fistulosa*	India (IMI, 1977)
C. lunatus Nelson and Haosis	*I. fistulosa*	India (IMI, 1978)
C. spicifera Nelson	*Ipomoea* sp.	India (IMI, 1974)
Coleosporium ipomoeae (Schwein.) Burr.	*I. angulata*	Trinidad (IMI, 1948)
	I. cairica	Uganda (IMI, 1967)
	I. fistulosa	Jamaica (IMI, 1961)
	I. glabra	Venezuela (IMI, 1954)
	I. hederacea	USA (IMI, 1954)
	I. lacumosa	USA (IMI, 1954)
	I. operosa	Malawi (IMI, 1950; Peregrine and Kassim Bin Ahmad, 1982)
	I. panduratae	USA (IMI, 1954)
	I. purpurea	USA (IMI, 1954)
	Ipomoea sp.	Malawi, Tanzania (IMI, 1948, 1945)
Corticium sp.	*I. purpurea*	Sierra Leone (IMI, 1934)
	I. setifera	Sierra Leone (IMI, 1935)
	I. triloba	Sierra Leone (IMI, 1937)
Elsinoe batatas Saw.	*I. aquatica*	Cambodia (Hanson, 1963a)
Fusarium avanaceum (Fr.) Sacc. — No wild species hosts listed		
F. graminearum Schwabe — No wild species hosts listed		
F. equiseti	*I. reniformis*	India (IMI, 1983)
F. moniliforme Sheld.	*I. pes-caprae*	Sri Lanka (IMI, 1959)
	I. reniformis	India (IMI, 1983)
F. moniliforme var. *subglutinans* — No wild species hosts listed		
F. oxysporum Schl.	*I. trichocarpa*	USA (Clark and Watson, 1983)
	I. wrightii	
F. pallidoroseum (Cooke) Sacc. — No wild species hosts listed		
F. semitectum	*I. aquatica*	India (IMI, 1977)
F. solani	*I. pes-caprae*	Sri Lanka (IMI, 1959)
Fusarium sp.	*I. aquatica*	Indonesia (Anon, 1975), Papua New Guinea (IMI, 1960)
	I. fistulosa	India (IMI, 1976)
Glomerella cingulata	*I. fistulosa*	India (IMI, 1976¶)
	I. hederacea	India (IMI, 1974)
	I. tridentata	India (IMI, 1984)
Leptosphaeria sp.	*I. fistulosa*	India (IMI, 1976)
Meliola clavulata Wint. — numerous records on many wild species		
Monilochaetes infuscans Harter	*I. hederacea*	USA (Clark and Watson, 1983)
	I. hederifoli	
	I. lucunosa	
	I. purpurea	
	I trichocarpa	
	I. wrightii	
Nigrospora sphaerica	*Ipomoea* sp.	India (IMI, 1965)
Phoma sp.	*Ipomoea* sp.	Venezuela (IMI, 1970)
Phomopsis ipomoeae Petrak	*I. aquatica*	Brunei, India (IMI, 1971, 1974‡)
	I. argentifolia	Cuba (IMI, 1967)
	I. carnea	Pakistan (IMI, 1968)
	I. hederacea	India (IMI, 1976)
	I. palmata	India (IMI, 1972)
	Ipomoea sp.	Brunei (IMI, 1970)
Phomopsis ipomoeae-batatas Punith. (syn. *Phyllosticta batatas*)	*I. aquatica*	Malaysia (Williams and Liu, 1976)
	Ipomoea sp.	Kenya, Sudan, Venezuela (IMI, 1967, 1951, 1970)
Phomopsis sp.	*I. aquatica*	Hong Kong, India (IMI, 1962, 1969)
	I. nil	Pakistan (IMI, 1963)
Pseudocercospora ipomoeae-purpurea (Yen) Yen	*I. purpurea*	Singapore (IMI, 1970)

Pathogen	Wild species	Distribution
P. timorensis Cooke Deighton	*I. aquatica*	Malaysia (IMI, 1934)
	I. biloba	Ghana (IMI, 1951; Hughes, 1953)
	I. campanulata	India (IMI, 1967)
	I. capitata	India (IMI, 1986)
	I. cordofana	Sudan (IMI)
	I. indica	Taiwan (IMI, 1933)
	I. involucrata	Guinea, Sierra Leone (IMI, 1962, 1954)
	I. peltrata	India (IMI, 1985)
	I. purpurea	Mauritius (IMI, 1932), South Africa (Gorter, 1977)
	I. setifera	Malaysia (IMI, 1936), Sierra Leone (Deighton, 1936)
	I. turpethum	India (IMI, 1979)
	Ipomoea sp.	Taiwan, Uganda (IMI, 1930, 1936)
Pseudocercospora sp.	*I. angulata*	India (IMI, 1985‡)
Puccinia batatae Syd.	*I. digitata*	Ghana (IMI, 1949; Peregrine, 1988), Sierra Leone (IMI, 1935), South Africa (Gorter, 1977)
	Ipomoea sp.	Mauritius (Orieux and Felix, 1968)
P. crassipes Berk. and Curt.	*I. jamaicensis*	Argentina (IMI, 1954)
	I. triloba	USA (IMI, 1954)
	Ipomoea sp.	Nigeria, Venezuela (IMI, 1964, 1969‡)
P. holosericea Cooke	*I. lilacina*	Sudan (IMI, 1954)
	I. wrightii	Kenya (IMI, 1966), Tanzania (IMI, 1966; Ebbels and Allen, 1979)
	Ipomoea sp.	Ethiopia (IMI, 1964), Kenya (IMI, 1959‡; Nattrass, 1961), Sudan, Tanzania (IMI, 1954), Uganda (IMI, 1966; Hansford, 1937)
P. incompleta	*I. ciliare*	Pakistan (Ghafoor and Khan, 1976)
P. megalospora (Ort.) Arthur and Johnson	*I. fistulosa*	Mexico (IMI, 1965)
P. nocticolor Holway	*I. mucuroides*	Guatemala (IMI, 1954)
Puccinia sp.	*I. bona nox*	Burma (IMI, 1954)
Uredo ipomoeae Yadav	*I. turpethum*	India (IMI, 1960)
Uromyces ipomoeae Berk.	*I. kurmanii*	Kenya (Nattrass, 1961), South Africa (IMI, 1954), Uganda (IMI, 1954; Hansford, 1937)
	I. tenuirostris	Malawi (IMI, 1950), Uganda (IMI, 1954)
	Ipomoea sp.	Malawi, Uganda (IMI, 1950, 1962)
Uromyces pieningi Cummins	*I. argentaurea*	Ghana (IMI; Hughes, 1953)
	I. illustris	India (IMI, 1982)
Bacteria		
Pseudomonas solanacearum	*I. setosa*	Bradbury (1986)
	I. triloba	
Xanthomonas campestris pv. *uppalii*¶	*I. muricata*	Bradbury (1986)
Little leaf mycoplasma	*I. nibro-coenilia*	Papua New Guinea (Shaw, 1985)
	I. plebeia	Australia (Simmonds, 1966)
	I. purpurea	Australia (Simmonds, 1966), Papua New Guinea (Shaw, 1985)
	I. setosa	Papua New Guinea (Shaw, 1985)
Viruses		
Mosaic virus	*I. cardinalis*	Nigeria (Bailey, 1943)
	I. obscura	Mauritius (Welles)
	I. purpurea	Nigeria (Bailey, 1943)
	I. tricolor	Nigeria (Bailey, 1943)
Ring Spot virus	*I. purpurea*	Australia (Simmonds, 1966)
SPFMV	*I. incarnata*	USA (Cadena-Hinojosa and Clark, 1981a), (Clark *et al.*, 1986a)
	I. hederacea	
	I. pandurata	
	I. trichocarpa	
	I. wrightii	

Pathogen	Wild species	Distribution
Nematodes		
Meloidogyne incognita	*I. alba* *I. hederacea* *I. lacunosa* *I. purpurea* *I. trichocarpa* *I. wrightii*	USA (Clark and Watson, 1983)
Rotylenchulus reniformis	*I. hederacea* *I. hederifolia* *I. lacunosa* *I. trichocarpa*	USA (Clark and Watson, 1983)

Notes:
* Broad spectrum pathogens such as *Botryodiplodia theobromae, Corticium rolfsii, Macrophomina phaseolina, Rhizopus stolonifera* and *Thanatephorus cucumeris* are not included. Crop hosts are potentially far more important sources of inoculum for sweet potatoes than are wild *Ipomoea* species. A list of *Ipomoea* spp. hosts of *Cylas formicarius* including 27 species is given in Sutherland (1986b).
† IMI=Unpublished herbarium records of the International Mycological Institute.
‡ More than one sample for the specific country exists in the IMI herbarium; date of accession of the first sample is given.
¶ This bacterium does not affect *I. batatas* by inoculation.

Distribution

Alternaria stem and petiole blight, caused by *A. alternata,* is present in the Southern and Western Highlands and Simbu provinces of Papua New Guinea (P. Kokoa, personal communication). It has also been reported from New Caledonia (Bugnicourt and Marty, 1961). It may be more widespread in the Pacific region than is presently documented. Stem blight is manifest in the wet season as stem necrosis and dieback and is especially serious in dryer periods. In 1990, it was present in the Papua New Guinea highland germplasm collection at Kuk Research Station near Mount Hagen, affecting 42 clones. Field resistance has been identified in the collection. A leaf spot caused by *A. bataticola* was identified by Waller (1984) in Papua New Guinea but it is not known whether this pathogen also causes stem blight.

In Africa, Alternaria leaf and stem blight caused by *A. solani* has been recorded in Burundi (Buyckx, 1962; Simbashizweko and Perreaux, 1988) and Rwanda (IMI; Buyckx, 1962; Ndamage, 1988). *Alternaria* tax. sp. IV is known in Ethiopia (IMI, 1963-80; Van Bruggen, 1984), Uganda (IMI) and Zambia (IMI); and an *Alternaria* sp. has been recorded in Kenya (Gatumbi *et al.*, 1990), Uganda (IMI), Zambia (Riley, 1956; Angus, 1963) and Zimbabwe (Whiteside, 1966). The disease is serious and of increasing importance in Burundi and Rwanda, particularly on infertile, acid soils and at higher altitudes (Simbashizweko and Perreaux, 1988; Ndamage, 1988; J. Lenné, personal observation).

Characterization of the apparent complex of *Alternaria* species responsible for stem blight is urgently needed. More information on the geographical distribution of species and strains is required, especially to establish if different species and races cause the same diseases in different countries and regions. This would help in developing resistant varieties and predicting future problems with this relatively new, largely unstudied disease.

CONTROL

No work has been done on cultural or chemical control of this disease complex.

Resistance

Varieties with resistance have been identified in glasshouse screening in Burundi (Simbashizweko and Perreaux, 1988) and in field screening in Rwanda (Ndamage, 1988) and Papua New Guinea (P. Kokoa, personal communication). The development of glasshouse screening methodologies in Burundi could serve as a base to facilitate selection of resistant varieties relevant to each country or region. A low-input, host-plant resistance approach would directly benefit subsistence farmers. However, 'resistant' varieties selected at low altitude on relatively fertile soils frequently show severe stem blight at higher altitudes and/ or on poorer soils in Rwanda. It is not known whether field screening techniques are inadequate; if the pathogen is more abundant in infertile acid soils; or whether poorer growth of sweet potato in such soils makes it more susceptible to *Alternaria* spp. Studies of the effects of soil type, climate and variety on disease incidence and severity in the field would be worthwhile. It has been recommended that all germplasm destined for medium to high altitudes in Africa should be tested for reaction to *Alternaria* species (Matata, 1988).

Little leaf mycoplasma (LLM)

Little leaf, witch's broom or 'ishuku-byo' has been recorded on sweet potato in more than 12 countries throughout Asia and the Pacific (see Table 5). The association of mycoplasma-like organisms (MLOs) has been proven (Khan *et al.*, 1972; Xie *et al.*, 1983).

SYMPTOMS

Affected plants show vein clearing, formation of small, chlorotic leaves and proliferation of axillary shoots giving plants a more erect growth habit and bushy appearance (Clark and Moyer, 1988). Root systems are stunted, latex is absent from roots and stems, and few harvestable tubers are produced.

LOSSES

Yield losses of 30 to 90%, mostly of tuber number, have been recorded throughout the Pacific (Jackson *et al.*, 1984). When young plants are affected, almost total yield loss may occur (Pearson *et al.*, 1984).

DISTRIBUTION

Little leaf mycoplasma was first reported from Ryukyu Island, Japan in 1951 (Jackson *et al.*, 1984). It is now widely distributed throughout Asia and the Pacific. In the Pacific, LLM is a disease of lowland sweet potato-growing areas with marked dry seasons, such as the lowlands of Papua New Guinea, the Solomon Islands, and in Sumatra and east Java, Indonesia. It can be very severe in dry years. The geographical distribution of LLM is highly correlated with that of its leaf-hopper vectors, *Orosius lotophagorum ryukyuensis* and *Nesophrosyne ryukyuensis*. The severity of LLM in dry seasons and dry years is partly because dry conditions favour the vectors. Infected planting material is also very important to the dissemination of LLM. As the pathogen has a very long latent period such material can appear healthy, which makes detection difficult (Clark, 1988).

It would be worthwhile systematically to map the distribution of LLM to identify regions within countries where it is absent and where sweet potato could escape infection, for example, in the highlands of Papua New Guinea. Epidemiological studies would further help to explain within-country differences in distribution. Although LLM has not been detected outside Asia and the Pacific, it has also not been deliberately sought. In east Africa, little leaf-like symptoms, commonly identified as viral, were in some cases very similar to symptoms caused by MLOs. Further investigation on the distribution of LLM would be worthwhile.

CONTROL

Strategies include exclusion of infected plants through quarantine, roguing and destruction of diseased plants, selection of disease-free planting material, destruction of alternative hosts, chemical control and resistant varieties (Jackson *et al.*, 1984).

Quarantine

Because LLM is restricted geographically both within and between countries, strict quarantine procedures could be used to prevent its spread. Under the international guidelines for movement of sweet potato germplasm, all germplasm must be moved in tissue culture or as seed to minimize the risk of further spread of LLM (Moyer *et al.*, 1989). Such precautions could also be applied within countries. MLO-free plants can be produced using thermotherapy and tissue culture (P. Beetham and A. Mason, Victoria Plant Research Institute (PRI), Australia, unpublished data).

Cultural control

Removal of diseased plants by roguing and burning is an economical and reliable method of control. Frequent cutting of vines will facilitate the detection of LLM which is more obvious on young regrowth (Pole, 1987). Several wild *Ipomoea* species are alternative hosts of LLM (see page 57). In the Solomon Islands, LLM has been found on *I. triloba, I. indica* and *Merremia pacifica* (Jackson and Zettler, 1983) while in Tonga wild hosts include *I. purpurea* and *I. pes-caprae* (Pole, 1987). Effective roguing of these weeds presents many practical problems (particularly in the case of *Merremia*) because of their rapid growth rates, especially once the canopy has been removed. Legume little leaf vectored by the related leaf hopper, *Orosius argentatus*, often found on legume weeds associated with sweet-potato fields, is unrelated to sweet-potato little leaf (Jackson *et al.*, 1984).

Chemical control

Tetracycline treatment of affected plants has resulted in remission of symptoms for varying lengths of time (Pearson *et al.*, 1984; Clark and Moyer, 1988). However, such treatments and the use of insecticides to control leaf-hopper vectors are generally too costly for wide application.

Resistance

Resistance has been sought unsuccessfully. At AVRDC, only one of 365 clones was immune to LLM, however the same clone was not resistant in the Solomon Islands. Only one of 220 clones tested in the Solomon Islands was moderately resistant (Jackson *et al.*, 1984). Potential sources of resistance have been identified among germplasm screened at Laloki in Papua New Guinea. Further screening under controlled conditions could be focussed on resistance to the leaf-hopper vectors rather than on general resistance.

VIRUSES

Diseases caused by viruses are probably the most poorly understood diseases of sweet potato (Clark and Moyer, 1988). Although virus-like symptoms have been observed on sweet potato in most countries where the crop is grown, causal agents have been characterized in only a few countries (see Plates 14–16, see Plate section, opp. p. 17). The aetiology of many of these diseases has not been determined (Moyer and Salazar, 1989). The most recent definitive list of viruses of sweet potato includes 16 apparently different viruses which have been reported on sweet potato worldwide (Table 6; P. Beetham and A. Mason, unpublished data). Further records from specific countries in Asia, the Pacific and Africa are also listed in Table 6. Sweet-potato virus pathosystems are not well understood (Moyer, 1988). Most virologists have found great difficulty in working with sweet potato: viruses are difficult to transmit, and virus-indexed sweet potato plants are not always available for comparative tests.

SYMPTOMS AND DISTRIBUTION

With the exception of widely-distributed sweet potato feathery mottle virus, SPFMV, feathery mottle strain, sweet-potato viruses have a limited geographical distribution, being restricted to regions and to countries (Table 6). This may also reflect lack of information about viruses in many countries. Eleven sweet-potato viruses have been partly or completely characterized (P. Beetham and A. Mason, unpublished data).

SPFMV, a potyvirus, is probably the best-known virus, occurring in all major sweet potato-growing areas of the world (Moyer and Salazar, 1989). Four strains have been defined: feathery mottle (FMV), russet crack (RCV), internal cork (ICV) and chlorotic leaf spot (CLSV) (Moyer, 1986a,b). The latter three have only been reported from the USA (Clark and Moyer, 1988). Sweet potato virus disease complex (SPVDC), manifest as vein clearing, severe stunting and leaf distortion, is a complex of two viruses — SPFMV and the whitefly-borne sweet potato virus-like agent (SPVLA) — which has not been completely characterized (Schaefers and Terry, 1976; Thottappilly and Rossel, 1988). It is widespread within Africa, and has also been reported from Israel.

Sweet potato mild mottle virus (SPMMV), also a potyvirus, causes leaf mottling, chlorosis, stunting and distortion and is restricted to east Africa (Hollings *et al.*, 1976a,b; Moyer and Salazar, 1989). The association of SPFMV and SPMMV causes severe symptoms in east Africa similar to those caused by SPVDC. Sheffield (1957) described these two sweet potato viruses as A and B, now usually recognized as SPFMV and SPMMV, respectively (Alan Brunt, Horticulture Research International (HRI), Littlehampton, UK, personal communication). Sweet potato caulimo-like virus (SPCLV), which is usually symptomless but can cause chlorotic spots and veinal chlorosis in association with SPFMV, is distributed throughout the Pacific but was originally reported in plants originating from Puerto Rico (Atkey and Brunt, 1987; Moyer and Salazar, 1989). Sweet potato latent virus (SPLV), sometimes causing vein clearing and leaf mottling, is a possible potyvirus and has been reported only from Taiwan (Green *et al.*, 1988; Moyer and Salazar, 1989). Sweet potato chlorotic stunt virus (SPCSV), causing vein clearing and general leaf yellowing, is known only from Puerto Rico.

Sweet potato ringspot virus (SPRV), causing chlorotic spotting, is probably a nepovirus and is restricted to Papua New Guinea. Sweet potato yellow dwarf virus (SPYDV) produces mottling, chlorosis and dwarfing. It is known only from Taiwan. Other viruses include cucumber mosaic virus (CMV), which has been reported on sweet potato in several areas; sweet potato vein mosaic virus (SPVMV) causing general chlorosis and diffuse mosaic in Argentina (Nome, 1973); sweet potato phytoreo virus (SPPRV) which occurs in Thailand; and sweet potato leaf curl virus (SPLCV) in Taiwan (Chung *et al.*, 1985; Moyer and Salazar, 1989; P. Beetham and A. Mason, personal communication).

Virus-like symptoms have been reported on sweet potato in many countries but, usually, no work has been done to determine which virus, if any, is responsible. Systemic interveinal chlorotic spotting, both aphid- and mechanically transmitted, was first detected in the Philippines on sweet potato in 1983 (Gapasin and Suico, 1984). There are now thought to be at least three viruses on sweet potato in the Philippines but no work has been done on characterization (R. M. Gapasin, PRCRTC, Visca, personal communication).

In Indonesia, virus-like symptoms have been observed at a number of locations. The existence of viruses in Indonesia is presently not viewed as a problem as there is no apparent effect on yield. Monitoring of symptoms and perhaps characterization would be helpful in Indonesia. There is no doubt that without adequate quarantine of affected planting material, viruses will spread throughout sweet potato production areas of Indonesia and the Philippines.

In Papua New Guinea, surveys have documented a relatively low incidence of virus-like symptoms, but at certain times of the year moderate to severe symptoms are observed. Both SPFMV and SPCLV have been identified in Papua New Guinea (Atkey and Brunt, 1987). Most researchers feel that viruses are not a major field problem at present, but some believe that complexes of viruses have built up in certain varieties over time and may be responsible for yield decline (B. Muthappa, Kilakila Research Station, personal communication). There is a perceived need for further research input and to assess yield loss. Monitoring of virus distribution and further characterization would be useful.

In Kenya, virus-like symptoms are common but extremely variable. They include vein clearing, stunting, feathery mottle, chlorotic spots, mosaic and leaf curl. Viruses were first detected on sweet potato in Kenya and other east African countries in the late 1930s to early 1940s (Hansford, 1945; Sheffield, 1953, 1957). Sheffield (1953) suggested that the most common virus (later found to be SPMMV) had been long established in Africa. Sheffield (1957) emphasized the difficult problem of selecting disease-free planting material and the urgent need to develop resistant varieties.

Since this early work, little has been done on sweet potato viruses in Kenya until recently. Characterization and assessment of viruses of sweet potato and their vectors is now being carried out from Muguga. Florence Wambugo has recently completed an extensive survey of sweet potato viruses in the most important sweet potato production regions of Kenya. Her findings will provide important basic information for the formulation of future projects on viruses in the region. Work on viruses is also in progress at Edgerton University, Njoro, Central Kenya.

Viruses are presently obvious and severe in western Kenya, especially around Kakamega. Studies on epidemiology, native hosts, vectors, and climatic conditions to determine why viruses are important in this region would be useful. Germplasm collections at the various research stations should be surveyed for viruses as soon as possible to distinguish potentially resistant material from susceptible, tolerant and symptomlessly colonized germplasm. Some attempt should be made to initiate production of virus-free material for dissemination between regions in Kenya as well as internationally. Tissue culture facilities are available at Muguga.

Many Kenyan varieties show some field tolerance to local viruses. Most USA and AVRDC varieties, however, although high-yielding, are very susceptible. Such varieties are also unacceptable due to the high water content of these tubers. Possibly long exposure of Kenyan varieties to viruses has selected higher levels of tolerance to the virus complex. Virus-'resistant' varieties from IITA are tolerant and have good agronomic characters, and crosses made from IITA and local varieties are showing some promise.

In Rwanda, virus-like symptoms are widespread and severe. Viruses are regarded as the most widespread and important pathogens. Although no basic studies have been done on viruses in Rwanda, SPVDC is suspected to be the most common problem. Of the two common vectors observed, whiteflies are always present, although in greater numbers in the dry season, while aphids are mainly present in the dry season. In Rwanda, serious yield losses due to viruses are suspected but have not been quantified. Characterization of the viruses present and comparison with other African viruses is needed in Rwanda. Such knowledge would facilitate more efficient identification of resistant varieties which could be of use throughout east Africa. Field-selected 'resistant' sweet potato varieties also need to be indexed.

In Uganda, virus symptoms were first found on sweet potato at Kwanda Research Station in 1944 (Hansford, 1945). Large numbers of whiteflies were associated with plots. Symptoms included severe stunting, chlorosis, small leaves, excessive branching and short internodes, indistinct vein banding, indefinite mosaic, mottling and vein clearing, and older leaves showed bronzing, distortion, crumpling and thickening. Above-ground symptoms suggested yield reduction but losses were not quantified. All varieties were affected to some extent and there was a considerable problem in selecting 'virus-free' cuttings for planting. Although Hansford (1945) stressed that viruses were potentially serious for sweet potato in east Africa and the need to develop resistant varieties, limited work has been done on sweet potato viruses in Uganda during the past 50 years. The combination of SPFMV and SPMMV is thought to be common in Uganda (Sheffield, 1957; MacDonald, 1963, 1967; Mukiibi, 1976b). Serious and frequent variety deterioration has apparently occurred due to viruses, with some varieties disappearing altogether from farmers' fields (Aldrich, 1963). Field screening for 'resistance' to viruses is being carried out in the germplasm and breeding programme, but there is no laboratory or screenhouse back-up.

Although a limited number of studies have been done, characterization and distribution studies to date clearly show differences between regions with respect to the viruses (Table 6). However, no direct comparative studies on viruses have been carried out, either within the south-east Asia/Pacific region, within Africa, or between the two regions. Some viruses are apparently region-restricted. For example, SPMMV occurs in Africa only, while SPLV and SPRV occur in the Asia/Pacific region only. It would be most worthwhile to elucidate if these differences are real or whether they reflect a lack of information on the distribution of viruses. Contrasting reports on the severity of sweet-potato viruses under different climatic conditions in different countries highlight the urgent need for systematic characterization of viruses of sweet potato in Africa.

LOSSES

There are many reports that viruses cause significant losses in sweet potato, but there is a dearth of published accounts of quantified losses. Acute diseases such as SPVDC found in Africa, and RCV and ICV found in the USA, have a dramatic impact on production of edible roots. Chronic diseases such as SPFMV have a less severe effect on individual plants but may affect yield on a regional basis (Moyer, 1988). Yield losses due to SPVDC have been reported as 75% in Nigeria (Hahn, 1979) and 56–90% in Cameroon (Ngeve and Bouwkamp, 1991), while losses in Uganda ranged from 57–66% of tuber weight and number (Aldrich, 1963; Mukiibi, 1976b). No other quantified reports from the tropics were found. This may be due to a lack of availability of virus-free varieties with which to make comparisons. Sweet potato decline, where varieties suffer yield decline over time, has been reported from Papua New Guinea, the Philippines and east Africa. It has been attributed to virus build-up, but this has not been proven. Up to two- and three-fold increases in yield of pathogen-tested varieties, compared to the same infected varieties, have been reported from south-east Asian and Pacific countries collaborating in the CIP/ACIAR clean-up programme.

INDEXING

Indexing sweet potato for uncharacterized viruses is cumbersome and evaluation of large numbers of genotypes impossible (Moyer, 1988). High-quality antisera are not widely available due to difficulties in purifying these viruses, further complicated by the presence of phenolics, phenol oxidases, quinones, latex and carbohydrates which interfere with assays. HRI, Littlehampton has high-quality antisera to many sweet potato viruses (Alan Brunt, personal communication). Variable concentrations of sweet-potato viruses in plants make serology an unreliable method at present for the detection of viruses. Due to poor quality antisera, the relationship between sweet potato viruses and yield loss is difficult to study quantitatively. The effect of environmental influences on symptom expression also causes problems. In addition, there are no internationally agreed criteria for sweet potato virus identification. All viruses so far reported on sweet potato are known to infect and show symptoms on *I. setosa* and *I. nil*. Although grafting to these plants is a reliable indexing method (Salazar, 1988), symptom expression is not of diagnostic value (Moyer and Salazar, 1989). Mechanical assays from sweet potato to other virus indicators are recommended (Moyer and Salazar, 1989).

Development of an improved virus-indexing system for sweet potato will require careful, detailed evaluation of existing techniques in relation to the developmental biology of sweet potato (Moyer, 1988). Most major institutions working with sweet potato viruses, including CIP, IITA, AVRDC, HRI, PRI and North Carolina State University, complement grafting to *Ipomoea* spp. with ELISA or ISEM.

CONTROL

Cultural control

The most common means of dissemination of sweet-potato viruses is by infected planting material. This is especially obvious in the Philippines, Indonesia, Papua New Guinea, Kenya, Rwanda and Uganda. The importance of clean material to the international movement of sweet-potato germplasm has been addressed by various organizations including the Food and Agriculture Organization of the UN (FAO), the International Board of Plant Genetic Resources (IBPGR), CIP and ACIAR. IBPGR and FAO have developed international guidelines for the safe movement of sweet-potato germplasm (Moyer *et al.*, 1989). Material should be cultured from meristems *in vitro*, treated by thermotherapy and further checked for the presence of virus by grafting to a susceptible indicator. PRI, through ACIAR and CIP, has helped to clean up elite germplasm from south-east Asia and the Pacific for international distribution. Although essential to the safe international movement of germplasm, varieties rapidly become infected again when grown in the field (A. Mason, personal communication). The clean-up process therefore offers no practical benefits in terms of increases in yield in the long term.

Resistance

In the Philippines, the seasonality of symptoms creates difficulties for field screening. Although characterization of viruses is planned, no antisera are currently available. It is also likely that antisera from other countries may not function for viruses in the Philippines. For example, recent tests have shown that SPFMV antisera from the USA will not react with strains of SPFMV from the Pacific and south-east Asia (P. Beetham and A. Mason, personal communication). Appropriate antisera may have to be made for different regions and countries.

Virus-like symptoms are common on sweet potato throughout Uganda. All screening for resistance to viruses is done in the field. Trials are carried out in the wetter Lake Victoria region, as virus-like symptoms are usually more severe in this area. This is in contrast to Rwanda, Kenya, south-east Asia and the Pacific where viruses appear most severe under dryer conditions. Production and rapid multiplication of virus-free material is an important aim of the sweet potato improvement programme at Namulonge Research Station. Surveys have indicated that there are few varieties currently available which are sufficiently resistant to viruses and weevils. It is thought that many varieties have apparently disappeared because of virus build-up.

Increased exchange of sweet-potato germplasm in recent years has facilitated screening of the same improved varieties in many different countries. Elite IITA clones with resistance to SPVDC in Nigeria have proven susceptible to what is thought to be the same virus complex in several locations in east Africa, for example, Rwanda. This suggests that the viruses, their vectors, or a combination of these factors are different in Rwanda. SPVDC is thought to be widely distributed throughout Africa. Results from field screening suggest that comparative strain studies would be worthwhile. Studies of viruses and strains from east and west Africa would provide valuable feedback on the adaptability of promising germplasm across the continent and on the identity, importance and distribution of the most common sweet potato viruses in Africa. The need for further characterization of sweet-potato viruses, not only regionally but also world-wide, is clear. Development of resistant or tolerant cultivars is the only viable long-term strategy for control of sweet potato viruses. The difficulties outlined above make this a very distant aim for most viruses. In a number of developing countries, field screening is possible under high virus pressure; however, expertise and funding are lacking for back-up laboratory and glass-house studies.

The International Working Group on Sweet Potato Viruses, which produces a newsletter (begun in 1988) to stimulate contact and collaboration between virologists working on sweet potato, is a positive move toward addressing this neglected problem.

Bacteria

Sweet potato is affected by five bacterial pathogens (Table 7), three of which can cause serious diseases and yield losses. *Erwinia chrysanthemi* pv. *zeae*, the causal agent of bacterial soft rot, is widespread in sweet potato-growing regions throughout the world and causes soft, moist decay of storage roots (Clark, 1988). Economic losses are reported from the USA only (Clark and Moyer, 1988). Although bacterial soft rot is not presently a problem in sweet potato-growing regions of south-east Asia, the Pacific or east Africa, it has been reported from India, Malaysia, Papua New Guinea and Zimbabwe, as well as Central and South America and the Caribbean (Bradbury, 1986; Muthappa, 1987). Monitoring the incidence and distribution of bacterial soft rot is considered worthwhile in these countries.

Bacterial wilt, caused by *Pseudomonas solanacearum*, although a pathogen of many crops world-wide, has only been reported on sweet potato from China, as causing vascular discoloration and vine wilt (Clark, 1988). Yield reductions of 30–80% have been recorded (Clark and Moyer, 1988). Chinese strains of the bacterium are unique in their pathogenicity to sweet potato (Clark, 1988). *Streptomyces ipomoeae*, the causal agent of soil rot or pox, has been reported from the USA and Japan, and in the former country can cause severe yield and quality losses (Clark and Moyer, 1988). The bacterium causes extensive necrosis of feeder roots and scab-like lesions on tubers which reduce tuber quality (Clark, 1988). Two other bacterial pathogens have been recorded on sweet potato – *Agrobacterium tumefaciens*, the causal agent of crown gall, and *Pseudomonas syringae* pv. *syringae*, causing leaf spot (Bradbury, 1986), but no information is available concerning their distribution or importance.

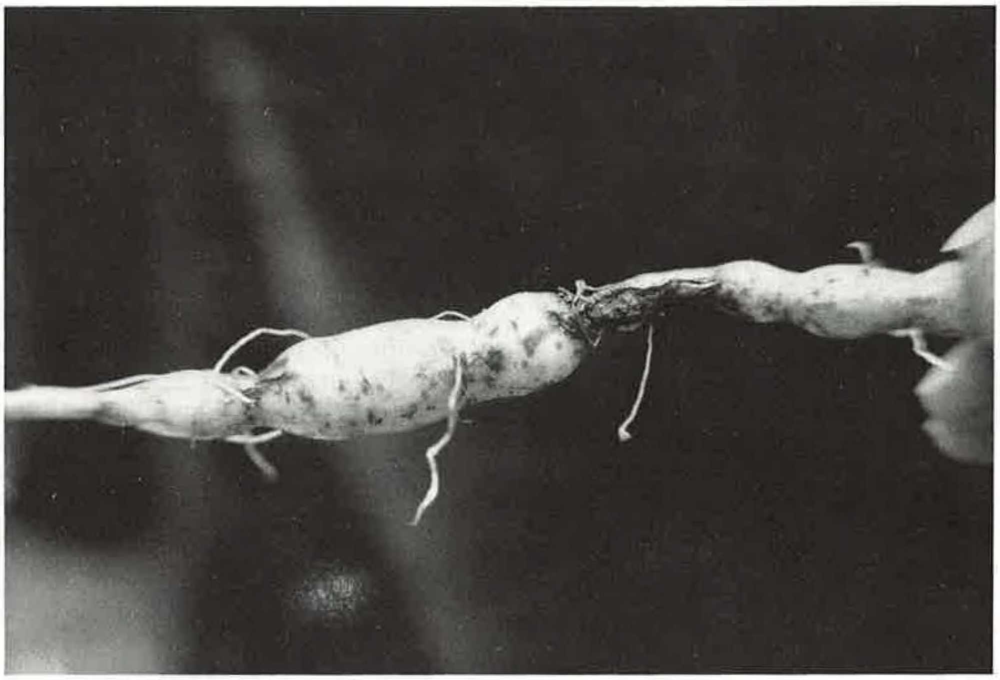
Rhodococcus fascians (syn. *Corynebacterium fascians*), the causal agent of fasciation, leafy gall and distortion of many plants, has been recorded widely in the UK, USA, Europe and Russia (Bradbury, 1986). Although it has been implicated as the causal agent of fasciation of sweet potato in Kenya, the bacterium has never been recorded on any *Ipomoea* spp., nor anywhere in the tropics. Fasciation, observed on sweet potato in Kenya and Rwanda and on a herbarium specimen from Indonesia, is manifest as apparent fusion of normal vines to form flat, wide vine stems. Vines, however, appear healthy and vigorous. It has also been reported from the USA, and is regarded as a disorder of unknown aetiology (Clark and Moyer, 1988). The incidence of fasciation was very low in both Kenya and Rwanda. Similar observations have been made in the USA (Clark and Moyer, 1988). There is no evidence to implicate *R. fascians* as the causal agent of fasciation. Presently, there are no serious bacterial diseases of sweet potato in south-east Asia, the Pacific or east Africa.

Nematodes

Many genera of plant parasitic nematodes have been found associated with sweet potato, but only root-knot nematodes, *Meloidogyne* spp., and the reniform nematode *Rotylenchus reniformis*, have been studied to any extent (Clark and Moyer, 1988) (see Figures 10 and 11). Other nematodes recorded on sweet potato are listed in Table 8.

Figure 10

Young sweet potato tuber constricted due to infestation by root knot nematode, *Meloidogyne incognita* in Papua New Guinea. (Source: J. Bridge, International Institute of Parasitology.)



SYMPTOMS

Although root galling is the most characteristic symptom of root-knot nematode, it is usually not well-developed on sweet potato roots (J. Bridge, CAB International Institute of Parasitology, St Albans, UK, personal communication). The most obvious symptoms on tubers are the development of longitudinal cracks and/or blister-like bumps (Clark and Moyer, 1988). However, as such symptoms can be produced by other biotic and abiotic agents, the only certain diagnosis is the presence of nematodes within roots. Nematodes can cause roughening and cracking of tubers and generalized decay of the root system, reducing yield and quality of tubers. Complexes of *M. incognita* with *Fusarium* spp. can cause severe wilting and premature death (Jatala, 1988). In several surveys in the highlands of Papua New Guinea, the association of rots with root-knot damage was common (P. Kokoa, personal communication) but the rotting agents have not been identified.

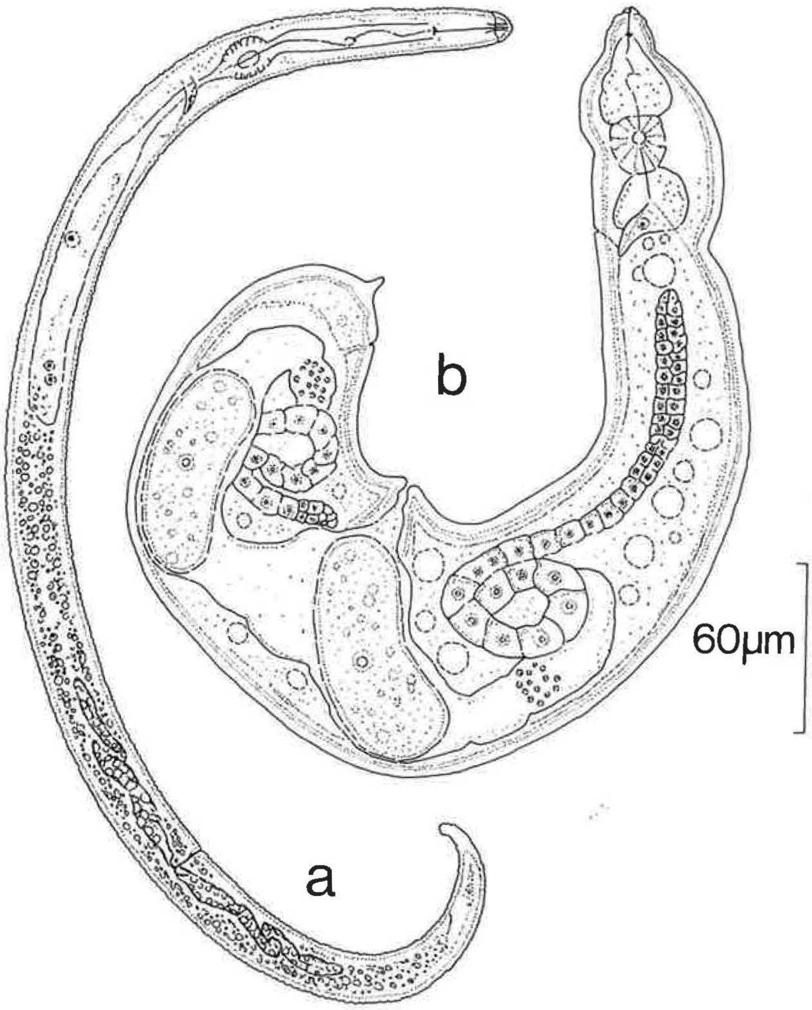
LOSSES

Although root-knot nematodes reduce both tuber yield and quality, losses have rarely been quantified. In the Philippines, losses of about 50% have been measured but can reach 100% with three continuous croppings in infected fields (Gapasin, 1984b, 1986). In the Southern Highlands of Papua New Guinea, one trial using varieties susceptible to root-knot nematodes and nematicides measured 18% yield loss (P. Kokoa, personal communication). Yield losses have not been documented for *R. reniformis*. The need to quantify losses caused by nematodes was emphasized by Bridge and Page (1982): it would be useful to study yield loss under farmers' traditional cultural systems and practices. Bridge and Page (1982) also recommended studies of the economics of chemical control and the effect of traditional practices on nematode population and damage.

DISTRIBUTION

The most important nematode of sweet potato is *Meloidogyne incognita* (Jatala, 1988, 1989). It is widespread, occurring in most sweet potato-growing regions,

Figure 11
The reniform nematode, *Rotylenchus reniformis,* a widespread pest of sweet potato in the tropics. (a) Immature female (b) Mature female. (Source: C.I.H. *Descriptions of Plant-Parasitic Nematodes* Set 1, No. 5, International Institute of Parasitology, St. Albans, Herts.)



and often serious. *Meloidogyne hapla* also attacks sweet potato, but is confined to cooler environments, while *M. arenaria* and *M. javanica* cause some damage but cannot complete their life cycles on sweet potato (Jatala, 1988, 1989). In the Philippines, *M. incognita* is common and two races have been identified (Castillo and Maranan, 1974; Gapasin and Valdez, 1979; R. Gapasin, personal communication).

The reniform nematode, *R. reniformis,* is widespread in tropical regions and can also cause serious damage to sweet potato (Siddiqi, 1972; Clark and Moyer, 1988), but it has been studied to a limited extent only. E. Orolfo, at Bicol Regional Research Station, will study the importance of the reniform nematode to sweet potato in the Bicol region of the Philippines.

Declining sweet-potato yields in the Southern Highlands of Papua New Guinea have been variously attributed to declining soil fertility caused by continuous cropping; build-up of viruses and little leaf mycoplasma in traditional varieties; or increasing nematode damage. An extensive survey was therefore carried out in 1981 to assess the role of nematodes in this decline (Bridge and Page, 1982). The association of nematodes with sweet potato and other crops was surveyed throughout five provinces of Papua New Guinea: Southern Highlands, Western Highlands, East Sepik, East New Britain and Morobe Province (the Markham Valley). In East Sepik, no damage due to *M. incognita* was found on sweet potato. In the Southern Highlands, where sweet potato is a major staple, *M. incognita* was widespread and serious damage was reported in some areas. Resistant varieties were also identified. In the Nembi plateau, nematodes were not widely distributed or serious. The long-term decline in sweet potato yield in this region has been attributed to extended cultivation and shorter periods of fallow caused by population pressure (Rangaii and Kanua, 1988). The survey gave no evidence that root-knot nematodes are contributing to this decline (Bridge and Page, 1982). In the Western Highlands, where sweet potato is also a major staple crop, serious root galling due to *M. incognita* was recorded at one site only. In the Markham Valley, only *R. reniformis* was recorded on one planting, which was also severely affected by scab. Previous studies also indicated that root-knot nematode was not a pest of sweet potato in this region (Thrower, 1958). Of 100 root samples taken throughout the highlands, *Meloidogyne* spp. were detected in 45, but only 15 were severely damaged with more than 10 females/g root. Nematode damage was rare in areas where there were no land shortages and long periods of bush fallow were practised.

On the basis of these findings, *Meloidogyne* spp. cannot presently be considered a major limiting factor to sweet- potato production in the highlands of Papua New Guinea, with the exception of isolated areas with high population pressure in the Southern Highlands. In the future, however, increasing shortage of land and a tendency toward shortened rotations and continuous cropping may cause increased nematode problems.

No information was found on nematodes of sweet potato from Indonesia, Thailand, Kenya, Rwanda or Uganda. Either studies have not been done, or nematodes are not a problem on sweet potato in these countries. One example of devastation of sweet potato by *Meloidogyne* spp. was observed in Burundi (M. Potts, CIP, personal communication).

CONTROL

Cultural control

Control strategies recommended for root-knot of sweet potato include crop rotation, hot-water treatment and the selection of nematode-free planting material (Clark and Moyer, 1988). Failure to practise rotation in root-knot-infected soils in Papua New Guinea and the Philippines has resulted in serious losses (Bridge and Page, 1982; R. Gapasin, personal communication). Both rotation and selection of nematode-free planting material can be employed by subsistence farmers to reduce initial nematode populations very successfully. On marginal soils where other crops cannot be grown, sweet potato should be rotated with fallow. Recommended cultural control strategies for *R. reniformis* are the same as for root-knot nematode (Clark and Moyer, 1988).

Chemical control

Treatment of soil with nematicides, such as dichloropropene, methyl bromide, ethoprop and fenamiphos, can be effective in reducing existing populations of nematodes (Clark and Moyer, 1988). Use of systemic nematicides such as oxalmyl for treatment of cuttings (Clark and Moyer, 1988) has wider applicability.

Resistance

Resistance to root-knot has been widely-sought (Giamalva *et al.*, 1963; Jatala and Russell, 1972; Bonsi and Phils, 1979; Jatala, 1988, 1989; Clark and Moyer, 1988). In the Philippines and Papua New Guinea, high levels of resistance have been identified in germplasm collections (Shiga and Takemata, 1981; Gapasin, 1981, 1984b, 1986; P. Kokoa, personal communication). Sweet potato varieties, highly resistant to *M. incognita*, have been found more frequently in Papua New Guinea and neighbouring islands than in any other country (Shiga and Takemata, 1981). Of 69 Papua New Guinea varieties screened for reaction to *M. incognita*, 75% were highly resistant (Takagi, 1988). The frequency of resistant clones decreased with distance from Papua New Guinea (Shiga and Takemata, 1981). Germplasm from Irian Jaya and the Philippines also had a high frequency of resistant varieties. In contrast, the frequency of resistant varieties in the centre of origin of sweet potato, Colombia, Ecuador, Mexico and Peru, was only 6% (Jatala, 1988). It is probable that farmers in the highlands of Papua New Guinea, one of the most important secondary centres of diversity of sweet potato, have selected less affected, possibly more tolerant, varieties over a long period. Some traditional varieties planted in the highlands of Papua New Guinea are poor hosts for the highland race of *M. incognita* (Bridge and Page, 1982).

In the Philippines, resistant varieties continue to be identified within local and introduced (W-86 from North Carolina) germplasm in screening trials at PRC-RTC, Visca. Of 50 varieties from the Visca collection, 35 were moderately to highly resistant to *M. incognita*. Some local varieties were highly resistant. Highly significant positive correlations were found between resistance rating and parameters used to assess nematode damage such as egg masses, root galls, and the nematode population in roots. Results clearly show that a considerable proportion of sweet potato germplasm available in the Philippines is resistant to root-knot nematodes (Gapasin, 1984b). Pre-infection resistance was indicated by the fact that fewer nematodes penetrated the resistant cultivars than the susceptible ones; post-infection resistance was shown by delayed or retarded development of nematodes after penetration, and failure to develop to maturity. The number of eggs per egg mass, and the size of egg-laying females, were significantly greater in susceptible cultivars than in resistant ones (Gapasin, 1986). Such resistance mechanisms are usually associated with synthesis of toxic compounds in reaction to penetrating nematodes, or with a lack of necessary nutrients for growth. The possible involvement of phenols in sweet potato resistance to root-knot nematode was shown by the analysis of compounds from root extracts of resistant cultivars, in which the reduced number of eggs hatched and high larval mortality of *M. incognita* and *M. javanica* were seen, even at concentrations as low as 10% (Gapasin *et al.*, 1988). Compounds present were heat-resistant, of low molecular weight and water soluble. Thin-layer chromatography revealed two distinct groups of compounds corresponding to chlorogenic acid, scopoletin and esculin. Terpenes, produced in tubers as a reaction to weevil damage, also repel nematodes (R. Gapasin, personal communication).

A new research programme (partly funded by CIP) on nematode problems of sweet potato has recently started in the Bicol region of the Philippines. A local population of *M. incognita* is maintained on tomato, and screening is done in the field and the glasshouse. Inoculation of 10,000 nematodes per pot is used in screening. By mid-1990, 54 local and introduced lines had been screened, and ten highly resistant lines have been identified under glasshouse screening (E. Orolfo, personal communication). Although resistance to *R. reniformis* has been sought in the USA, no usable resistance has yet been identified (Martin *et al.*, 1966; Clark and Moyer, 1988).

Sweet potato weevils – *Cylas* species

Cylas spp. weevils are the most important pests of sweet potato world-wide. They are the most important biotic factor affecting sweet potato in south-east Asia, the Pacific and east Africa. The considerable amount of research on their biology, ecology and control has been extensively reviewed (Sherman and Tamashiro, 1954; Talekar, 1982; Sutherland, 1986b; Macfarlane and Jackson, 1989; Chalfant *et al.*, 1990). Adult weevils oviposit in the bases of vines and tubers exposed either by rain washing soil away or by soil cracking in dry conditions. As high rainfall reduces soil cracking, preventing or reducing tuber accessibility for oviposition, *Cylas* spp. weevils are less of a problem in wetter areas. Weevils are also important where tubers are harvested sequentially, progressively or piecemeal as in most traditional sweet potato farming systems of south-east Asia, the Pacific and east Africa. IPM is widely regarded as the best control strategy (Talekar, 1988a, 1989; Raman, 1989).

LOSSES

Studies commonly report between 50 and 100% yield loss due to *Cylas* spp. weevils, especially under dry conditions, throughout south-east Asia, the Pacific and east Africa. Even low numbers of larvae and adults, feeding on tubers and causing slight physical damage, stimulate production of terpene phytoalexins which renders tubers inedible (Sutherland, 1986c). Losses of quality have not been adequately quantified. Low-level, insidious damage is not given enough attention when screening for resistance. In addition, all published yield loss estimates consider only tuber loss. The significance of damage to vines and its effect on yield has rarely been considered (Sutherland, 1986c; E. Bernardo, University of the Philippines, Los Baños, personal communication).

In the lowlands of Papua New Guinea, where *C. formicarius* (Plate 13, see Plate section, opp. p. 17) is an important pest, mean losses in commercial plantings have been estimated at 20–50% (S. Sar, Kuk Agricultural Research Station, personal communication). Where sweet potato is continuously cultivated, as by commercial farmers in Thailand, losses may reach 100% if no insecticides are used (P. Keinmeesuke, Horticultural Research Institute, Bangkhen, Bangkok, personal communication). In Indonesia, losses have been estimated to range from 5–100% depending on region, season and cultural practices (Bahagiawati, 1989). Losses due to the complex of *Cylas* spp. occurring in east Africa have not been well quantified.

With the exception of one report from Papua New Guinea, weevil–fungus complexes have not been documented in the literature. Although this may be an under-rated problem, there is no indication of a need for further work at present.

DISTRIBUTION

The distribution of *Cylas* spp. weevils varies between regions. *Cylas formicarius* is the most widespread, being the only species found in the Philippines, Indonesia and Thailand, and in Pacific countries such as Papua New Guinea. In east Africa, three species have been reported — *C. formicarius, C. puncticollis* and *C. brunneus*, the former two species being the most common and the latter two being restricted to Africa.

In the Philippines and Thailand, *C. formicarius* is a widespread destructive pest and is found wherever sweet potato is grown (Keinmeesuke and Vattanatangum, 1988; D. M. Amalin, CIP, personal communication). In Indonesia, although no country-wide survey has been done, *C. formicarius* is common in many sweet potato-growing areas, notably throughout Java and Irian Jaya. In Papua New Guinea, weevil damage is most serious in the lowlands with its marked dry season (Sutherland, 1985a). In the highlands, as it rains for most of the year, weevils rarely attack tubers and are known mainly as vine borers.

Cylas spp. weevils are the most important pests of sweet potato in Kenya. *Cylas puncticollis* is the most widespread *Cylas* species in Kenya; *C. brunneus* is of equal importance to *C. puncticollis* in Western Kenya, while *C. formicarius* is restricted to Msabaha on the coast (N. Smit, CIP, personal communication). A study of the distribution of weevils in Kenya is presently being carried out by CIP. Sweet potato weevils are also the most important pests in Rwanda. Both *C. formicarius* (possibly *C. brunneus*?) and *C. puncticollis* are present. Both weevils are also present in Uganda, but *C. formicarius* (*C. brunneus*?) is more common and the more serious pest (Ingram, 1967). Throughout east Africa, *Cylas* spp. weevils cause most damage in dry areas and during dry seasons.

CONTROL

Cultural control

Cultural controls for sweet potato weevil have been recommended since the early 1900s. Early workers (Franssen, 1934; Cockerman, 1943; Holdaway, 1943) recommended deep planting, hilling up, early harvest, rotation, use of weevil-free planting material, and removal of previous crop debris. Many of these techniques were practised by traditional farmers before researchers became involved with sweet potato, and most are still recommended today. Talekar (1983) also recommended destruction of wild *Ipomoea* species in and near sweet potato-growing areas with herbicides. More than 30 alternative hosts of *Cylas* species have been documented, most of which are *Ipomoea* species (Cockerman *et al.*, 1954; Sherman and Tamashiro, 1954; Talekar, 1983; Sutherland, 1986b). A recent review of the diversity of cultural recommendations for weevil control is given by Chalfant *et al.* (1990). Flooding of weevil-infested fields for two or more weeks after harvest may also reduce weevil infestation (Chalfant *et al.*, 1990).

In the Philippines, recommended cultural controls include deep planting, rotation, propagation of weevil-free cuttings, hilling up, use of varieties which form deep tubers, and sanitation. Early-maturing varieties which are harvested at 3 to 4 months and escape weevil damage, are also recommended. IPM strategies are well-developed in the Philippines. In Indonesia, early harvests at 4 months are recommended to escape weevil problems. Although insecticides are not generally recommended, cutting dips are being considered for incorporation into an IPM programme. Irrigation at 10-day intervals has been shown to reduce weevil infestations (Chalfant *et al.*, 1990). As many farmers have access to irrigation in Indonesia, it is a potentially important strategy. Ridging and hilling up are common cultural practices, although ridging is not as well developed as in the Philippines. Other recommendations include use of weevil-free cuttings, rotation and sanitation (Franssen, 1934; Bahagiawati, 1989). Potential components for an IPM approach to weevil control are being assembled in Indonesia. In Thailand, guidelines for sweet potato weevil control include the use of weevil-free cuttings, avoidance of weevil-infested areas, crop rotation, and destruction of *Ipomoea* weeds in the field and surrounding area (Keinmeesuke and Vattanatangum, 1988). Few of these practices are used by commercial producers, however, who depend on chemical control in the form of cutting dips, soil treatments and sprays.

Recommended controls in Papua New Guinea include deep planting, rotation, use of weevil-free cuttings, hilling up, use of varieties which form deep tubers, sanitation and destruction of *Ipomoea* weeds (Sutherland, 1986b). Irrigation during the dry season has been found to greatly reduce weevil damage (S. Sar, personal communication). This is relevant to both commercial producers and also to small farmers. If irrigation is not used in the dry season in the lowlands, losses can be as high as 100%. Further research on the frequency and amount of irrigation needed for adequate control would be worthwhile.

In Uganda, hilling up, use of weevil-free cuttings and rotation are recommended cultural practices (Mwanga and Wanyera, 1988). Recommended cultural methods in Kenya include use of 20- to 30-cm weevil-free shoot-tip cuttings for planting, use of mounds or ridges, hilling up, destruction of crop residues after harvesting, and rotation. Use of rotation, however, depends on the farming system. Many farmers grow sweet potato on marginal land where other crops do not grow and rotate with fallow. In east Africa, an intensive programme to implement recommended strategies for cultural control of weevils could have considerable impact.

Chemical control

Low-volume rates of application of several insecticides were found to be economic for weevil control in Papua New Guinea, especially when associated with early harvest (Sutherland, 1986a). Significantly higher undamaged (marketable) yields were obtained. It was not possible to establish a spray threshold because reduced yields and damage to tubers occurred at low population levels (Sutherland, 1986c). Although low-cost insecticide strategies are available in Papua New Guinea, most farmers do not use chemicals. Expanding commercial production may lead to increased use of insecticides in the future.

In the Philippines, pesticides are generally not used for sweet potato unless some remains after use on cash crops. Recommended foliar sprays for weevil control include fenthion, carbofuran and endosulphan, while carbofuran and phorate granules can be incorporated into the soil (D. M. Amalin, CIP, personal communication). Planting material can be dipped at low cost in insecticides such as carbofuran.

In sharp contrast with most other developing countries, commercial sweet potato farmers in Thailand depend on insecticides for weevil control. In the past, farmers used chlorinated hydrocarbons such as aldrin, heptachlor and dieldrin for controlling weevil which left toxic residues in tubers (Keinmeesuke and Vattanatangum, 1988). Subsequent trials with less harmful insecticides as soil treatments, cutting dips and sprays, found that soil treatments with carbosulphan 20% EC (at 5.55 kg a.i./ha) and carbofuran 3G (7.14 kg a.i./ha); spraying with carbosulphan (0.5 kg a.i./ha); cutting dipping treatments of carbosulphan (5% solution); and combinations of these were effective in controlling weevil and did not leave toxic residues in tubers. In several experiments, there were no significant differences between cutting dipping alone, and dipping combined with soil and spray treatments. Dipping in carbosulphan is a low-cost viable proposition for small farmers.

Effective insecticides have been identified for control of the most important pests of sweet potato in Kenya, but the economics of the crop may preclude the use of insecticides except under serious pest outbreaks and as pre-planting dips (Kibata, 1976). In Uganda, chemical control of *C. formicarius* using both cutting dips and sprays was investigated by Ingram (1967). Dipping cuttings in a solution of actual DDT (1/4 lb/gallon of water) gave significant reduction in the percentage of damaged tubers, number of weevils and degree of damage. Although it was found that such treatments would be profitable for yields in excess of 2.25 t/ha, pesticides are generally not used in Uganda.

A sex pheromone, produced by the female sweet potato weevil, *C. formicarius*, has been isolated, characterized and synthesized (Coffelt *et al.*, 1978; Heath *et al.*, 1986; Proshold *et al.*, 1986; Mason *et al.*, 1990). In several countries including the Philippines, Indonesia and Thailand, weevils are being trapped using this pheromone to monitor populations. One septum (ranging in strength from 1 to 10 μg) can be used for 4 to 5 months (one growing season), but the pheromone loses efficacy with time. Trials on the comparative effectiveness and economics of the sex pheromone and insecticides in controlling weevils are being carried out in the Philippines by various institutions and in Indonesia by the Bogor Research Institute for Food Crops (BORIF). In Thailand, the sex pheromone is also being tested. Various low-cost trap designs, constructed of local materials, are also being tested in these countries (D. M. Amalin, personal communication). Weevil populations are being correlated to levels of infestations in tubers. The value of traps for assessing damage and in decision-making regarding the frequency of insecticide applications, particularly in commercial production, will be evaluated in Thailand (P. Keinmeesuke, personal communication). Comparative experiments are essential before the pheromone is widely used, preferably under a range of field conditions including isolated, adjacent to contaminated, new, and old cultivated areas of sweet potato. Estimates of the proportion of the population trapped would be helpful. The problem of male weevils being less attracted to traps if the population of female weevils is high has been recognized. It is important to use the pheromone from the initiation of planting so that population build-up is restricted. A future problem could be the supply of pheromone to large-scale field production. Some consideration is also being given to developing a sex pheromone for *C. puncticollis*. As the pheromone attracts only male weevils, research is currently focused on identifying substances which will attract females (Chalfant *et al.*, 1990). Recent work has identified leaf and root volatiles which attract adult weevils (Nottingham *et al.*, 1989) and oviposition stimulants (Son *et al.*, 1990). Such attractants could be used in a trapping system in the future (Chalfant *et al.*, 1990).

Resistance

The history of the search for resistance to *Cylas* spp. weevils since the early studies by Cockerman and Deen (1947) has been reviewed in detail (Talekar, 1982). Field and controlled procedures have been developed at AVRDC for screening for resistance to *C. formicarius* (Talekar, 1982; 1987a,c) and are being used in many regions of the tropics. Most initial screening work was done in the field, and produced inconsistent results (Talekar, 1982). Some entomologists, however, have criticized Talekar's methodology as inappropriate for host-plant resistance studies (E. Bernardo, University of the Philippines, Los Baños, personal communication) '...the failure to breed a commercial cultivar utilizing parents with known sources of resistance to either weevil species despite years of research indicates the possibility that an adequate source of resistance to the weevils may not exist in sweet potato germplasm' (Talekar, 1982). This has created serious doubts as to the value of resistance in sweet potato germplasm and the feasibility of continuing to search for it.

Raman (1989) also criticized the basis of screening for weevil resistance in the field and outlined problems associated with the interpretation of results. Recently, controlled screening with known populations of weevils has been strongly advocated (Raman, 1989; E. Bernardo, personal communication). CIP also recommend forced-feeding screening (Raman, 1989). Although various screening methods have been used under controlled conditions, no standardized methodology presently exists and it is difficult to compare results among countries. Resistance alone will probably never completely control weevil, but it could be a valuable component of an IPM programme (Raman, 1989).

The strategy put forward by Raman (1989) for the international development of sweet potato varieties with resistance to weevil includes developing a database of information on screening methods, species of weevil, mechanisms of resistance, important environmental factors and varieties with resistance; assembling identified resistant germplasm for systematic evaluation; and developing an appropriate, standardized, international screening methodology.

In most resistance screening, damage to tubers only is assessed, damage to stems and vines rarely being considered. It is possible that varieties which suffer little tuber damage may suffer decreased yield due to stem damage (Sutherland, 1986c). The resistance of both tubers and stems should be evaluated (E. Bernardo, personal communication; Sutherland, 1986c; Macfarlane and Jackson, 1989).

In Indonesia, field screening for resistance to weevil has been carried out in Java with little success. No work has been done on resistance to weevil in Thailand. No controlled screening has been done in either country. In the Philippines, however, successful field and controlled screening programmes are in progress, based on AVRDC methodology (see Talekar, 1982). In on-going trials, varieties showing resistance to weevil are selected, after initial field evaluation, for intensive evaluation in the laboratory. Weevils are reared for this purpose on susceptible varieties and populations are often rejuvenated from the field. Controlled laboratory screening is based on the effect of ten adult weevils, five male and five female, on two tubers. After 60 days, tubers are evaluated for external damage (oviposition holes, entrance holes and exit holes on a 0–5 scale) and for internal damage (roots being cut open longitudinally and rated for the number of tunnels and number of insects of all stages). Varieties which show surface damage but reduced internal damage are evaluated further for antibiosis.

Work is in progress at UPLB to develop improved screening techniques (E. Bernardo, personal communication). The programme is looking at both stem and tuber resistance, the former being particularly important in reducing early weevil colonization. Ten-fold differences in weevil populations between susceptible and resistant varieties have been found. Resistance appears to be based on antibiosis: resistant clones show less damage and fewer, mainly immature insects (Gerona, 1987). Varieties with partial tuber resistance could now be used in an

IPM programme. A collaborative study on the biochemical basis of resistance to the weevil is planned between PRCRTC, Visca and the University of Georgia. Work is also in progress on rearing weevils on live material rather than harvested tubers to avoid potential adverse biological effects on weevil populations (E. Bernardo, personal communication).

Limited work has been done on resistance in Papua New Guinea and field screening is considered difficult. Small farmers tend to 'live with' the weevil. It is possible that traditional, local varieties have developed tolerance, selected over time. This would be worth looking at further. As lowland farmers grow a diversity of crops, rotations and mixtures may also indirectly contribute to weevil control.

In Rwanda, as in most countries of east Africa, all screening for resistance is presently done in the field under high weevil pressure. Varieties which normally mature at 4.5 months are deliberately not harvested for up to 8 months to increase weevil pressure. Weevil damage is evaluated on a 0–5 scale at harvest. Although this is a crude method, it mimics farmers' practices of sequential or progressive harvesting. Although several *Cylas* spp. occur in Rwanda, no attempt is made to distinguish species during field screening. The breeding programme in Rwanda has focussed on developing early-maturing varieties, most of which escape weevils. However, as most farmers progressively harvest these varieties, they often experience greater weevil damage than with their traditional late-maturing varieties which are probably tolerant. More input on screening for resistance to weevil is greatly needed in Rwanda and elsewhere in east Africa. Early-maturing varieties with higher resistance to weevil are needed, so that farmers have the option either of a single harvest at 4–4.5 months or of progressive harvesting over 8 months. Application of simple, controlled resistance-screening methodologies to the present breeding programme in Rwanda would have considerable impact in a short time.

Uganda's breeding programme, which began in 1984, aims to develop varieties with resistance to viruses and weevils, high yield, good root quality (high dry matter), acceptable taste and early maturity. On-farm trials are used to select superior varieties. All screening for reaction to weevils is done in the field, and is generally concentrated in dryer areas such as at Serere Research Station.

In Kenya, research on sweet potato weevils is being carried out by CIP, IIBC and the Kenya Agricultural Research Institute (KARI). IIBC has taken responsibility for *C. puncticollis* while CIP is working on *C. brunneus* and *C. formicarius*. Techniques for mass rearing have been developed by IIBC. Procedures for survey, evaluation and screening for resistance are being developed jointly by IIBC and CIP. Slight modifications of the resistance screening techniques used by CIP in Peru for the West Indian weevil (*Euscepes postfasciatus*) are used in Kenya for screening for resistance to *C. pucticollis* and *C. brunneus* (N. Smit, personal communication). Life studies on *C. puncticollis* are presently being completed by IIBC although some work has already been done by IITA (Hahn *et al.*, 1989). CIP and IIBC are also collaborating on developing a sex pheromone for *C. puncticollis* (G. Allard, personal communication).

KARI's research on sweet potato weevils is largely based at the root- and tuber-crop research stations. At Katumani Research Station, a breeding programme which includes selection for resistance to weevil has been in progress for about 10 years. All screening has been done in the field. The germplasm collection was also evaluated for weevil resistance at Ikeboko Substation under high weevil pressure. Plants were evaluated at 6 months for stem and tuber damage on a 0–5 scale. Many varieties showed severe stem damage where stems were severed from the tubers. If such damage occurs before tuberization, losses could be as high as 100%. The ten least affected varieties were included in the breeding programme. Promising materials, with good field tolerance to weevil, are emerging from this effort. In South Nyanza, western Kenya, CIP is screening local varieties for resistance to weevil in the field. Such trials will also look at the effect of harvest time on weevil incidence, severity and tuber yield.

Mechanisms of resistance include antibiosis, antixenosis and escape (Chalfant *et al.*, 1990). Characteristics which apparently make tubers less susceptible to weevil attack have been documented for many years and include deep rooting, thick skin, elongated shape, root density and chemistry, dry matter and starch content (Chalfant *et al.*, 1990). Vine or stem thickness has also been implicated. Other factors which could contribute to tuber resistance to weevil include latex chemistry, location of latex, root surface chemical and physical characteristics, oviposition stimulants and lignification. Stem hairiness and stem latex characteristics may also contribute to stem resistance (E. Bernardo, personal communication). Further work on both tuber and stem resistance to sweet potato weevil is needed.

With the exception of the Philippines, which is already successfully using improved, controlled screening techniques, most developing countries in south-east Asia, the Pacific and east Africa seeking resistance to *Cylas* spp. weevils rely exclusively on field screening. They would greatly benefit from the application of controlled screening methodologies to their selection and breeding programmes. In Papua New Guinea, Indonesia and Thailand, no controlled screening for weevil resistance has been done. Simple, low-cost methodologies, developed by AVRDC, have been available for almost 10 years but to date have only been used in the Philippines (of the countries visited in this region). Similarly, although no controlled screening for weevil resistance has yet been done in Kenya, Rwanda and Uganda, it is hoped that methodologies presently being developed by CIP and IIBC in Kenya will be rapidly disseminated to these countries. Such methodologies should make a positive contribution to the development of varieties with higher levels of resistance to *Cylas* spp. in the above countries.

The apparent lack of high levels of resistance to *C. formicarius* in *I. batatas* has stimulated an appraisal of wild *Ipomoea* species within the series Batatas (crossable with *I. batatas*). Possible stem resistance to weevil has been found in pentaploid interspecific hybrids between hexaploid *I. batatas* and tetraploid *I. trifida*, the latter being a non-tuber-forming species, in a recent CIP initiative (E. Chujoy, personal communication). Germplasm of *I. trifida* has also been introduced into the Philippines, and initial results suggest that it may contain some degree of stem resistance.

Biocontrol

Palaniswami (1989) has documented a wide range of parasites and entomopathogenic fungi on sweet potato weevil both in India and elsewhere. Natural enemies of sweet potato weevil which have been recorded world-wide include braconid ectoparasites on larvae — *Microbracon cylasovorus* and *Bassus cylasovorus* from the Philippines (Gonzales, 1925), *Microbracon mellitor*, *M. punctatus* and *Metaplema spectabilis* from Louisiana, USA (Cockerman, 1944), and *Rhaconotus* spp. and *Bracon* spp. from Trivandrum, India (Rajamma, 1980); entomopathogenic fungi on adults including *Isaria* species from Java and the East Indies (Kemner, 1924), *Fusarium* species and *Beauvaria globulifera* from Louisiana (Cockerman *et al.*, 1954), *Metarhizium anisopliae* and *Beauvaria bassiana* from Cuba (Castineiras *et al.*, 1984); entomogenous nematodes on larvae and pupae including *Neoplectana* spp. (Swain, 1943), *Rhabditis* sp. and *Aphelenchus* sp. from Louisiana (Cockerman *et al.*, 1954), *Heterorhabditis heliothidis* from Cuba (Hernandez and Mracek, 1984); and predators including *Drapetis exilis* on larvae in Trivandrum (Rajamma, 1980) and Argentine big-headed ant *Pheidole megacephala* from Cuba (Castineiras and Calderon, 1982).

In the Philippines, no useful natural enemies of *C. formicarius* have been found to date (L. Villacarlos, PRCRTC, Visca, personal communication). Potential candidates for biocontrol include the entomopathogenic fungi *Metarhizium*, *Beauvaria* and *Paecilomyces* species. *Beauvaria bassiana* is common on adult weevils. Of three strains tested (inoculum concentration 10^6 spores/ml), one from the island of Bubon was effective. Eight strains of *Metarhizium anisopleae* were also tested. One isolate from rhinoceros beetle was as effective as the

Bubon *B. bassiana* isolate causing death of *C. formicarius* adults in 3 to 7 days. The fungi affect both the life span of adults and the production and survival of the next generation.

As infection of males with *B. bassiana* does not affect their attraction to females, the sex pheromone has been used to spread the fungus in the field by trapping and releasing infected males. Dissemination of the fungus through the population was then monitored. Insects infected by the fungus were still trapped after 21 days. This method is potentially useful for spreading biocontrol fungi throughout the field in an IPM programme. Field applications of biocontrol fungi at the hilling-up stage have also been tested and shown to increase marketable root yield (L. Villacarlos, personal communication).

Preliminary work has begun on biological control of *C. formicarius* in Thailand. One Braconid parasite, *Rhaconatus* sp., was found in the central plain of Thailand (Keinmeesuke and Vattanatangum, 1988), but is presently considered of minor value for weevil control. *Beauvaria bassiana* is common on adult weevils in the field (Miss Panyarachun, Entomologist, Horticultural Research Institute, Bangkok, personal communication) but no pathogenicity tests have been done. The nematodes *Neoplectana carpecapsae* (from the USA) and *Heterorhabditis* spp. (from Australia), which have been isolated from other insects, show promise against *Cylas* spp. in laboratory tests. Field tests have yet to be carried out.

In Kenya, IIBC has identified *Beauvaria bassiana* on *C. puncticollis* adults in various parts of Kenya and other neighbouring countries (G. Allard, personal communication). Collection and testing of isolates of *B. bassiana* is in progress. Another species of this fungus, *B. brogniartii*, has been identified on adults of the rough sweet potato weevil, *Blosyrus* spp., which is prevalent in parts of Kenya. This will also be tested as a biocontrol fungus on *Cylas* spp.

Integrated pest management

IPM is widely accepted as the most appropriate control strategy for sweet potato weevils, particularly in developing countries. Talekar (1988a, 1989) has developed an IPM programme for sweet potato weevil at AVRDC. This approach emphasizes the use of cultural and chemical control strategies including weevil-free planting material either selected naturally or by chemical dipping treatments, crop rotation, control of alternative *Ipomoea* hosts around fields, frequent hilling up of plants to prevent oviposition, sanitation, and continuous use of the sex pheromone to trap male weevils. The programme has been tested successfully in Taiwan and is being promoted throughout Asia where *C. formicarius* is a serious pest. In some cases, for example in the Philippines, it is being modified to include local cultural practices.

In the Philippines, considerable work has been done on developing an IPM programme for sweet potato weevil. A planned CIP-funded project will look further at IPM strategies including the incorporation of resistant varieties; monitoring weevil populations using the sex pheromone; cytological and genetic studies to determine the presence of biotypes within *C. formicarius* (the existence of biotypes is suspected as some sweet potato varieties show different reactions to weevils at different sites); cultural control using already existing and modified farmers' practices; and biological control. Chemicals will be included as dips for cuttings.

In Thailand, the need for development of an IPM programme to reduce reliance on pesticides is clear. Experiments are planned to evaluate various components of IPM including cultural, chemical and biological control at Pichit Research Station, in the main sweet potato production zone. There is some doubt, however, whether cultural practices will be readily adopted in Thailand as farmers have no tradition of using such practices (P. Keinmeeksuke, personal communication).

In Kenya, CIBC's programme for control of sweet potato weevil, *C. puncticollis*, includes development of biocontrols to be included with cultural controls and host-plant resistance in an IPM programme. Although low-cost pesticides could also play a role in weevil control (Sutherland, 1986c), chemical control, even as cutting dips, is not going to be considered in this programme. No work has yet been done to develop IPM strategies for control of sweet potato weevils in Rwanda or Uganda.

As IPM is considered the most appropriate strategy for control of sweet potato weevils, regional and international effort is urgently needed to bring existing and potential technologies together for systematic evaluation throughout sweet potato-growing areas in developing countries. Refinement of some IPM components will be needed: in particular, research on aspects of cultural controls specific to countries and regions; further development of low-cost pesticide strategies for particular countries; and application and implementation of controlled screening methodologies for resistance so that the best varieties can benefit from the other control strategies. A combination of early-maturing varieties which escape weevil, early harvest, which also facilitates escape from attack, and development of effective storage and processing technologies would also greatly reduce weevil damage. Although this strategy may not be applicable to traditional subsistence farmers who harvest progressively, it should be relevant to commercial producers. However, if storage and processing technologies are developed, small farmers will not have to rely as much on progressive harvesting. There is considerable need for a network linking researchers on sweet potato weevil to increase communication, bring together the diversity of programmes presently in progress, and develop an international strategy to control the most important pest of sweet potato. It would help to avoid duplication of research as well as to develop standardized methodologies (Raman, 1989).

Other important pests of sweet potato

In south-east Asia and the Pacific, no pests other than the weevil, *C. formicarius*, have presently been identified as worthy of research effort. In east Africa, however, both clear wing moths, *Synanthedon* spp., and sweet potato butterfly, *Acraea acerata*, (Lepidoptera), are considered sufficiently serious pests to warrant research input. In Kenya, clear wing moths, (*Synanthedon* spp.), are regarded as serious pests on the coast (Wheatley, 1961; Bradley, 1968). They have not been reported as pests elsewhere to date. They affect stems usually just above the soil line: tunnelling larvae cause galling, thus debilitating the plant and reducing yield (Wheatley, 1961). Control measures used for *Cylas* spp. weevils will reduce the incidence of this pest also, including insecticides; rotation (one year's rest from sweet potato is sufficient to reduce infestation); clean planting material or dusting with insecticides; and destruction of residues after harvest (Wheatley, 1961; Kibata, 1976). A sweet potato germplasm collection at Mtwapa Research Station on the Kenyan coast was severely affected by larvae of clear wing moths.

The sweet potato butterfly, *A. acerata*, is a sporadic but often serious pest especially in the dry season in Burundi, Rwanda, Uganda and Ethiopia. In dryer years, it may cause total crop failure. It has not been reported outside Africa. The young larvae are initially concentrated in folded leaves surrounded by a protective web (see Plate 12). If these are mechanically destroyed early, the pest can be controlled. After about 14 days, groups of larvae separate and rapidly disseminate through the crop destroying foliage. Outbreaks are sporadic and seasonal but the insect often attains pest status during the dry season (G. Allard, personal communication). In severe infestations, defoliation is severe, young plants die and yields are severely reduced, but losses have never been quantified. The concentration and close proximity of farms means that even if one farmer destroys this pest, his crop may still be affected if neighbouring farmers do not. Manual control must be on a regional basis. Pesticides are effective but the cost is prohibitive for most farmers. No basic work has been done on this pest. Studies on clear wing moth and sweet potato butterfly should be directed at developing low-cost control strategies applicable to small farmers.

Virus and mycoplasma vectors including aphids, whiteflies and leaf hoppers also merit consideration, especially aphids and whiteflies in east Africa and leaf hoppers in south-east Asia and the Pacific. As almost no reference to them is made in the literature, it is not known whether studies on resistance to viruses and LLM have included any evaluation of resistance to their vectors. Such studies would be worthwhile components of any projects directed at resistance to particular viruses or mycoplasma.

Several vertebrates have been referred to as sporadic but occasionally severe pests of sweet potato. The most common are rats and mice, but squirrels and monkeys have also been noted as pests. Cultural controls which include hilling up and planting on mounds or ridges may impede such pests. Because they are sporadic, it would be difficult to justify research input at this stage.

ROLE OF WILD SPECIES OF *IPOMOEA*

Wild species of *Ipomoea* can influence sweet potato pests and diseases in two ways. Firstly, wild species could be used as sources of genes for resistance to diseases and pests, especially when good sources of resistance are found in those which are crossable with *I. batatas*. Secondly, their role as alternative hosts of diseases and pests of sweet potato may influence control strategies where wild species are common in sweet potato production areas.

Tremendous genetic variability has been observed in sweet potato germplasm, both in primary and secondary centres of diversity. Much diversity has not yet been adequately collected and characterized. There is also increasing interest in the potential of wild germplasm as sources of resistance to pests and diseases, particularly for *Cylas* spp. weevils, nematodes and viruses (Iwanaga, 1988). CIP's germplasm collection holds over 1000 accessions of wild *Ipomoea* spp. and active collection is continuing (CIP, 1989a). Breeding with wild germplasm, including *I. trifida* and *I. littoralis*, has been in progress in China, Japan and Taiwan (AVRDC) since the early 1970s (Kobayashi, 1978). Recently, CIP has successfully manipulated wild germplasm in the taxonomic series Batatas, to which *I. batatas* and nine other species belong, for use in the sweet potato breeding programme (CIP, 1989a, b). For example, stem resistance to *C. formicarius* from *I. trifida* is being evaluated in CIP breeding programmes in Peru and the Philippines. However, the use of much wild *Ipomoea* germplasm is presently hampered by cytogenetic barriers and undesirable wild characters such as lack of tuber production by most wild species.

The importance of wild *Ipomoea* spp. as alternative hosts of pathogens and pests of sweet potato is clear (Table 9; Jackson and Zettler, 1983; Sutherland 1986b; Clark *et al.*, 1986). Pathogens documented in Table 9 are restricted to the most specific pathogens of sweet potato; the table does not include less specific pathogens such as *Botryodiplodia theobromae*, the causal agent of Java black rot, or *Macrophomina phaseolina*, the causal agent of charcoal rot, as, for these pathogens, other crops are potentially more important as inoculum sources than are wild *Ipomoea* species. Eighteen fungal, one bacterial, one mycoplasmal, several viral and two nematode pathogens of sweet potato are hosted by wild *Ipomoea* species. Sutherland (1986b) lists 27 *Ipomoea* species among alternative hosts of the weevil *C. formicarius*.

Among the more important diseases of sweet potato, scab is hosted by water spinach, *I. aquatica*, *I. gracilis* and *I. triloba*; and *Alternaria* spp., LLM, sweet potato feathery mottle virus and probably SPVDC are hosted by several *Ipomoea* species (Jackson and Zettler, 1983; Clark *et al.*, 1986). Interestingly, at least ten rusts, including species of *Aecidium, Puccinia, Uredo* and *Uromyces*, have been recorded on *Ipomoea* spp. worldwide, but rust has never been reported on sweet potato. In sweet potato-growing areas where wild *Ipomoea* species are common weeds, awareness of their ability to host sweet-potato diseases is necessary in any consideration of disease control strategies. Destruction of *Ipomoea* spp. weeds is a recommended control strategy for sweet potato weevil in south-east Asia and the Pacific (Talekar, 1982, 1983, 1988a; Sutherland, 1986b; Keinmeesuke and Vattanatangum, 1988). In south-east Asia, relationships between pests and diseases of *I. batatas* and *I. aquatica* would be worth investigating where these two crops are grown together. No work has been published on the importance of wild *Ipomoea* spp. to diseases and pests of sweet potato in east Africa.

Although not widely recognised, some wild tuber-forming *Ipomoea* spp. have been and are still used as food for indigenous cultures in several parts of the world. Three wild tuber-forming *Ipomoea* species, *I. costata, I. gracilis* and *I. polpha,* were important in Arnhem Land and Cape York, Northern Australia as secondary food for the hunter-gatherer tribes of aborigines which inhabited this region (Yen, 1982; 1989). *Ipomoea costata* features in many aboriginal myths. Two wild species, *I. oenantherae* (elongated leaf) and *I. longituba* (morphologically like *I. pes-caprae*), native to the dryer areas of the rift valley, are eaten as vegetables by the Masai (C. Kabuya, National Herbarium, Nairobi, personal communication). *Ipomoea longituba* produces succulent, fleshy, starchy and juicy tubers, chewed by the Masai to quench thirst. The species is distributed throughout Machakos, Laikipia and the Masai Mara, Kenya and is also reported from Ethiopia, Tanzania and Uganda. It could be an important host of sweet potato diseases and pests, or alternatively could be affected by diseases and pests from sweet potato. *Ipomoea oenantherae* is a multi-lobed, thin-leafed species with numerous stems forming fusiform roots. The small carrot-like roots are eaten by Masai and Kipsigis children. It is widespread in east Africa throughout Uganda, Tanzania, Kenya, Ethiopia, Zimbabwe, Zambia and South Africa. This species could also host pests and diseases of sweet potato.

Because of the potential loss of genetic material, and the consequent likelihood of reduced food security, self-sufficiency, and varietal and nutritional quality of people's diets, as well as loss of knowledge and national heritage, the Indigenous Food Plant Programme in Kenya is gathering information about such locally cultivated crops. Traditional indigenous food plants, including roots, are being collected, evaluated and re-introduced to traditional cultures. These species may host diseases and pests which could spread to sweet potato; or presently important sweet-potato problems, especially viruses and weevils, could spread to the indigenous species, thus threatening their revival.

Section 4

Research resources

SOUTH-EAST ASIA/PACIFIC

Indonesia

The Central Research Institute for Food Crops (CRIFC) at Bogor is an important component of the Agency for Agricultural Research and Development of the Ministry of Agriculture. CRIFC is responsible for co-ordinating research activities on all food crops, including root crops, in Indonesia. The mission of CRIFC is implemented by six Research Institutes for Food Crops – BORIF at Bogor; SURIF at Sukamandi, west Java; MARIF, at Malang, east Java; SARIF at Sukarmi, west Sumatra; BARIF, at Banjarbaru, south Kalimantan; and MORIF at Maros, south Sulawesi (see Figure 2, page 22). Apart from BORIF, which does basic research, each institute is responsible for specific agro-ecological and climatic zones. Emphasis on marginal lands is growing due to the increasing scarcity of fertile land. BORIF and MARIF are the major insitutes working on root and tuber crops. Several universities also conduct research on roots and tubers, including Bogor Agricultural University; Brawijaya University at Malang; and Cendrawashih University at Manokwari, Irian Jaya. International funding for research has been obtained from various agencies including IDRC, ACIAR, the Japanese and Dutch governments, and international centres of the CGIAR including IRRI, CIP, CIMMYT, ICRISAT, ISNAR AND CIAT (see page vii).

Germplasm quality is considered a major problem for all 'palawija' (secondary or non-rice) crops. In the past, research has focussed on rice, and at least 50% of the research expertise has been concentrated in Bogor. Now Indonesia is self-sufficient in rice, there is increasing diversification into improving 'palawija' crops and research efforts in other parts of Indonesia. There is a significant lack of improved varieties of root and tuber crops, and even among these crops sweet potato is of low priority.

The changing research focus includes more emphasis on marginal areas such as eastern Indonesia and crop diversification to corn, cassava, grain legumes (soya bean, peanut, mung bean, pigeon pea, cowpea) and sweet potato. Many biological, technical, economic and social constraints are being faced. Excellent laboratory and glasshouse facilities, mostly funded by a Japanese government project over 20 years (terminated in 1989), have been established at Bogor. A new tissue culture facility has been established. It will facilitate the removal of viruses from sweet potato varieties.

Philippines

The Philippines Root Crops Research and Training Center (PRCRTC), at Visca, Leyte, directs all research on sweet potato in the Philippines (Palomar *et al.*, 1989). This includes varietal improvement, pest and disease management, and processing. Recently, the potential of sweet potato as a source of various processed foods was recognized. Considerable product development has already been done (Truong Van Den, PRCRTC, personal communication) and the Philippines is a leading country in sweet potato-processing research. The germplasm collection numbers over 1000 lines, including 900 local varieties. This collection is evaluated by all disciplines involved in sweet potato improvement. The Northern Philippine Root Crop Research and Training Center, sister institution of PRCRTC, Visca, is located at Baguio, Northern Luzon. A collection of 900 varieties, including 500 local, is being characterized with support from IDRC. A modified and expanded set of descriptors based on the IBPGR descriptors is being used to characterize germplasm in the Philippines (E. Chujoy, CIP, personal communication). The programmes of the two PRCRTCs are partly funded by IDRC, CIP, FAO, the Japanese Society for the Promotion of Science, and other international organizations.

Other institutions in the Philippines currently working on sweet potato include the University of the Philippines, Los Baños (UPLB) (see page 73); the Plant Breeding Institute, Los Baños; the Bicol Regional Research Station, Department of Agriculture, Pili, Southern Luzon; and other Department of Agriculture Research Stations located in sweet potato-growing regions. In 1987, there were a total of 174 sweet potato research and development personnel in the Philippines (Palomar *et al.*, 1989).

Papua New Guinea

Research on sweet potato is mainly carried out by the Highlands Food Crops Research Team at Kuk Research Station, near Mount Hagen, and the Lowlands Research Team at Laloki Research Station, near Port Moresby. The major areas identified for research are soil fertility, cultivar improvement, pest and disease management and, with lesser emphasis, breeding and farming systems. In the past, agronomic research only has received priority. There is no national sweet potato programme in Papua New Guinea.

"Most of the research carried out on sweet potato in Papua New Guinea during the last 40 years has not produced sufficiently clear-cut results or reliable data to convince farmers to change either their methods or their varieties" (Hadfield, 1989). Research has been oriented toward the researcher rather than the farmer, and the result is a huge collection of random information which lacks general applicability to the major problems of the crop (Hadfield, 1989).

Papua New Guinea is an important secondary centre of diversity of sweet potato and there is a tremendous variety of germplasm. Large collections have been assembled at Laloki and Kuk Research Stations. A duplicate of part of the highland collection at Aiyura was the focus of an intensive two-year IBPGR-funded characterization study. The germplasm collection for the lowlands, at Laloki Research Station, numbered about 1000 varieties but, at present holds about 700. Most are local varieties; some germplasm has been introduced from AVRDC. The collection is being evaluated using selected IBPGR descriptors. Most of the germplasm has been characterized for foliage, flower and tuber characteristics, but important characters such as yield, dry matter and reaction to diseases and pests are still being documented. Scab, LLM and weevil damage were observed in the collection. Maintenance of the collection is a considerable problem, as for most vegetative collections. It must be irrigated in the dry season and replanted every 6 months at a different site to reduce pest and disease build-up. As duplicates have not yet been identified, it is presently difficult to reduce the collection to a manageable size. Already about 30% has been lost.

The tissue culture laboratory at Laloki was set up in 1986 with the initiation of the ACIAR virus elimination project. Promising varieties were sent to PRI, Australia, for elimination of both viruses and MLOs. Since then, 52 varieties have been cleaned up. The rate of re-contamination of clean material is also being monitored. Although yield improvement of clean material has been measured, the transfer rate of MLOs to clean material is rapid. The future of the tissue culture laboratory and its capacity to continue the clean-up process is dependent on outside funding.

The highland germplasm collection at Kuk Research Station also originally numbered about 1000 varieties but now has 700. It was assembled on an *ad hoc* basis, beginning about 20 years ago, and was largely collected according to individual interest or opportunistic access to germplasm during survey trips (M. Gunther, Kuk Agricultural Research Station, personal communication). Although the collection represents local varieties from approximately 900 to 2000 m elevation, it is thought that greater genetic variability exists and samples still need to be collected. A database of collection data has been developed. An EEC-funded project will soon begin intensive evaluation of the germplasm with the aim of selecting approximately 100 promising lines for eventual on-farm testing.

Rapid rural appraisals are periodically carried out in specific areas of the highlands. As sweet potato is the staple crop throughout most of the highlands, this crop figures prominently in all surveys. Disease incidence and severity are assessed visually, and soil samples are processed in the laboratory for nematodes. These surveys are an important tool in identifying major, widespread constraints and newly emerging problems.

Breeding of sweet potato is not presently of high priority in Papua New Guinea. One breeding effort is currently in progress at Lae (V. Kevesan, Papua New Guinea University of Technology, Lae).

Thailand

Although sweet potato is an important vegetable in Thailand, it is a neglected crop in terms of research and development. Research is carried out by the Horticultural Research Institute of the Department of Agriculture, various universities, and Pichit Agricultural Centre. Germplasm has been collected throughout every region of Thailand and some has been introduced from AVRDC, IITA, the USA and Japan. Over 300 varieties have been assembled and characterized with the IBPGR descriptors. Promising varieties have been evaluated in regional trials, and some cultivars have entered the breeding programme. However, considerable work still needs to be done on sweet potato: for example, there is no national programme to supply good planting material to farmers; no basic survey and characterization work has been done on diseases including viruses; and no yield-loss studies have been carried out. Work on biotic factors has primarily concentrated on weevil control.

A sweet potato improvement plan has been put forward by the Departments of Agriculture and Agricultural Extension. The following priority areas of research and development have been identified: germplasm collection and evaluation; varietal improvement for high yield for the processing industry, human consumption and animal feed; improvement of agronomic practices and plant protection; improvement of post-harvest technology and utilization at village and industrial levels; and transfer of technologies in the above areas (Thongjiem and Piriyathamrong, 1989).

Australia

Sweet potato is a minor crop in Australia with annual production of 6000 t/ha and a mean yield of 13.5 t/ha (FAO, 1989). Production areas include Gatton in southern Queensland and Mareeba and Tolga in northern Queensland. In the south, sweet potato is a summer crop while in the north it is grown in the winter and enjoys premium prices in southern markets. Gatton Research Station is responsible for varietal improvement, and also for evaluation and selection of introduced varieties from the USA, AVRDC, south-east Asia, the Pacific, and Papua New Guinea. Orange-fleshed, high water-content varieties are preferred. Sweet potato is a single-harvest crop in Australia. Cattle graze remaining plant refuse after harvest. Planting material is often selected from previous crop residues which can create sanitation problems. Although sweet potato is a minor crop in Australia, there is a notable research input on diseases.

ACIAR, together with CIP, has funded and implemented projects on sweet potato improvement from 1986 to 1991 in south-east Asia and the Pacific through the South-east Asia Potato Production Research and Development Network (SAPPRAD). The major aim of these projects was to produce pathogen-tested sweet potato germplasm for south-east Asia and the Pacific. This region is of particular concern because of the apparent association of low yields with virus symptoms (although no direct association has been proven); the very strict quarantine regulations in some south-east Asian and Pacific countries; and the limited availability of germplasm in this region.

The major objectives of the projects were to identify and characterize superior sweet potato varieties with good yield potential, resistance to weevil, scab, LLM and viruses, and high nutritional value. A range of plant types for various cropping systems was collected. Research was carried out at the Plant Research Institute (PRI), Burnley, Victoria. Pathogens were eradicated from selected varieties by heat treatment and meristem culture. This was followed by virus indexing. Pathogen-tested varieties were maintained in tissue culture, recultured every 3 months, and distributed to participating countries. Personnel from these countries were trained and assisted in developing their own clean-up and rapid-multiplication facilities. Information on handling and maintenance of tissue cultures and pathogen-tested plants was disseminated. Follow-up agronomic trials were carried out in participating countries to compare yields of pathogen-tested and untreated material; to study rates of re-infection; and to compare characteristics of local material with imported lines.

In January 1990, PRI's pathogen-tested sweet potato collection numbered 102 varieties. One pathogen-tested variety in Papua New Guinea has yielded 1.8 times the marketable roots produced by untreated material, but other pathogen-tested varieties have not shown significant yield differences. In Tonga, where yields of pathogen-tested and untreated material have been compared over 3 years, one variety continues to produce twice the yield of the untreated material (A. Mason, personal communication). Other Tongan lines, however, have not shown the same yield improvements. This suggests that the yield-reducing effects of virus are variety-specific; cleaning up will benefit some varieties but not others. This effect may be related to varietal resistance to particular viruses. However, rates of re-infection of some pathogen-tested varieties with viruses and mycoplasma are alarmingly high, approaching the level of untreated material by the end of one growing season (Mason *et al.*, 1989). As farmers' varieties are often not as 'dirty' as the research station material being cleaned up, the relevance to farmers of these considerable yield differences is questionable. Pathogen-tested material is, however, vital for international germplasm exchange. Although pathogen-tested cultures are available, and personnel have been trained, participating countries do not have the long-term support necessary to maintain culture facilities. This need should be addressed in future projects.

One major problem faced by this project is that collection of information about viruses from these trials is inaccurate due to poor quality antisera (A. Mason, personal communication; see p.63). The relationship between sweet-potato viruses and yield loss therefore cannot be studied quantitatively. A real difficulty has been that polyclonal antisera have not reacted to specific viruses. Some attempts have been made at producing high quality antisera by fractionation: this has been successful for sweet potato mild mottle virus, but not for sweet potato feathery mottle virus. Recent research has concentrated on developing new antisera to caulimo-like virus and to a Tongan isolate of SPFMV which will be used for serological indexing of sweet potato in the field.

EAST AFRICA

Uganda

Although sweet potato is one of the most important food crops in Uganda, it has received limited research attention. The National Root and Tuber Crops Improvement Programme is based at Namulonge Research Station (originally the research station of the Empire Cotton Board), near Kampala, but lack of funding is a constraint to its progress (Mwanga and Wanyera, 1988). Research is directed towards identifying virus- and weevil-resistant, high-yielding, stable varieties of wide adaptability and consumer acceptance (mainly palatability). At present, IDRC partly funds the national programme. The Ugandan Root Crops Research

Team, based at Namulonge, makes periodic surveys throughout sweet potato-growing areas of Uganda, particularly the north, east and central regions, to assess major production constraints. Viruses and weevils are clearly the major biotic constraints. Screening for resistance to these constraints is an important part of the breeding programme (see pages 63 and 74).

The original germplasm collection consisted of 400 local varieties, mainly from northern, eastern and central Uganda. Although originally maintained at both Serere Research Station in northern Uganda and Namulonge, it is now kept at Namulonge for logistic reasons. Major maintenance problems including viruses and drought have reduced the collection to only 200 of the original 400 varieties. As this is not thought to be representative of the germplasm diversity in Uganda, more collecting is needed (R. O. M. Mwanga, Namulonge Research Station, personal communication). Twenty-six superior varieties have been selected for further evaluation, after which the best varieties will be selected and screened multi-locationally and on-farm.

Variety development is a continual process in Uganda, and the crossing block at Namulonge includes local and IITA material. All IITA varieties were seriously affected by virus, as was also observed in Rwanda. Apparently 'virus-resistant' germplasm from IITA is not resistant to the virus complex in east Africa. These findings further support the need for comparative studies of viruses throughout Africa.

The poly-crossing block has 26 varieties, including 13 local ones. From the original crossing, 1800 were selected from 50,000 seedlings. Selection is not difficult at Namulonge as viruses usually eliminate about 50% of the seedlings in the first planting. Sweet potato butterfly damage was moderately severe in the experiments. This pest is often controlled with insecticides in trials at Namulonge during dryer periods of the year.

A further aim is to generate improved germplasm with specific adaptation to particular environments, such as the higher altitude Mount Elgon, and lower altitudes where viruses are the main constraint. Although there are no agronomic trials presently in progress due to lack of funds, the effect of planting methods and systems on yield will be studied. Effects of mounds as opposed to ridges, number of cuttings planted per site, and planting density will also be evaluated. There are plans for specific screening trials for weevil when funds are available. There are two perceived needs: first, a tissue culture laboratory to facilitate rapid multiplication of virus-free planting material, and for international exchange and secondly, the development of a system for dissemination of virus-free material to farmers.

Rwanda

The National Sweet Potato Improvement Programme of the Institut des Sciences Agronomiques du Rwanda (ISAR) is based at Rubona. Its major objectives are increased production by selection and breeding, and improved agronomic practices. Research on cultural practices, on-farm testing, and training courses are also important. Pesticides are not researched as their cost is prohibitive in Rwanda.

Germplasm has been collected widely throughout the country during surveys of farmers' fields. The collection has 315 varieties and is difficult to maintain. It is replanted every 2 years, and several plantings of different ages are maintained concurrently at different sites. All germplasm has been evaluated and the best varieties are included in the breeding programme. Germplasm has also been introduced from IITA.

The main aims of the breeding programme, which began in 1978, are high yield and dry matter, resistance to the most important pests and diseases (weevils, sweet potato butterfly, viruses and Alternaria stem blight), early maturity, and tolerance to climatic and edaphic constraints. Taste and nutritional qualities are also of high priority in the selection process. The activities of the breeding programme include field screening and selection among local and introduced varieties; crossing selected material by both controlled and natural means; preliminary and multi-locational yield trials; and on-farm trials (Janssens, 1980). Reaction to pests and diseases is evaluated in seedlings from the first generation. Parameters include virus incidence, Alternaria stem blight severity, weevil damage in tubers (all of which are rated on a 0–5 scale), flesh colour, dry weight of vines, tuber yield and number of tubers (Janssens, 1980; Ndamage, 1989). Although yield is the principal selection criterion, all lines showing serious virus and weevil damage are eliminated. Because further screening is not done under controlled conditions, there is a danger of selecting susceptible lines which escape weevil and virus damage, and lines which are latently affected by viruses.

Both controlled and natural crossing are carried out, the former to move specific traits into otherwise promising lines. Some superior varieties may remain in the block for 4 to 5 years. New, promising local and introduced varieties are added when they are identified. Similar crossing blocks have been developed by IITA and AVRDC, but the Rubona block was developed for local needs. Crossing is carried out all year round. Potential flowers are identified the day before, tied up, then pollinated the following day. Seed from this block has been sent to many countries including Kenya, Ethiopia, Malawi and Mozambique. The East and Southern African Rootcrops Research Network (ESARRN) has promoted this activity in Rwanda and will continue to support it. Maintenance of old plants in the crossing block is difficult due to weevils and root rots. Introduced IITA varieties are high yielding and early maturing, but their taste and high water content are not acceptable to farmers. Attempts are being made to incorporate their desirable characters into tasty, high dry-matter, locally preferred varieties. Some IITA varieties are susceptible to viruses.

On-farm testing (pre-extension) is an important part of the improvement programme and ISAR has developed a highly successful approach. On-farm trials are carried out to highlight production constraints and to encourage farmers to participate in finding solutions (Mulindangabo, 1989). Farmers are now more aware of the importance of pests and diseases. Since the selection and breeding programme began, several new varieties have been tested successfully in farmers' fields. In the medium-altitude region, the varieties Caroline Lee (23 t/ha), Rusenya (14 t/ha) and Cordes Rouges (12.5 t/ha) show great potential, out-yielding local varieties (Ndamage, 1984b). The first two varieties are well adapted to several agro-ecological zones of Rwanda.

Considerable effort in breeding sweet potato is being made by ISAR at Rubona. Field trials in progress advance from the first clonal propagation after seed with 1000+ entries, to advanced screening trials with 20 superior lines. Improvements made through selection were particularly obvious for virus, symptoms of which were common and severe in the clonal propagation trial, and almost absent from the advanced lines. High populations of aphids and whiteflies were seen in these trials. Initial trials are scored for vigour, reaction to pests and diseases, and drought tolerance on 0–5 scales. Entries with scores of 3 and above are eliminated. In advanced screening trials, lines are harvested at 4.5 months and yield, earliness and reaction to pests and diseases, especially weevil, are scored. Most improved varieties mature in 4.5 months, but varieties which mature in 4 months are being sought. Selected varieties are tested at a number of locations and the best two or three are tested on-farm against superior local varieties. Improved varieties presently yield 50 to 80% more than the best local varieties in farmers' fields.

An assessment of tuber characteristics is made at an early stage. Tuber shape, uniformity and cracking are evaluated. High dry matter (33–37%) and taste are also important. Taste, as a combination of sweetness and starchiness, is evaluated through panels of local farmers. It is assessed on a comparative rating scale from 0–100%. Individual components are not analysed. Taste tests are usually carried out at each harvest of advanced materials. Since the breeding programme was initiated, seven varieties have been released to farmers. From initial crossing to on-farm testing takes about 4 years. A farmers' field day is held in September each year: farmers are exposed to new varieties, and recognition of pests and diseases and the use of recommended control strategies are emphasized.

A well-organized system of multiplication plots supplies planting material to farmers at the beginning of each season. Planting material of new varieties is also multiplied on a sub-regional basis. Multiplication plots, varying from 0.5 to several hectares depending on the size of the farming community which they serve, are planted and managed through ISAR or by the compulsory community labour system. Cuttings are taken about every 2 months. If well managed, such plots can be maintained for 2 years. There is an inevitable build-up of pests such as weevils, viruses and possibly stem and root rots. Over time, serious biotic factors may have to be controlled periodically to avoid dissemination to farmers' fields. Insecticides are available to control sporadically severe pests such as the sweet potato butterfly. Different varieties are multiplied in the different agro-ecological zones of Rwanda, but some varieties, such as the widely adapted Mugande, are multiplied almost everywhere. Farmers have their own sources of local variety planting material which they usually mix with ISAR varieties.

The Rwanda rapid multiplication system is successfully alleviating the problem of seasonal supply of planting material to farmers and should be used as a basic model for other countries with the same problem. There are, however, three major disadvantages of such multiplication plots: firstly, the reduced number of varieties offered; secondly, the location of the multiplication sites; and thirdly, the failure to ensure that original material was disease- and pest-free. Although farmers can mix the ISAR varieties with their own preferred varieties, in times of shortage of farmer material, the sweet-potato crop in Rwanda will become more uniform. An excessive uniformity of planting material (for example the ISAR variety Mugande is especially common) could increase the potential for disease and pest problems. Secondly, the lack of availability of transport for farmers and pressure for land has led to multiplication plots being located within major production areas. This will also increase the risks of build-up of diseases and pests over time. Multiplication plots should be distanced as far as possible from other sweet potato production areas. If this is not possible, border barriers of maize or trees could be used to reduce the movement of pests and pathogens into the plots. Although initial stocks of planting material for the multiplication plots were visually assessed as healthy, it was impossible to ensure that they were disease- and pest-free. Of most concern are viruses. In the future, care should be taken to use virus-free stocks, or multiplication plots could develop into an effective tool for disseminating virus as well as planting material. Attention to these three factors will improve the already very valuable system.

Most improved ISAR varieties are not free from pest and disease problems. The incidence of virus-like symptoms is common although their severity is low, and Alternaria stem blight is severe on poor soils. All varieties are susceptible to the sweet potato butterfly if the population pressure is high, while *Cylas* spp. weevils are always a problem in the dry season. Although the present breeding programme effectively selects productive, vigorous, early-maturing varieties, field selection for pest and disease resistance is less effective. Basic studies are required to develop simple controlled techniques for these problems. It is possible that initial screening trials of progenies at Rubona may not encounter sufficient pressure of all pests and diseases to effectively screen out susceptible material. Early multi-locational screening may help, but screening under controlled conditions is still needed.

The ISAR station facilities at Rubona include a basic plant pathology laboratory and screenhouses. There are plans for a tissue culture laboratory which would facilitate maintenance of the collection.

Kenya

Sweet potato germplasm collections are located at research stations of the Kenya Agricultural Research Institute (KARI). They include Katumani, with emphasis on dryer regions; Kakamega and Kisii, servicing the high to medium production area in western Kenya; and Mtwapa, directed at coastal areas and the hinterland. The national collection numbers about 200 varieties, including 154 local and introduced varieties from IITA, AVRDC and the USA (Shakoor *et al.*, 1988). Although introduced varieties with orange flesh and high water content from the USA and AVRDC are not acceptable to farmers, IITA varieties are promising except at higher altitudes.

Preliminary germplasm evaluation has shown a wide range of genetic variability for plant type, skin colour, flesh colour, maturity and reaction to pests and diseases. Erect varieties are common in Kenya. Promising lines have been selected on the basis of yield, maturity, tuber character and disease tolerance including food, forage and dual-purpose varieties (Shakoor *et al.*, 1988). The extent of variation present in Kenya is probably not represented by only 154 varieties, and it would be worthwhile to collect more local germplasm. Support is needed to build up these collections, and to characterize and maintain them (Matata, 1988). All varieties in regional collections should be characterized, as the same varieties commonly have different local names in different regions. Standardization of the procedures for evaluating the reaction of breeding materials to common biotic and abiotic stresses in Kenya is needed (Matata, 1988). Although collaborating east African countries would benefit from germplasm exchange (Matata, 1988), without adequate knowledge of country- and region-specific pests and diseases this will be extremely risky. A recent study by the German Agency for Technical Co-operation (GTZ) and KARI evaluated the status and future application of tissue culture and related biotechnologies to crop improvement in Kenya. The need for tissue culture facilities for maintaining and distributing germplasm of sweet potato was stressed. Basic tissue culture facilities are available at Muguga.

The KARI plant diseases diagnostic service, in operation since 1903, will offer important feedback to a proposed Kenya-wide collaborative survey of sweet-potato diseases by CIP and KARI. Farmers bring in samples which are identified by pathologists at KARI. Information is collected on the most common diseases, changes in the status of diseases, and new disorders. This information is used by KARI to plan further research. Many farmers will recognize serious and unusual problems, but insidious infections which build up over time may not be detected.

Katumani, near Machakos, has an impressive history in sweet potato improvement, with a consistent effort being made during the last 10 years. The present programme began in 1983 with extensive collection of local varieties throughout Kenya as well as germplasm from IITA, AVRDC, Rwanda, Uganda and the USA. The total germplasm collection numbered 315 accessions, about 70% being local material. The collection is very difficult to maintain in Katumani due to an inadequate water supply during the dry season. During droughts it is often necessary to dig up and store varieties as tubers in order to maintain them. The collection has been characterized and information has been gathered on field reactions to weevils and viruses. Breeding objectives include early maturity, high yield, good tuber character, tolerance to pests and diseases, and wide adaptation. Breeding is focussed on both dual-purpose and food types (Shakoor *et al.*, 1988). Promising lines have been selected, and some crosses made with Ugandan and Rwandan germplasm (introduced to Kenya as seed). Ten elite lines were evaluated in advanced yield trials then tested at a network of evaluation sites. Three KSP lines were released: KSP 20 and 28, selected from an IITA seed source, and KSP 11, a local variety. All three are high-yielding and drought-tolerant, with good field resistance to weevils and viruses. These three lines have been multiplied and distributed to farmers. Further breeding and evaluation work is in progress.

Kisii is in the main sweet potato-producing area of western Kenya. It will be the site of the National Sweet Potato Germplasm Centre which will act as the source of germplasm for all of Kenya, and will hopefully be operational within the next 3 years. Plans are being made to collect, clean up and assemble all

Kenyan germplasm at Kisii. The region has rain throughout the year which will facilitate maintenance. Limited introduction of exotic varieties in the past has minimized the introduction of diseases but care must be taken to maintain this situation. However, being a major production region, Kisii does face potential risks of disease and pest build-up.

The germplasm collection at Kisii, presently 41 local varieties, is being expanded. Local varieties are being collected and characterized but more input is needed. The collection shows a wide range of morphological characters. An extensive survey and collection of sweet potato has also been carried out throughout the major growing regions of Kakamega, Bungoma and Busia by researchers at Kakamega Research Station. Ninety varieties have been collected and assembled at Kakamega. The collection also contains Katumani and IITA sweet potato varieties, the latter being very susceptible to weevils.

Research began on sweet potato at Mtwapa Research Station in 1988. Promising varieties have been selected and are being tested at the two main screening sites. Ten superior varieties have been identified on the basis of yield, dry matter, fibre content and resistance to weevils. Multi-locational trials in the five major agro-ecological zones in the region are planned.

The CAB International Institute of Biological Control (IIBC), located at Muguga near Nairobi, co-ordinates an IDRC-funded project on integrated control of arthropod pests of root crops, which is aimed at helping member countries of the ESARRN with pest problems of cassava, sweet potato, and white potato in collaboration with IITA and CIP. Each country takes responsibility for a particular aspect of the research: for example, Rwanda is developing rapid multiplication techniques (see page 86). This method has been modified for Muguga conditions to ensure a reliable, adequate and standardized food source of both vines and tubers for mass rearing of weevils until acceptable artificial diets can be developed. In May 1990, IIBC sponsored a workshop to present information and to stimulate further collaborative research on pests and diseases of sweet potato. More meetings are planned to support a consistent effort on sweet potato pests and diseases.

Section 5

Recommendations

The past neglect of sweet potato research in the tropics facilitates the task of preparing recommendations for research. However, a rational prioritization of needs within the limited resource base available is of most interest.

Both basic and applied research are needed to solve the most important problems of sweet potato in the tropics. Basic research is needed both on agronomic issues, such as improving soil fertility and developing storage and processing technologies, and on major disease problems such as scab, LLM and viruses. The application of already developed techniques and methodologies, with minor modifications, will contribute to solving some problems, for example controlling *Cylas* spp. weevils and improving the supply of planting material to farmers. Recommendations are directed at three main areas of sweet potato research: cultivation and agronomy; diseases and pests; and research resources.

CULTIVATION AND AGRONOMY

The complexity of the sweet potato production systems and the long-term stability of traditional systems in south-east Asia, the Pacific and east Africa are relevant to research on diseases and pests of sweet potato. CIP is aware of the complexity and lack of understanding of sweet potato production systems world-wide, and has committed funds to study these systems (CIP, 1989c). Traditional production systems in the highlands of Papua New Guinea and the Philippines, western Kenya and Rwanda have been developed over a long period. Production systems are based on traditional land races and cultural practices. During the past few years, international input into improving sweet-potato production has expanded rapidly. Traditional systems are facing potentially drastic changes from this recent increase in international funding and research interest. Improved varieties and new technologies such as intensive crop rotation and alley cropping, along with other cultural practices, have the potential to displace many land races and subsistence techniques.

The methodologies now being used to develop improved varieties, especially screening for resistance to pests and diseases, do not take account of traditional practices. In particular, the use of varietal mixtures, intercropping, complex planting systems and sequential harvesting methods are being largely ignored. The value of such improved varieties will be reduced when they are grown on farms with traditional cultural practices. There is an increasing need to develop screening methodologies which reflect the system in which the improved variety will be grown. In addition, without sufficient evaluation of the advantages of the traditional systems and how the new technologies can improve but not replace them, there is considerable danger of important traditional systems being destabilized and lost. The potential impact of sweet potato improvement on these traditional systems should be evaluated before major cultural changes and new varieties are introduced. Farmers in traditional regions should be involved in the development of improved practices and varieties. Characterization of traditional production systems before major changes are made, and the development of new varieties and technologies within a framework of understanding of the traditional systems, is strongly recommended.

Sweet potato cultivation systems are extremely diverse (see Chapter 2) and include monocropping, intercropping (with a range of crops including maize, grain legumes and vegetables), multiple cropping and rotation as well as the widespread use of varietal mixtures. Farmers also use a wide range of cultural practices including planting methods, composting, weeding, mulching, and harvesting methods, all of which can affect the incidence and severity of diseases. There is a need to determine the effect of these complex cultural systems on the success of control strategies for pests and diseases.

The supply of planting material and especially disease-free material (particularly for viruses, LLM and weevils) is a major problem for all the countries visited, with the exception of Rwanda which has a well-organized system of multiplication plots (see page 86). It is strongly recommended that the Rwandan system be used as a model for countries facing a limited supply of planting material. However, two disadvantages of the Rwandan system should be stressed: firstly, the failure to ensure that initial stocks were disease- and pest-free, and secondly, the necessary location of multiplication plots near production areas for accessibility, but without protection against diseases and pests from neighbouring farmers' fields, especially mobile pests such as weevils. The need to ensure that initial stocks of material are disease- and pest-free, and to locate such facilities in protected locations to reduce contact with diseases and pests, should be addressed on a country basis.

Low soil fertility, especially in marginal areas, is a major problem for sweet potato production in many of the countries visited. Pressure for land in the highland areas of the Philippines, the highlands of Papua New Guinea, and in Rwanda and Uganda has led to shortened fallows and continuous cropping. Research on management for improved soil fertility including rotation with legumes, alley cropping, and composting is needed. Some traditional systems such as compost mounding in the highlands of Papua New Guinea should be studied to assess the potential of introducing them elsewhere.

No simple methods are presently available for storage of harvested sweet-potato tubers in the tropics. In traditional production systems, farmers ensure an extended supply of fresh tubers by harvesting as needed. This can extend the harvest period for up to 6 months, but greatly increases problems with diseases and pests, especially weevils. There is a considerable need to develop storage technologies in the tropics and, as an extension, simple, village-orientated processing technologies. This could reduce the need for farmers to harvest sequentially and so reduce weevil problems.

Many farmers in traditional production areas grow varietal mixtures. Mixtures reach considerable complexity in the highlands of Papua New Guinea and Irian Jaya (see page 22). It would be worthwhile to characterize the importance and contribution of varietal mixtures to disease control through monitoring the incidence and severity of diseases in these mixtures. Such studies would provide useful information on the potential role of mixtures for managing diseases including scab, LLM and viruses, and the potential for wider application of this control strategy.

DISEASES AND PESTS

The lack of systematic surveys of diseases and pests in some countries, and of quantitative studies of their importance, reduces the information base on which to make recommendations for future research. However, systematic surveys of diseases of sweet potato are being carried out in Papua New Guinea and Kenya, and surveys of pests have been done in the Philippines, Indonesia, Papua New Guinea, Thailand and Kenya (systematic surveys of diseases are needed in the Philippines, Indonesia, Thailand, Rwanda and Uganda). In addition, the effects of scab, LLM, SPVDC and the weevil *Cylas formicarius* have been measured in several countries. These, together with observations by key researchers in all the countries visited, provide sufficient information to make recommendations regarding research on the most important diseases and pests.

Scab

Although scab does not warrant a major input, international co-ordination would improve work already in progress and further research on some aspects would be worthwhile. To date, scab research has been location- and institute-specific. Different institutions in the Philippines, Indonesia and Taiwan have developed different inoculation, screening and evaluation methodologies: there is an obvious need for a more integrated and co-ordinated effort on scab. A standardized methodology for inoculation and evaluation is needed. An international workshop involving all pathologists and breeders working on scab could achieve this.

Recent comparative isolate studies at PRCRTC, Visca, the Philippines, have indicated the presence of pathogenic variation within *Elsinoe batatas*. Moreover, apparently scab-resistant varieties developed in one location are not resistant in other sites in the Philippines. The extent of pathogenic specialization in *E. batatas* should be determined by comparing isolates from countries where scab is a major disease. This could be readily done in a third country such as the UK. Information from PRCRTC, Visca would be helpful in developing a differential set. Such information is essential to programmes breeding scab-resistant varieties.

Studies on the epidemiology of scab, especially where sweet potato is intercropped or grown in varietal mixtures, would contribute to the development of control strategies. And, as feed-back to breeding programmes, studies on the basis of resistance to scab would be worthwhile.

Alternaria diseases

Little is known about diseases caused by *Alternaria* species (see p. 53). Alternaria stem blight, which affects sweet potato in Rwanda, Burundi, Uganda, Ethiopia, Kenya, and Papua New Guinea, merits basic research input. Its increasing importance in Burundi and Rwanda and its potential importance in the highlands of Papua New Guinea justifies both basic and applied research.

Characterization of the complex of *Alternaria* species present in different countries and regions is essential. Several different species of *Alternaria* have been implicated as causal agents of stem blight of sweet potato. More information is needed on the geographical distribution of this relatively new, largely unstudied disease. Simple, standardized glasshouse and field screening methodologies are needed to facilitate the selection of resistant varieties. In addition, as observations in Rwanda have indicated that certain varieties are more resistant to stem blight in fertile soils compared to infertile, acid soils, studies of the effects of soil type, climate and variety on disease incidence and severity in the field would also be worthwhile.

LLM

Although LLM has not been detected outside Asia and the Pacific, no systematic world survey of its distribution has been carried out (see p. 59). In East Africa, symptoms thought to be caused by viruses are similar to those expressed by LLM in other regions. Further definition of the distribution of LLM would be useful.

The importance of LLM in the Pacific has been clearly shown. In south-east Asia, however, although LLM is widely distributed, it has never been monitored and the author considers it to be an underrated problem. In Papua New Guinea, LLM is the most important disease in the lowlands but does not occur in the highlands. Restriction of the distribution of LLM in Papua New Guinea is possibly due to climatic effects on leaf-hopper vectors. This has not been observed elsewhere. It would therefore be worthwhile systematically to map the countries where LLM has been reported, to identify regions where it does not occur and where sweet potato could escape the disease. Epidemiological input would further help to explain the differences in distribution. Studies on the effect of varietal mixtures on the incidence and severity of LLM would also provide valuable feedback for the development of control strategies.

Several control strategies, including the exclusion of infected plants through quarantine; roguing and destruction of diseased plants; selection of disease-free planting material; destruction of alternative hosts; and the use of resistant varieties, have been recommended for LLM. Although attempts to select for resistance to LLM have not been successful, selection for resistance to leaf-hopper vectors under controlled conditions could be considered. The possibility of combining these components into an IPM programme for LLM may also be worth considering.

Viruses

Sweet potato viruses have been characterized in few developing countries throughout south-east Asia, the Pacific and east Africa (see page 60). With the exception of Kenya, no monitoring or systematic surveys of viruses have been done. Lack of information precludes the identification of viruses in the field. During the present survey, many researchers in south-east Asia and the Pacific minimized the importance of viruses. Although information available to date shows differences between regions with respect to viruses (Table 6), comparative studies of viruses from the south-east Asia/Pacific region and from Africa have not been made. This is partly due to a lack of good quality antisera.

Increased exchange of germplasm in recent years has led to screening of the same improved varieties in different countries. Elite IITA clones with resistance to SPVDC in Nigeria have proven susceptible to what is thought to be the same virus complex elsewhere in Africa. Such observations support the need for characterization of sweet potato viruses regionally and world-wide.

Three areas where research support could make a valuable contribution to reducing problems with sweet potato viruses are in cleaning up valuable varieties; virus characterization; and resistance. A clean-up programme associated with the rapid multiplication and distribution of clean material could have an immmediate impact on yields, particularly in east Africa. Characterization of viruses of sweet potato is also needed. In order of priority, Rwanda, Uganda, the Philippines, Papua New Guinea and Indonesia are listed. Virus characterization has already been done in Kenya by Mrs. Florence Wambugo (Ph.D. thesis, University of Bath, in preparation).

Basic input is also needed to support programmes screening for resistance to viruses in the field. Field selection of apparently resistant varieties is not enough; these clones should also be indexed. Training is required in virus indexing in most countries visited. This could be done at IITA, Nigeria; CIP, Peru; North Carolina State University, USA; Plant Research Institute, Australia; Horticultural Research International, Littlehampton, UK; and Muguga, Kenya. Such a programme would be of immediate benefit to Rwanda, Uganda, the Philippines and Kenya, which have advanced breeding programmes. Commitment to research on sweet potato viruses would necessarily be long-term because of the complex nature of the viruses and because very little work has been done in developing countries.

Cylas spp. weevils

The complex of weevils, *Cylas* spp., are the most important pests of sweet potato world-wide. *C. formicarius* is the most widespread species and the most serious pest in south-east Asia and the Pacific, and has been the subject of much research world-wide. A considerable amount of work has been done on control strategies, including cultural, chemical and biological control, and resistance. An IPM programme, developed by AVRDC, has been introduced in several countries in south-east Asia. This research effort has produced recommendations which should be widely applicable. There is an urgent need for wider application of these strategies, either individually (particularly cultural controls and low-cost chemical strategies) or in an IPM programme, before further research is initiated. Site-specific problems can then be identified and the appropriate modifications made or applied research done.

Some specific recommendations can be made regarding futher research on *C. formicarius*. Despite contrasting opinions as to the value of resistance to *C. formicarius*, recent work in the Philippines using controlled screening methodologies has suggested that resistance based on antibiosis may be useful. Various researchers have also strongly recommended the need to look at both tuber and stem resistance to the weevil. Support for research in these areas would be worthwhile. In addition, research to date on biological control strategies for *C. formicarius* using entomopathogenic fungi including *Metarhizium anisopliae* has given promising results in the Philippines. Further work on developing simple, low-cost field application strategies would be useful.

In east Africa, where *C. puncticollis* and *C. brunneus* also occur together with *C. formicarius*, *C. puncticollis* is of most concern. In comparison to *C. formicarius*, very limited research has been done on other *Cylas* spp. Characterization of the distribution of the three species in east Africa is needed. Some work is being done by CIP. As studies to date suggest that the biology of the different *Cylas* spp. is not dissimilar, it is strongly recommended that some of the extensively researched control strategies developed for *C. formicarius*, especially cultural and low-cost chemical controls, should be applied to controlling *C. puncticollis* prior to initiating long-term research on developing specific strategies. The IPM programme for *C. formicarius*, developed by AVRDC, could be tested for *C. puncticollis* in several locations in east Africa and appropriately modified. Control strategies for weevils in east Africa are urgently needed.

Other pests

Although no other pests of sweet potato have reached the serious status of the weevil *C. formicarius* in south-east Asia and the Pacific, two pests in addition to *Cylas* spp. weevils can cause serious damage in east Africa – clear wing moth (*Synanthedon* spp.) and sweet potato butterfly (*Acraea acerata*). Clear wing moth can reduce yields and cause plant death. Although cultural control strategies similar to those used for *Cylas* spp. weevils are recommended, no basic studies have been done to screen for resistance or to develop an IPM programme. The sweet potato butterfly is a sporadic, but serious, pest in east Africa during the dry season. In severe infestations, total destruction of the crop may occur. As insecticides are too costly, manual control is the only strategy presently available, but is only effective on a regional basis. Biological control may be a possibility. Studies are needed to develop low-cost control strategies applicable to small farmers.

RESEARCH RESOURCES

All the countries visited in south-east Asia, the Pacific and east Africa have research objectives for sweet potato which are difficult to fulfil within national research capabilities, due to a lack of funds, infrastructure, manpower or expertise. National programmes therefore depend on international support from CGIAR centres, particularly CIP, donor agencies and other research organizations.

The most limiting factor for research input on sweet potato in Papua New Guinea is manpower. Plant protection input is limited to one pathologist and one entomologist, and there are no virologists or nematologists. Other countries with manpower problems include Rwanda and Uganda, where small teams have responsibility for all research on root and tuber crops. In such situations, training, for example on controlled screening methodologies for specific biotic factors affecting sweet potato, would be only a partial solution, as the trained national scientist would still have limited time to implement newly acquired technologies. Many national root- and tuber-crop improvement programmes would benefit from international scientists based at their centres to work on diseases and pests of sweet potato.

Basic tissue culture laboratories, or access to such facilities, are needed in most countries to develop stocks of disease- and pest-free sweet-potato varieties. Sweet-potato researchers have access to tissue culture laboratories at Bogor, Indonesia; at Baguio, the Philippines; at Muguga, Kenya; and at Laloki, Papua New Guinea. However, the lack of low-level, long-term maintenance funding has already reduced the value of some of these facilities. All countries which are endeavouring to clean up germplasm for movement and for the rejuvenation of local varieties need access to either regional or international facilities. Due to the problems of maintaining tissue culture facilities in developing countries (supplies of chemicals, power, water, etc. are often limited), present needs may best be addressed through international funding, for example the ACIAR project.

Support is needed for the collection and characterization of germplasm diversity in sweet potato, especially in secondary centres of diversity such as Papua New Guinea and Irian Jaya, prior to further emphasis on wild germplasm. IBPGR has funded some projects, for example in Papua New Guinea, but further support is needed before traditional land races are replaced by improved varieties.

Efforts are also needed on the improvement of germplasm maintenance. Variation may be stored as seed but this will not conserve varieties. The possibility of conserving pollen could be researched. Tissue culture is not a practical answer in most developing countries unless there is a regional or international facility. Research is most needed to improve present field maintenance practices.

Priorities for research can be allocated from a country perspective in terms of the importance of sweet potato in the country; the importance of disease and pest problems; the activity of the sweet-potato research programme; and the perceived impact of the research. Rwanda is considered of highest priority, as sweet potato is an important staple food; the research programme is active and enthusiastic and has already achieved much; and there are major problems with *Cylas* spp. weevils and viruses. Of slightly lower priority are research on scab and viruses in the Philippines; on scab and LLM in Papua New Guinea; and on viruses and weevils in Uganda.

Research priorities can also be allocated from disease and pest perspectives. *Cylas* spp. weevils are clearly the most important pests of sweet potato worldwide. Considerable effort is needed for the wider application of existing IPM strategies for *C. formicarius* in south-east Asia and the Pacific, and to develop IPM strategies based on the existing programme for *C. puncticollis* in east Africa. Viruses are considered of highest priority among the diseases. Production of virus-free material and characterization of viruses are of highest priority in east Africa. Research on scab and LLM, although of lower overall priority, would potentially have a considerable regional impact in south-east Asia and the Pacific. Research on *Alternaria* diseases is assigned the lowest priority among the most important diseases, mainly because of their restricted distribution.

Bibliography

ADAIR, C. N. (1971) A review of fungi reported from the Mariana Islands. *Micronesia,* **7** : 79–83.

AHMAD, S. (1956) *Fungi of West Pakistan.* Monograph No. 1, Lahore: Biological Society of Pakistan, 126 pp.

AHMAD, S. (1969) *Fungi of West Pakistan.* Monograph No. 5, Suppl. 1, Lahore: Biological Society of Pakistan, 110 pp.

AHMED, Q. A. (1952) Fungi of East Bengal. *The Pakistan Journal of Forestry,* **2** : 91–115.

ALCONERO, R. (1975) Meristem tip culture and virus indexing of sweet potatoes. *Phytopathology,* **65** : 769–773.

ALDRICH, D. T. A. (1963) The sweet potato crop in Uganda. *East Africa Agricultural and Forestry Journal,* **29** : 42–49.

ALLARD, G. B. (1990) *Important Pests of Sweet Potato – a Short Review with Strategies for Control.* Training notes (Unpublished).

ALLNUT, R. B. (1942) A method of storing sweet potato. *East African Agricultural Journal,* **8** : 73.

AMALIN, D. M., OPENA, G. B. and VANDER ZAAG, P. (1989) Increasing sweet potato productivity : an on-farm research approach. *CIP Region VII Report* (Unpublished).

AMALIN, D. M. and VANDER ZAAG, P. (1989) Survey of the arthropod fauna in sweet potato agroecosystems in the Philippines. *CIP VII Region Working Paper* No. 89–12.

AMESTOSO, F. J., ROA, J. R. and TRUONG VAN DEN. (1989) Sweet potato marketing in selected urban areas in the Philippines. *CIP Region VII Working Paper* No. 89–17.

ANGGIANI, A. and MUKELAR, A. (1988) Varietal resistance to sweet potato scab (*Elsinoe batatas*) in the laboratory. Paper presented at the National Congress of the Indonesia Plant Pathology Society, Surabaya, October 1988. (Indonesian with English summary) (Unpublished).

ANGUS, A. (1963) *Plant Pests and Diseases in Northern Rhodesia,* Part 5. Mt. Makulu, Northern Rhodesia. 33 pp.

ANGUS, A. (1966) *Plant Pests and Diseases in Northern Rhodesia.* Supplement. Mt. Makulu, Northern Rhodesia. 97 pp.

ANON. (1950) List of common names of Indian plant diseases. *Indian Journal of Agricultural Science,* **20** : 107–142.

ANON. (1962) List of important diseases of economic plants in the Philippines including ornamentals. In : *Proceedings of the 4th Meeting of the FAO Plant Protection Commission for South-east Asia and the Pacific Region,* Manila: Philippines, 22 pp.

ANON. (1966) Observations on the plant diseases and their control in south Vietnam (in Vietnamese) (Unpublished).

ANON. (1967) List of insect pests and diseases of plants. South Pacific Commission. Technical Meeting on Plant Protection (Unpublished).

ANON. (1970a) A preliminary list of plant diseases in Thailand. *FAO Plant Protection Commission for South-east Asia* and the *Pacific Region. Technical Document* No. **72**.

ANON. (1970b) Provisional list of diseases of various crops in Laos. *FAO Plant Protection Commission for South-east Asia and Pacific Region. Technical Document* No. **73**.

ANON. (1973) Preliminary list of pests and diseases of principal crops in French Polynesia. *FAO Plant Protection Commission for South-east Asia and the Pacific Region. Technical Document* No. **89**.

ANON. (1975) List of diseases of important economic crop plants already reported in Indonesia. *Fakultas Pertanian Univeritas Gadjah mada Yogyakarta Bulletin* No. **14**.

ANON. (1978) Sweet potato – diseases. pp. 57–79, In : *Pest Control in Tropical Root Crops.* PANS Manual No. **4**.

ANON. (1989) IPM for sweet potato weevil. *International Ag-Sieve,* **2**: 6.

ARENE, O. B. (1978) Sweet potato diseases in Nigeria. *PANS,* **24** : 294–305.

ARRENDELL, S. and COLLINS, W. W. (1986) Reaction of sweet potato seedlings to the russett crack strain of feathery mottle virus. *HortScience,* **21** : 1191–1193.

ATKEY, P. T. and BRUNT, A. A. (1987) Electron microscopy of an isometric caulimo-virus from sweet potato (*Ipomoea batatas*). *Journal of Phytopathology,* **118** : 370–376.

AUSTIN, D. F. (1978) The *Ipomoea batatas* complex. I. Taxonomy. *Bulletin of the Torrey Club,* **105** : 114–129.

AUSTIN, D. F. (1983) Variability in sweet potato in America. In : *Proceedings of the American Society of Horticultural Science,* Tropical Region 27 (Part B) : 15–26.

AUSTIN, D. F. (1988) The taxonomy, evolution and genetic diversity of sweet potatoes and related wild species. pp. 27–60. In : *Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources.* Report of the 1st Sweet Potato Planning Conference, February 1987, Lima, Peru: CIP.

AVRDC (1985) *Sweet Potato Pathology : Resistance Screening for Sweet Potato Scab.* Progress and Planning Workshop 1985, Horticultural Crop Programme. 9 pp.

BACKER, C. A. and BAKHUIZEN VAN DEN BRINK, R. C. (1962) *Flora of Java,* Vol. 3. pp. 661–761.

BAHAGIAWATI, A. H. (1989) Bionomics and control of the sweet potato weevil *Cylas formicarius* F. in Indonesia. Paper presented at the Seminar on Pests and Diseases of Sweet Potato, Trivandrum, India, August 1989.

BAILEY, A. G. (1943) A check list of plant diseases in Nigeria. *Federal Department of Agricultural Research, Ibadan. Memorandum* No. 96. 37 pp.

BAJIT, G. B. and GAPASIN, R. M. (1987) Relationship between morphological characteristics and varietal resistance of sweet potato to scab infection caused by *Sphaceloma batatas* Saw. *Annals of Tropical Research,* **9** : 75–83.

BEBEE, C. N. (1987) The protection of potatoes, sweet potatoes and yams, 1979 – March 1987. Citations from Agricola concerning diseases and other environmental considerations. *Bibliographies and Literature of Agriculture, USDA.* No.61. 159 pp.

BENOIT, M. A. (1985) Plant quarantine perspectives in tropical root and tuber crop diseases. pp. 205–216. In: *Proceedings of a Regional Conference on Plant*

Quarantine and Support for Agricultural Development, Kuala Lumpur: Malaysia, 1985.

BERNARDO, E. N. and ESGUERA, N. M. (1984) Technique for evaluating resistance to weevil *Cylas formicarius elegantulus*. p. 589. In : *Proceedings of the 6th Symposium of the International Society for Tropical Root Crops*, 1984, Lima, Peru: CIP.

BOHOUT, D. and MALLAMAIRE, A. (1965) *Les Principales Maladies des Plantes Cultivees au Senegal*. Tome 1. Dakar, Senegal: Grande Imprimerie Africaine

BONSI, C. K. and PHILS, B. R. (1979) Reaction of twelve sweet potato cultivars and breeding lines to two root-knot species with three experimental methods. *HortScience*, **14** : 539–541.

BOURKE, R. M. (1982) Sweet potato in Papua New Guinea. pp. 45–58. In : *Sweet Potato – Proceedings of the 1st International Symposium, AVRDC*, Shanhua, Taiwan.

BRADBURY, J. F. (1986) *Guide to Plant Pathogenic Bacteria*. Kew, UK: Commonwealth Agricultural Bureaux – International Mycological Institute, 332 pp.

BRADLEY, J. D. (1968) Two new species of clear wing moths (Lepidoptera, Sesiidae) associated with sweet potato (*Ipomoea batatas*) in East Africa. *Bulletin of Entomological Research*, **58**: 47–53.

BRAITHWAITE, C. W. D. and DUNCAN, E. J. (1974) Development and histopathology of *Rotylenchulus reniformis* in sweet potato roots. *Tropical Agriculture*, **51** : 437–441.

BRIDGE, J. and PAGE, S. L. J. (1982) Plant nematodes of Papua New Guinea : their importance as crop pests. *Report of a Plant Nematode Survey in Papua New Guinea*. Kew, UK: Commonwealth Agricultural Bureaux – Commonwealth Institute of Parasitology. 91 pp.

BROWN, J. F. (1973) *Micro-organisms associated with Plant Disease in the British Solomon Islands Protectorate*. Information Document No. 32. Noumea, New Caledonia: South Pacific Commission.

BUGNICOURT, F. and MARTY, F. (1961) *Champignons Parasites des Plantes Cultivees en Nouvelle-Caledonie*. Institut Français D'Oceanie La Phytopathologie.

BUYCKX, E. J. E. (1962) Precis des maladies et des insectes nuisibles recontres sur les plantes cultivees au Congo, au Rwanda et au Burundi. L'Institut National pour L'Etide Agronomique du Congo.

CADENA-HINOJOSA, M. A. and CAMPBELL, R. N. (1981a) Serological detection of feathery mottle virus strains in sweet potatoes and *Ipomoea incarnata*. *Plant Disease*, **65** : 412–414.

CADENA-HINOJOSA, M. A. and CAMPBELL, R. N. (1981b) Characterization of isolates of four aphid-transmitted sweet potato viruses. *Phytopathology*, **71** : 1086–1089.

CALI, B. B. and MOYER, J. W. (1981) Purification, serology, and particle morphology of two russett crack strains of sweet potato feathery mottle viruses. *Phytopathology*, **71** : 302–305.

CAMPBELL, T. M. and COLLINS, W. W. (1987) *Fusarium solani* root rot resistance in sweet potatoes. *Journal of the American Society of Horticultural Science*, **112**: 386–389.

CAMPBELL, R. N., HALL, D. H. and MIELINIS, N. M. (1974) Etiology of sweet potato russet crack disease. *Phytopathology*, **64** : 210–218.

CARVALHO, T. DE and MENDES, O. (1958) *Doencas de Plantas em Mozambique*. Direccoa de Agricultura e Florestas. Reparticao de sanidad vegetal. Seccao de Patologia Vegetal. 84 pp.

CASTILLO, M. B. and MARANAN, L. R. (1974) Plant parasitic nematodes associated with sweet potato and cassava in the Philippines. *Philippine Phytopathology*, **10** : 56–70.

CASTINEIRAS, A., CABELLERO, S., REGO, G. and GONZALEZ, M. (1982) Technical cost effectiveness of the use of big-headed ant *Pheidole megacephala* in control of the sweet potato weevil *Cylas formicarius elegantulus*. *Ciencia y Tecnica en la Agricultura, Proteccion de Plantas*, Supplement **66/67**.

CASTINEIRAS, A. and CALDERON, A. (1982) Susceptibilidad de *Pheidole megacephala* a tres insecticidas: Dipel, bitoxobacillin 202 y *Beauveria bassiana* en condiciones de laboratorio. *Ciencia y Tecnica en la Agricultura, Proteccion de Plantas*, **5** : 61–66.

CASTINEIRAS, A., PEREZ, M., OBREGON, O. and CATANEDA, I. (1984) Virulence of three strains of *Metarhizium anisopliae* on adults of *Cylas formicarius elegantulus*. *Ciencia y Tecnica en la Agricultura, Proteccion de Plantas*, **7** : 129–136.

CHALFANT, R. B., JANSSON, R. K., SEAL, D. R. and SCHALK, J. M. (1990) Ecology and management of sweet potato insects. *Annual Review of Entomology*, **35** : 157–180.

CHANTARASRIKUL, A. (1962) A preliminary host list of plant diseases in Thailand. *Department of Agriculture, Bangkok, Thailand. Technical Bulletin* No. 6. 1–23.

CHANTARASRIKUL, A. (1968) A. supplementary host list of plant diseases in Thailand. *Department of Agriculture Bangkok, Thailand. Technical Bulletin* No. 9. 1–13.

CHEN, J. Y., CHEN, X. K., LI, K. B., LING, K. S. and KE, C. (1985) Transmission tests of sweet potato witches broom. *Fujian Agricultural Science and Technology*, **1** : 6–8.

CHIU, R. J. (1976a) Diseases of sweet potatoes : Diseases caused by viruses and mycoplasma-like organisms. *Technical Bulletin ASPAC*, **27** : 14.

CHIU, R. J. (1976b) Sweet potato diseases of non-viral origin. *Technical Bulletin ASPAC*, **28** : 14.

CHUNG, M. -L., LIAO, C. -H., CHEN, M. J. and CHIN, R. J. (1985) The isolation, transmission and host range of sweet potato leaf curl disease agent in Taiwan. *Plant Protection Bulletin, Taiwan*, **27** : 333–341.

CHUNG, M. -L., LIAO, C. -H. and LI, L. (1981) Effect of virus infection on yield and quality of sweet potatoes. *Plant Protection Bulletin, Taiwan*, **23** : 137–141.

CIE (1984a) *Arthropod Pests of Sweet Potato, 1964–1972.* Annotated Bibliography, Series E116, Commonwealth Agricultural Bureaux, 14 pp.

CIE (1984b) *Arthropod Pests of Sweet Potato, 1973–1983.* Annotated Bibliography, Series E115, Commonwealth Agricultural Bureaux, 61 pp.

CIP (1988a) *Annual Report.* Lima, Peru: CIP.

CIP (ed.) (1988b) *Improvement of Sweet Potato in East Africa.* Report of the Workshop on Sweet Potato Improvement in Africa, ILRAD, Nairobi, Kenya, Sept-Oct., 1987. 208 pp.

CIP (ed.) (1988c) *Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources.* Report of the 1st Sweet Potato Planning Conference, February 1987, Lima, Peru: CIP. vii + 369 pp.

CIP (1989a) *Annual Report.* Lima, Peru: CIP.

CIP (ed.) (1989b) *Improvement of Sweet Potato (Ipomoea batatas) in Asia.* Report of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India, Oct. 1988. 253 pp.

CIP (1989c) Sweet Potato : Laying the foundation. pp. 47–54. In : *An Assessment of CIP's Program : Achievements, Impact and Constraints. A Working Paper.*, Oct., 1989. 54 pp.

CLARK, C. A. (1988) Principal bacterial and fungal diseases of sweet potato and their control. pp. 275–289. In : *Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources.* Report of the 1st Sweet Potato Planning Conference, February 1987, Lima, Peru: CIP.

CLARK, C. A., DERRICK, K. S., PACE, C. S. and WATSON, B. (1986a) Survey of wild *Ipomoea* spp. as potential reservoirs of sweet potato feathery mottle virus in Lousiana. *Plant Disease,* **70**: 931–932.

CLARK, C. A. and MATTHEWS, S. W. (1987) Histopathology of sweet potato infection by *Streptomyces ipomoea. Phytopathology,* **77**: 1418–1423.

CLARK, C. A. and MOYER, J. W. (1988) *Compendium of Sweet Potato Diseases.* American Phytopathological Society Press. 74 pp.

CLARK, C. A., RANDLE, W. M. and PACE, C. S. (1986b) Reactions of sweet potato selections to *Fusarium* root and stem canker caused by *Fusarium solani. Plant Disease,* **70** : 869–871.

CLARK, C. A. and WATSON, B. (1983) Susceptibility of weed species of Convolvulaceae to root-infecting pathogens of sweet potato. *Plant Disease,* **67** : 607–609.

CLARK, C. A., WILDER-AYERS, J. A. and DUARTE, V. (1989) Resistance of sweet potato to bacterial root and stem rot caused by *Erwinia chrysanthemi. Plant Disease,* **73** : 984–987.

CLARK, C. A. and WRIGHT, V. I. (1983) Effect and reproduction of *Rotylenchulus reniformis* on sweet potato selections. *Journal of Nematology,* **15** : 197–203.

CMI (1981) *Diseases of Tropical Root Crops. Part 2.* Annotated Bibliography, No. M 12, Kew, UK: Commonwealth Agricultural Bureaux, 31 pp.

COCKERMAN, K. L. (1943) The host preference of the sweet potato weevil. *Journal of Economic Entomology,* **36** : 471–472.

COCKERMAN, K. L. (1944) Some parasites of sweet potato weevil. *Journal of Economic Entomology,* **37** : 546–547.

COCKERMAN, K. L. and DEEN, O. T. (1947) Resistance of new sweet potato seedlings and varieties to attack by sweet potato weevil. *Journal of Economic Entomology,* **40** : 439–441.

COCKERMAN, K. L., DEEN, O. T., CHRISTIAN, M. B. and NEWSOM, L. D. (1954) The biology of sweet potato weevil. *Lousiana Agricultural Experimental Station Technical Bulletin* No. 483. 1–30.

COCKERMAN, K. L. and HARRISON, P. K. (1952) New sweet potato seedlings that appear resistant to sweet potato weevil attack. *Journal of Economic Entomology,* **45** : 132.

COFFELT, J. A., VICK, K. W., SOWER, L. L. and MCCLELLAN, W. T. (1978) Sex pheromone of the sweet potato weevil, *Cylas formicarius elegantulus*: laboratory assay and evidence for a multiple component system. *Environmental Entomology,* **7** : 756–758.

COHEN, J., LOEBENSTEIN, F. and SPEIGEL, S. (1988) Infection of sweet potato by cucumber mosaic virus depends on the presence of sweet potato feathery mottle virus. *Plant Disease,* **72** : 583–585.

COLLINS, W. (1988) Bacterial and fungal diseases of sweet potato. pp. 73–77. In : *Improvement of Sweet Potato (Ipomoea batatas) in East Africa.* Report of the Workshop on Sweet Potato Improvement in Africa. September–October, 1987, Nairobi: ILRAD, 208 pp.

COPR (Centre for Overseas Pest Research) (1978) *Pest Control in Tropical Food Crops*. PANS Manual No 4, p.58.

DABEK, A. J. and GOLLIFER, D. E. (1975) Mycoplasma-like organisms in *Ipomoea batatas* in the Solomon Islands. *PANS*, **21**: 384–387.

DABEK, A. J. and SAGAR, C. (1978) Witches' broom chlorotic little-leaf of sweet potato in Guadalcanal, Solomon Islands, possibly caused by mycoplasma-like organisms. *Phytopathologische Zeitschrift*, **92** : 1–11.

DALISAY, R. F., DIVINAGRACIA, G. G. and MENDOZA, E. M. (1987) Screening sweet potato roots for resistance to Java black rot caused by *Diplodia tubericola* (Ell. & Everh.) Taubenh. *Philippine Journal of Crop Science*, **12** : 33–37.

DEIGHTON, F. C. (1936) Preliminary list of fungi and diseases of plants in Sierra Leone and list of fungi collected in Sierra Leone. *Bulletin of Miscellaneous Information*, **7** : 1–37.

DE LA CRUZ, C. S., LORETO, F. L. and PALOMAR, M. K. (1981) Effect of brown leaf disease on the growth and yield of sweet potato. *Annals of Tropical Research*, **3** : 206–213.

DINGLEY, J. M., FULLERTON, R. A. and MCKENZIE, E. H. C. (1981) Records of fungi, bacteria, algae, and angiosperms pathogens of plants in Cook Islands, Fiji, Kiribati, Niue, Tonga, Tuvalu & Western Somoa, *Survey of Agricultural Pests and Diseases. Technical Report* Vol. 2., South Pacific Bureau for Economic Cooperation, UN, UNDP & FAO. 485 pp.

DIVINAGRACIA, G. G. and MAILUM, N. P. (1976) Chemical control of stem and foliage scab. *Fungicide and Nematicide Tests*, **31** : 104.

DUMBLETON, L. J. (1954) A list of plant diseases recorded in the South Pacific Territories. *Technical Paper* No. 78., Noumea, New Caledonia: South Pacific Commission, 78 pp.

DUNBAR, A. R. (1975) *The Annual Crops of Uganda*. pp. 35–43. In : East Africa Literature Bureau Publication.

EBBELS, D. L. and ALLEN, D. J. (1979) A supplementary and annotated list of plant diseases, pathogens and associated fungi in Tanzania. *Phytopathogical Papers* No. 22.

ELLIS, M. B. and HOLLIDAY, P. (1970a) *Alternaria cucumerina. Commonwealth Mycological Institute Descriptions of Pathogenic Fungi and Bacteria.* No. 244, Kew, UK: CMI.

ELLIS, M. B. and HOLLIDAY, P. (1970b) *Alternaria passiflorae. Commonwealth Mycological Institute Descriptions of Pathogenic Fungi and Bacteria.* No. 247, Kew, UK: CMI.

EMECHEBE, A. M. (1975) *Some Aspects of Crop Diseases in Uganda*. Uganda: Department of Crop Science, Makerere University.

ESBENSHADE, P. R. and J. W. MOYER (1982) An indexing system for sweet potato feathery mottle virus in sweet potato using the enzyme-linked immunosorbent assay. *Plant Disease*, **66** : 911–913.

FAO (1987) Root and tuber crops, plantains and bananas in developing countries – challenges and opportunities. *FAO Plant Production and Protection Paper* No. 87. 83 pp.

FAO (1989) Sweet Potato Production, *FAO Yearbook 1989*, Vol. 42 : 139–140.

FIRMAN, I. D. (1972) A list of fungi and plant parasitic bacteria, viruses and nematodes in Fiji. *Phytopathological Papers* No. 1.

FLOYD, C. N. (1988) Control and effect of leaf scab (*Elsinoe batatas*) in sweet potato. *Tropical Agriculture*, **65** : 6–8.

FRANSSEN, C. J. H. (1934) Insect pests of sweet potato in Java. *Overdruk uit Landbouw*, **10** : 205–225. Translated and reprinted by AVRDC, 1986.

FRISON, E. A. and NG, S. Y. (1981) Elimination of sweet potato virus disease agents by meristem tip culture. *Tropical Pest Management*, **27** : 452–454.

GAPASIN, R. M. (1979) Survey and identification of plant parasitic nematodes associated with sweet potato and cassava. *Annals of Tropical Research*, **1** : 120–134.

GAPASIN, R. M. (1981) Control of *Meloidogyne incognita* and *Rotylenchus reniformis* and its effect on the yield of sweet potato and cassava. *Annals of Tropical Research*, **3** : 92–100.

GAPASIN, R. M. (1984a) *Studies on Plant Diseases especially Sweet Potato Scab.* IDRC/PCARRD Report 8 pp. (Unpublished).

GAPASIN, R. M. (1984b) Resistance of fifty-two sweet potato (*Ipomoea batatas* (L.) Lam.) cultivars to *Meloidogyne incognita* and *M.javanica*. *Annals of Tropical Research*, **6:** 1–19.

GAPASIN, R. M. (1986) Pre- and post-infectional resistance of sweet potato to *Meloidogyne incognita* and *M. javanica*. *Annals of Tropical Research*, **8** : 176–188.

GAPASIN, R. M. and SUICO, L. (1984) Occurrence of a chlorotic spotting disease of some Visca sweet potato hybrids. *Annals of Tropical Research*, **6** : 77–79.

GAPASIN, R. M. and VALDEZ, R. B. (1979) Pathogenicity of *Meloidogyne* spp. and *Rotylenchus reniformis* on sweet potato. *Annals of Tropical Research*, **1** : 20–26.

GAPASIN, R. M., VALDEZ, R. B. and MENDOZA, E. M. T. (1988) Phenolics involvement in sweet potato resistance to *Meloidogyne incognita* and *M.javanica*. *Annals of Tropical Research*, **10**: 63–73.

GATTANI, M. L. and OKA, I. N. (1964) *List of Diseases of Important Economic Crop Plants of Indonesia.* 5th Meeting of the Plant Protection Commission for South-east Asia.

GATUMBI, R. W. (1986) Host Lists of Kenya Fungi and Bacteria (A ten year supplement 1971–1980). *East African Agricultural and Forestry Journal*, **45**: Special issue.

GATUMBI, R. W., KIHURANI, A. and SKOGLUND, L. G. (1990) *Current status of Sweet Potato Diseases in Kenya.* (Unpublished).

GERONA, R. G. (1987) Identification of sweet potato accessions with resistance to weevil (*Cylas formicarius elegantulus* Fabr.) and analysis of the mechanisms involved. MSc. Thesis, Baybay, Leyte, Philippines: Visayas State College of Agriculture.

GHAFOOR, A. and KHAN, S. A. F. (1976) *List of Diseases of Economic Plants in Pakistan.* Karachi: Department of Plant Protection, Ministry of Food, Agriculture, and Underdeveloped Areas, Pakistan.

GIAMALVA, M. J., MARTIN, W. J. and HERNANDEZ, T. P. (1963) Sweet potato varietal reaction to species and races of root-knot nematodes. *Phytopathology*, **53** : 1187–1189.

GOODBODY, S. (1982) Plant pathology note : No. 17. Sweet potato scab. *Harvest*, **8** : 99–100.

GOODBODY, S. (1983) Effect of sweet potato leaf scab (*Elsinoe batatas*) on sweet potato tuber yield. *Tropical Agriculture*, **60** : 302–303.

GONZALES, S. S. (1925) The sweet potato weevil (*Cylas formicarius* Fab.). *Philippine Agriculture*, **14** : 257–283.

GORTER, G. J. M. A. (1977) *Index of Plant Pathogens and Diseases they cause in Cultivated Plants in South Africa.* Department of Agriculture and Technical Services, South Africa. 177 pp.

GREEN, S. K. (1988) AVRDC virus elimination and indexing procedures for international exchange of sweet potato germplasm. pp. 311–317. In : *Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources.* Report of the 1st Sweet Potato Planning Conference, February 1987, Lima, Peru: CIP.

GREEN, S. K., KUO, Y. J. and LEE, D. R. (1988) Uneven distribution of two potyviruses feathery mottle virus and sweet potato latent virus in sweet potato plants and its implication on virus indexing of the meristem-derived plants. *Tropical Pest Management,* **34** : 298–302.

GREENWAY, P. J. (1944) Origins of some East African food crops. Part 1. *East African Agricultural Journal,* **10** : 34–39.

GUARINO, L. and JACKSON, G. (1986) Describing and Documenting Root Crops in the South Pacific. *FAO Field Document* 12, Suva, Fiji.

HADFIELD, W. (1989) Country paper – Papua New Guinea. pp. 71–77. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in Asia.* Report of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India, Oct. 1988.

HAHN, S. K. (1979) Effect of viruses on growth and yield of sweet potato. *Experimental Agriculture,* **15** : 253–256.

HAHN, S. K., ISOBA, J. C. G. and ILOTIN, T. (1989) Resistance breeding in root and tuber crops at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. *Crop Protection,* **8** : 147–168.

HAHN, S. K. and LEUSCHNER, K. (1981) Resistance of sweet potato cultivars to African sweet potato weevil. *Crop Science,* **21** : 499–503.

HAHN, S. K. and LEUSCHNER, K. (1982) Breeding sweet potato for weevil resistance. pp. 331–336. In : *Sweet Potato. Proceedings of the 1st International Symposium, AVRDC,* Shanhua, Taiwan.

HAHN, S. K., TERRY, E. R. and LEUSCHNER, K. (1981) Resistance of sweet potato to virus disease complex. *HortScience,* **16** : 535–537.

HALSTED, B. D. (1890) Some fungus diseases of sweet potato. *New Jersey Agricultural Experimental Station Bulletin,* **76**: 32 pp.

HAMMETT, H. L., HERNANDEZ, T. P., MARTIN, W. J. and CLARK, C. A. (1982) Breeding sweet potato for disease resistance. pp. 321–330. In : *Sweet Potato. Proceedings of the 1st International Symposium, AVRDC,* Shanhua, Taiwan.

HANSFORD, C. G. (1937) Annotated host list of Ugandan parasitic fungi and plant diseases. Part IV. *East Africa Agriculture Journal,* **3** : 235–240.

HANSFORD, C. G. (1944) A probable virus disease of sweet potato. *East Africa Agricultural Journal,* **10** : 126–127.

HANSFORD, C. G. (1945) Ugandan plant diseases. Part IV. Diseases of sweet potato. *East Africa Agricultural Journal,* **10** : 150–151.

HANSON, H. C. (1963a) *Diseases and Pests of Economic Plants of Vietnam, Laos and Cambodia.* American Institute of Crop Ecology, Washington DC, USA.

HANSON, H. C. (1963b) *Diseases and Pests of Economic Plants of Burma.* American Institute of Crop Ecology, Washington DC, USA.

HARTER, L. L. and WEIMER, J. L. (1929) A monographic study of sweet potato diseases and their control. *United States Department of Agriculture Technical Bulletin* No. 99. 118 pp.

HEATH, R. R., COFFELT, J. A., SONNET, P. E., PROSHOLD, F. I., DUBEN, B. and TUMLINSON, J. H. (1986) Identification of sex pheromone produced by female sweet potato weevil, *Cylas formicarius elegantatulus* (Summers). *Journal of Chemical Ecology,* **12** : 1489–1503.

HERNANDEZ, E. M. A. and MRACEK, Z. (1984) *Heterorhabditis heliothidis* – a parasite of insect pests in Cuba. *Folia Parasitologica*, **31** : 11–17.

HILDEBRAND, E. M. (1958a) Two syndromes caused by sweet potato viruses. *Science*, **128** : 203–204.

HILDEBRAND, E. M. (1958b) Morning glories as the indexing host for sweet potato viruses. *Phytopathology*, **48** : 462.

HOLDAWAY, F. G. (1943) Insects of sweet potato and their control. *Hawaii Agricultural Experimental Station Progress Notes* 26, 7 pp.

HOLLINGS, M., STONE, O. M. and BOCK, K. R. (1976a) Purification and properties of sweet potato mild mottle, a white fly-borne virus from sweet potato (*Ipomoea batatas*) in East Africa. *Annals of Applied Biology*, **82** : 511–528.

HOLLINGS, M., STONE, O. M. and BOCK, K. R. (1976b) Sweet potato mild mottle virus. *Descriptions of Plant Viruses* No. 162. Kew, UK: Commonwealth Mycological Institute, 4 pp.

HOPKINS, J. C. F. (1950) A descriptive list of plant diseases in Southern Rhodesia and list of bacteria and fungi. *Memoirs of the Southern Rhodesian Department of Agriculture* No. 2.

HORTON, D. (1988) *Underground Crops : long-term trends in production of roots and tubers.* Winrock International.

HUAMAN, Z. and DE LA PUENTE, F. (1988) Development of a sweet potato gene bank at CIP. *CIP Circular*, **16** : 1–7.

HUGHES, S. J. (1953) Fungi from the Gold Coast. II. *Mycological Papers* No. 50.

HUGUENIN, B. (1967) Microfungi of New Caledonia. *FAO Plant Protection Commission for the South-east Asia and Pacific Region Technical Document* No. 57.

IBPGR (1981) *Genetic Resources of Sweet Potato.* Rome: IBPGR.

IBPGR (1986) *Directory of Crop Germplasm Collections.* 2. *Root and Tuber Crops.* Rome: IBPGR. 178 pp.

IBPGR (1988) *Conservation and Movement of Vegetatively Propagated Germplasm* : In vitro *culture and disease aspects.* IBPGR Advisory Committee on *in vitro* Storage, Rome: IBPGR.

IDRC (1980) *Proceedings of a Workshop on Root Crops in Eastern Africa,* Kigale, Rwanda, Nov. 1980. IDRC – 177e.

IITA (1985) Sweet potato – Pathology and Virology. *Annual Report, IITA.* Ibadan, Nigeria.

IITA (1986) Executive Summary, Virology Unit. pp. 130–132 In : *Annual Report and Research Highlights, 1985, IITA.* Ibadan, Nigeria.

IITA (1987) Comparative studies on sweet potato virus complexes world-wide. pp.125–126. In : *Annual Report and Research Highlights, 1986, IITA.* Ibadan, Nigeria.

INGRAM, W. R. (1967) Chemical control of sweet potato weevil in Uganda. *East Africa Agricultural and Forestry Journal*, **33** : 163–165.

ISHAQUE, M. and TALUKDAR, M. J. (1967) Survey of the fungal flora of East Pakistan. *Agriculture Pakistan*, **18** : 17–26.

IWANAGA, M. (1988) Use of wild germplasm for sweet potato breeding. pp 199–211. In : *Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources.* Report of the 1st Sweet Potato Planning Conference, February 1987, Lima, Peru: CIP.

JACKSON, G. V. H. (1988) Scab disease of sweet potato. *South Pacific Commission Advisory Leaflet* No. 20. Noumea, New Caledonia.

JACKSON, G. and BREEN, J. (1985) Collecting, Describing and Evaluating Root Crops. *FAO Field Document* No. 8. Suva, Fiji.

JACKSON, G. V. H., PEARSON, M. N. and ZETTLER, F. W. (1984) Sweet potato little leaf. *South Pacific Commision Advisory Leaflet* No. 19. Noumea, New Caledonia.

JACKSON, G. V. H. and ZETTLER, F. W. (1983) Sweet potato witches' broom and legume little leaf diseases in the Solomon Islands. *Plant Disease,* **67** : 1141–1144.

JANA, R. K. (1982) Status of sweet potato cultivation in East Africa and its future. pp. 63–72. In : *Sweet Potato. Proceedings of the 1st International Symposium, AVRDC,* Shanhua, Taiwan.

JANSSENS, M. J. J. (1980) Sweet potato improvement in Rwanda. pp. 27–32. In : *Proceedings of a Workshop on Root Crops in Eastern Africa, Kigale, Rwanda,* Nov. 1980. IDRC – 177e.

JAYARAMAIAH, M. (1975) Reaction of sweet potato varieties to damage of the weevil, *Cylas formicarius* (Coleoptera : Curculionidae) and on the possibility of picking up of infectation by weevil. *Mysore Journal of Agricultural Science,* **9** : 418–421.

JATALA, P. (1988) Important nematode pests of sweet potatoes. pp 101–102. In : *Improvement of Sweet Potato in East Africa.* Report of the Workshop on Sweet Potato Improvement in Africa, September–October 1987, Nairobi, Kenya: ILRAD.

JATALA, P. (1989) Important nematode pests of sweet potatoes and their management. pp. 213–218. In : *Improvement of Sweet Potato (Ipomoea batatas) in Asia.* Report of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India: October 1988.

JATALA, P. and GUEVARA, E. (1991) Reaction of some Peruvian sweet potatoes to *Meloidogyne incognita. Nematropica* (In press).

JATALA, P. and RAMAN, K. V. (1988) Major insect and nematode pests of sweet potatoes and recommendations for transfer of pest-free germplasm. pp. 319–322. In : *Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources,* Report of the 1st Sweet Potato Planning Conference, February 1987, Lima, Peru: CIP.

JATALA, P. and RUSSELL, C. C. (1972) Nature of sweet potato resistance to *Meloidogyne incognita* and the effects of temperature on parasitism. *Journal of Nematology,* **4** : 1–7.

JENKINS, A. E. and FOSBERG, F. R. (1957) Records of citrus canker and sweet potato scab in Micronesia. *Plant Disease Reporter,* **41** : 1055–1056.

JENKINS, A. E. and VIEGAS, A. P. (1943) Stem and foliage scab of sweet potato (*Ipomoea batatas*). *Journal of the Washington Academy of Science,* **33** : 244–249.

JENKINS, P. D. (1981) Differences in the susceptibility of sweet potatoes (*Ipomoea batatas*) to infection by storage fungi in Bangladesh. *Phytopathologische Zeitschrift,* **102** : 247–256.

JOHNSTON, A. (1960a) *A Preliminary Plant Disease Survey in Sarawak.* Rome: FAO Plant Production and Protection Division, 17 pp.

JOHNSTON, A. (1960b) *A Preliminary Plant Disease Survey in North Borneo.* Rome: FAO Plant Production and Protection Division, 15 pp.

JOHNSTON, A. (1960c) *A Preliminary Plant Disease Survey in the British Solomon Islands Protectorate.* Rome: FAO Plant Production and Protection Division, 36 pp.

JOHNSTON, A. (1961) A preliminary plant disease survey in Netherlands New Guinea. *Bulletin of the Department of Economic Affairs, Agriculture Series* No. 4., 55 pp.

JOHNSTON, A. (1962) A preliminary plant disease survey in Netherlands New Guinea. *Bulletin of Economic Affairs, Netherlands New Guinea, Agriculture Series* No. 4. 55 pp.

JOHNSTON, A. (1963) Host list of plant diseases in the New Hebrides. *FAO Plant Protection Commission for South-east Asia and the Pacific Region. Technical Document* No. 27.

JONES, A. (1980) Sweet potatoes. pp. 645–655. In : *Hybridization of Crop Plants.* (W. R. Fehr and H. H. Hadley Eds). Madison, Wisconsin: American Society of Agronomy and Crop Science Society of America.

JOUGHIN, J. (1987) Let them eat sweet potato. pp. 183–196. In : *Sweet Potato Research In Papua New Guinea,* Port Moresby, Papua New Guinea: Ministry of Agriculture.

KAHN, R. P., LAWSON, R. H., MONROE, R. L. and HEARON, S. (1972) Sweet potato little-leaf (witches broom) association with a mycoplasma-like organism. *Phytopathology,* **62** : 903–909.

KANUA, M. B. and FLOYD, C. N. (1988) Sweet potato genotype x environment interaction in the highlands of Papua New Guinea. *Tropical Agricriculture,* **65** : 9–15.

KAY, D. E. and GOODING, E. G. B. (1987) Sweet potato. pp. 204–206. In: *Root crops.* UK: TDRI/ODA.

KE, C., CHEN, J. Y., CHEN, X. K., LING, K. S. and CHEN, H. (1985) Investigations and electron microscopic observation on sweet potato witches' broom in Fujian. *Fujian Agricultural Science and Technology,* **1** : 2–5.

KEINMEESUKE, P. (1985) *Field Study on the Population Fluctuation of Sweet Potato Weevil,* Cylas formicarius F., on sweet potato. MSc. Thesis. Bangkok, Thailand: Kasetsart University.

KEINMEESUKE, P., CHAOVALITVONPORN, P., RUCHATAPAKORNCHAI, V. and VATTANATANGUM, A. (1980) Studies on chemical control of major insects attacking sweet potato. In : *Proceedings of the 2nd Conference of Entomology, Division of Entomology and Zoology,* Bangkok, Thailand: Department of Agriculture.

KEINMEESUKE, P., TAOTUNG, S., THAYAMANON, P., THUMAJAREE, S., POOLPERM, N. and VATTANATANGUM, A. (1987) Field test on the efficacy of insecticides for controlling sweet potato weevil, *Cylas formicarius* F. pp. 1–7. In : *Annual Report of the Division of Entomology and Zoology,* Bangkok, Thailand: Department of Agriculture.

KEINMEESUKE, P. and VATTANATANGUM, A. (1988) Insect pests of sweet potato weevil. *Journal of Entomology and Zoology,* **10** : 231–238.

KEINMEESUKE, P., VITAYARUK, V., RUCHATAPAKORNCHAI, V., CHAOVALITVONPORN, P., TAOTONG, S., AUNREUN, V. and VATTANATANGUM, A. (1986) Study on methods for controlling sweet potato weevil with insecticides after rice harvesting. pp. 1–7. In : *Annual Report of the Division of Entomology and Zoology,* Bangkok, Thailand: Department of Agriculture.

KEMNER, N. A. (1924) Der Batateukafer (*Cylas formicarius* (F)) auf Java und benach barten Inseln Ostindiens [The sweet potato weevil *(Cylas formicarius* (F.)) in Java and the neighbouring islands of the East Indies]. *Zeitschrift für Angewandte Entomologie,* **10**: 398–435.

KENNEDY, G. G. and MOYER, J. W. (1982) Aphid transmission and separation of two strains of sweet potato feathery mottle virus from sweet potato. *Journal of Economic Entomology,* **75** : 130–133.

KEVESAN, V. and BANG, S. K. (1989) The augmented design as an aid to selection of sweet potato. pp. 641–644. In : *Proceedings of the 6th International Congress of SABRAO.*

KIBATA, G. N. (1976) Studies on the varietal susceptibility and pest control of sweet potato (*Ipomoea batatas*) in Central Kenya. pp. 93–96. In : *Proceedings of the 1st East African Conference on Entomology and Pest Control*, Nairobi, Kenya.

KOBAYASHI, M. (1978) Sweet potato breeding method using wild relatives in Japan. pp. 1–8. In : *Symposium on Methods of Crop Breeding, Tropical Agriculture Research Series* No. 11, Tropical Agricultural Research Center, Yatabe, Tsukuba, Japan.

KUMAR, J., KALTERARA, T. and KASHYAP, D. M. (1985) Control of kumala scab diseases with resistant varieties. pp. 37–38. In : *Annual Research Report*, Research Division, Suva, Fiji: Department of Agriculture, Ministry of Primary Industries.

KUMAR, R. (1989) Ecology and management of root and tuber pests in tropical Africa. *Discovery and Innovation*, **1** : 44–49.

KUO, C. G., SHEN, B. J., SHEN, M. J., GREEN, S. K. and LEE, D. R. (1985) Virus-free sweet potato storage roots derived from meristem tips and leaf cuttings. *Scientia Horticulturae*, **26** : 231–240.

LAO, F. O. (1980) Morphology of sweet potato scab fungus (*Sphaceloma batatas* Saw.). *Annals of Tropical Research*, **2** : 40–48.

LAO, F. O. and DIVINAGRACIA, G. G. (1979) Culture of sweet potato scab fungus (*Sphaceloma batatas* Saw.). *Annals of Tropical Research*, **1** : 1–13.

LAWRENCE, G. W., CLARK, C. A. and WRIGHT, V. L. (1986) Influence of *Meloidogyne incognita* on resistant and susceptible sweet potato cultivars. *Journal of Nematology*, **18** : 59–65.

LAWSON, R. H., HEARON, S. S. and SMITH, F. F. (1971) Development of pinwheel inclusions associated with sweet potato russet crack virus. *Virology*, **46** : 453–463.

LEATHER, R. I. (1959) Diseases of economic plants in Ghana other then cacao. *Ghana Ministry of Food and Agriculture Bulletin* No. 1. 40 pp.

LING, L. and JENKINS, A. E. (1951) Additional old world distribution of stem and foliage scab of sweet potato. *Plant Disease Reporter*, **35** : 120.

LIU, P. S. W. (1977) A supplement to a host list of plant diseases in Sabah, Malaysia. *Phytopathological Papers* No. 21.

LO, J. Y. and CLARK, C. A. (1988) Sources of inoculum and infection courts of *Diplodia gossypina* on sweet potato. *Phytopathology*, **78** : 1442–1446.

LOVE, S. L., RHODES, B. B. and MOYER, J. W. (1987) Meristem-tip culture and virus indexing of sweet potatoes. *Practical Manual for Handling Crop Germplasm* In Vitro. Rome: IBPGR.

MACDONALD, A. S. (1963) Sweet potatoes with particular reference to the tropics. *Field Crop Abstracts*, **16** : 219–225.

MACDONALD, A. S. (1967) Some aspects of sweet potato agronomy. In : *Proceedings of the 1st International Symposium on Tropical Root Crops*, Trinidad.

MACFARLANE, R. and JACKSON, G. V. H. (1989) Sweet Potato Weevil. *South Pacific Commission Pest Advisory Leaflet* No. 22.

MACMASTER, D. N. (1962) *A Subsistence Crop Geography of Uganda.* pp. 72–76. Geographic Publications Ltd.

MAFF (1978) Sweet potato scab. *Ministry of Agriculture Report*, Government of Tonga. 23 pp.

MAHTO, D. N. and SINHA, D. C. (1978) Mosaic disease of sweet potato and its tranmission. *Indian Journal of Entomology*, **40** : 443–444.

MAITAI, W. M. (1958) Annotated list of insects associated with the sweet potato. *East Africa Agricultural Journal*, **23** : 290–291.

MANSER, P. D. (1982) Liste provisiore des maladies et des insectes nuisibles des cultures au Gabon. *Report de Service de la Protection des Vegetaux Ministere de l'Agriculture des Eaux et Forets et du Developpment Rural.* 20 pp.

MANWAN, I. and DIMYATI, A. (1989) Sweet potato production and utilization research in Indonesia. pp. 43–52. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in Asia.* Report of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India, October 1988, Lima, Peru: CIP.

MARISCAL, A. M. and CARPENA, A. L. (1988) Genetic variation in a wide gene base population of sweet potato. *Annals of Tropical Research*, **10** : 78–84.

MARTIN, W. J. (1970) Elimination of root-knot and reniform nematodes and scurf infections from rootlets of sweet potato plants by hot water treatment. *Plant Disease Reporter*, **54** : 1056–1058.

MARTIN, W. J. and BIRCHFIELD, W. (1973) Further observations on variability in *Meloidogyne incognita* on sweet potato. *Plant Disease Reporter*, **57** : 199.

MARTIN, W. J., BIRCHFIELD, W. and HERNANDEZ, T. P. (1966) Sweet potato varietal reaction to reniform nematode. *Plant Disease Reporter*, **50** : 500–502.

MASON, A., TAUFATOFAU, P. and BEETHAM, P. (1989) *Performance of Two Pathogen-Tested Sweet Potato Cultivars in Tonga.* (Unpublished report).

MASON, L. J., JANSSON, R. K. and HEATH, R. R. (1990) Sampling range of male sweet potato weevils (*Cylas formicarius elegantulus* Summers) (Coleoptera: Curculionidae) to pheromone traps: influence of pheromone dosage and lure age. *Journal of Chemical Ecology*, **16**: 2493–2502.

MATATA, J. (1988) Welcome address. pp. 2–13. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in East Africa.* Report of a Workshop on Sweet Potato Improvement in Africa, ILRAD, Nairobi, Kenya, September–October 1987, Lima, Peru: CIP.

MORWOOD, R. B. (1955) *A Preliminary List of Plant Diseases in Fiji.* Suva, Fiji: Department of Agriculture, 9 pp.

MOYER, J. W. (1986a) Variability among strains of sweet potato feathery mottle virus. *Phytopathology*, **76** : 1126.

MOYER, J. W. (1986b) Serological detection of sweet potato feathery mottle virus in sweet potato. *Phytopathology*, **76** : 1133.

MOYER, J. W. (1988) Principal virus diseases of sweet potatoes, their control and eradication. pp. 303–310. In : *Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources.* Report of the 1st Sweet Potato Planning Conference, February 1987, Lima, Peru: CIP.

MOYER, J. W. and CALI, B. B. (1985) Properties of sweet potato feathery mottle virus RNA and capsid protein. *Journal of General Virology*, **66** : 1185–1189.

MOYER, J. W., CALI, B. B., KENNEDY, G. G. and ABOU-GHADIR, M. F. (1980) Identification of two sweet potato feathery mottle virus strains in North Carolina. *Plant Disease*, **64** : 762–764.

MOYER, J. W. and CAMPBELL, C. L. (1982) Stem canker of sweet potato induced by *Fusarium solani*. *Plant Disease*, **66** : 65–66.

MOYER, J. W. and ECHANDI, E. (1986) Serological detection and identification of *Streptomyces ipomoeae*. *Plant Disease*, **70** : 516–518.

MOYER, J. W., JACKSON, G. V. H. and FRISON, E. A. (Eds) (1989) *FAO/IBPGR Technical Guidelines for the Safe Movement of Sweet Potato Germplasm.* Rome: FAO/IBPGR.

MOYER, J. W. and KENNEDY, G. G. (1978) Purification and properties of sweet potato feathery mottle virus. *Phytopathology*, **68** : 998–1004.

MOYER, J. W. and SALAZAR, L. F. (1989) Virus and virus-like diseases of sweet potato. *Plant Disease*, **73** : 451–455.

MUKELAR, A. (1988) Problem of scab on sweet potato and its control. pp. 153–162. In : *Proceedings of a Seminar on Root Crops in Irian Jaya.* July 1988, Manokwari, Irian Jaya. (Indonesian).

MUKIIBI, J. (1976a) Synonymy in sweet potato virus diseases. pp. 163–167. In : *Proceedings of the 4th International Symposium on Tropical Root Crops,* Cali, Colombia: CIAT.

MUKIIBI, J. (1976b) Effects of mosaic virus on yield of sweet potato in Uganda. pp. 169. In : *Proceedings of the 4th International Symposium on Tropical Root Crops,* Cali, Colombia: CIAT.

MULINDANGABO, J. (1989) First results of cassava and sweet potato trials under normal conditions in Rwanda. pp. 178–187. In: Root Crops and Low-input Agriculture. *Proceedings of the 3rd Eastern and Southern Africa Regional Workshop on Root and Tuber Crops, Malawi, 1987.* Ibadan, Nigeria: IITA.

MULLEN, M. A. (1980) Rapid selection of sweet potato lines resistant to the sweet potato weevil. *HortScience*, **15** : 70–71.

MULLEN, M. A., JONES, A., ARBOGAST, R. T., SCHALK, J. M., PATERSON, D. R., BOSWELL, T. E. and EARHART, D. R. (1980) Field selection of sweet potato lines and cultivars for resistance to sweet potato weevil. *Journal of Economic Entomology*, **73** : 288–290.

MULLEN, M. A., JONES, A., PATERSON, D. R. and BOSWELL, T. E. (1980) Resistance of sweet potato lines to the sweet potato weevil. *HortScience*, **17** : 931–932.

MUTHAPPA, B. N. (1987) Records of micro-organisms in Papua New Guinea 1977–1986. *Department of Primary Industry*, Port Moresby, *Research Bulletin* No. 43.

MWANGA, R. O. M. and WANYERA, N. W. (1988) Sweet potato growing and research in Uganda. pp. 187–198. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in East Africa.* Report of a Workshop on Sweet Potato Improvement in Africa, ILRAD, Nairobi, Kenya, September–October 1987, Lima, Peru: CIP.

NATTRASS, R. M. (1961) Host lists of Kenya fungi and bacteria. *Mycological Papers* No. 81.

NAYGA, J. G. and GAPASIN, R. M. (1986) Effect of stem and foliage scab disease on the growth and yield of VSP-1 sweet potato variety. *Annals of Tropical Research*, **8** : 115–122.

NDAMAGE, G. (1984a) Sweet potato cultivation and research in Rwanda. pp. 64–77 In: *Crop Improvement in Eastern and Southern Africa – Research Objectives and On-farm testing.* Proceedings of a Regional Workshop, Nairobi, Kenya, 20–22 July 1983, IDRC.

NDAMAGE, G. (1984b) Sweet potato production potential in Rwanda. pp. 189–191. In: Tropical Root Crops – Production and uses in Africa. *Proceedings of the 2nd Triennial Symposium of the International Root Crops Africa Branch,* Cameroon, 1983, IDRC.

NDAMAGE, G. (1988) Developpement et amelioration de la production de la patate douce au Rwanda. pp. 167–184. In: *Improvement of Sweet Potato* (Ipomoea batatas) *in East Africa.* Report of a Workshop on Sweet Potato Improvement in Africa. Nairobi, Kenya 1987, Lima, Peru: CIP.

NDAMAGE, G. (1989) Twenty-five years of research into sweet potato from 1962–1987. pp. 159–177. In: Root crops and low-input agriculture. *Proceedings* *of the 3rd Eastern and Southern Africa Regional Workshop on Root and Tuber Crops*, Malawi, 1987, Ibadan, Nigeria: IITA.

NGEVE, J. M. and BOUWKAMP, J. C. (1991) Effects of sweet potato virus disease (SPVD) on the yield of sweet potato genotypes in Cameroon. *Experimental Agriculture*, **27** : 221–225.

NIEMANN, E., LARE, M., TSCHINDE, J. and ZAKARI, I. (1972) Beitrag zur Kenntnis der Pflanzenkrankheiten und Schadlinge Togos. *Zeitschrift fur Pflanzenkrankenheiten und Pflanzenschultz*, **79** : 599–608.

NOME, S. F. (1973) Sweet potato vein mosaic virus in Argentina. *Phytopathologische Zeitschrift*, **77** : 44–54.

NOME, S. F., SHALLA, T. A. and PETERSON, L. J. (1974) Comparison of virus particles and intracellular inclusions associated with vein mosaic, feathery mottle, and russet crack diseases of sweet potato. *Phytopathologische Zeitschrift*, **79** : 169–178.

NOTTINGHAM, S. F., SON, K. -C., WILSON, D. D., SEVERSON, R. F. and KAYS, S. J. (1989) Attraction of adult sweet potato weevils, *Cylas formicarius elegantulus* (Summers), to sweet potato leaf and root volatiles. *Journal of Chemical Ecology*, **15** : 1095–1106.

OLIVEIRA, G. H. N. DE, ALMEIDA, O. C. DE and RIBEIRO, R. DE L. D. (1982) Fusarium wilt of sweet potato : a new disease in Brazil. *Fitopatologia Brasileira*, **7** : 311–313.

OLIVERO, C. A. and OROPEZA, T. (1985) Effects of sweet potato feathery mottle virus on the yield and other agronomic parameters of sweet potato. *Agronomia Tropical*, **35** : 167–172.

ONDIEKI, J. J. (1973) Host lists of Kenya Fungi and Bacteria (A ten year supplement 1961–1970). *East African Agricultural and Forestry Journal*, **38**: Special issue.

ONWUEME, I. C. (1978) *The Tropical Tuber Crops*. John Wiley & Sons, Chichester. 234 pp.

ORIEUX, L. and FELIX, S. (1968) List of plant diseases in Mauritius. *Phytopathological Papers* No. 7.

PALANISWAMI, M. S. (1987) *Integrated control of sweet potato weevil* Cylas formicarius *Fab*. Ph.D. thesis, Vellanikkara, Trichur, India: Kerala Agricultural University.

PALANISWAMI, M. S. (1989) *Use of Parasitoids and Entomopathogenic Fungus on Sweet Potato Weevil*. Paper presented at the Seminar on Pests and Diseases of Sweet Potato (*Ipomoea batatas*), Trivandrum, India, August 1989.

PALANISWAMI, M. S., RAJAMMA, P. and PILLAI, K. S. (1988) Biological agents of the pests of tropical tuber crops in India — a review. *Journal of Root Crops*, **14** : 41–46.

PALOMAR, M. K., BULAYOG, E. F. and DEN, T. V. (1989) Sweet Potato Research and development in the Philippines. pp. 79–85. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in Asia*, Report of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India, Oct. 1988. Lima, Peru: CIP.

PALOMAR, M. K., SOLIS, A. D. and BANDALA, H. S. (1980) Sweet potato tuber rot disease (Java black rot) in the Philippines. *Annals of Tropical Research*, **2** : 111–121.

PANINGBATAN, R. A. (1987) Infectivity and *in vitro* production of sweet potato scab fungus (*Sphaceloma batatas* Saw.) inoculum. *Annals of Tropical Research*, **9** : 24–33.

PEARSON, M. N. (1981) Sweet potato little leaf. Plant Pathology note No. 8. *Harvest*, **7** : 50–51.

PEARSON, M. N., KEANE, P. J. and THIAGALINGAM, K. (1984) Little leaf : a disease of sweet potato in Papua New Guinea probably caused by mycoplasma-like organisms. *Phytopathologische Zeitschrift*, **109** : 269–276.

PEREGRINE, W. H. T. (1988) *Annual Report of the Plant Pathologist, 1988.* PADEP/ULG Agricultural Development Project.

PEREGRINE, W. H. T. and KASSIM BIN AHMAD (1982) Brunei : a first annotated list of plant diseases and associated organisms. *Phytopathological Papers* No. 27.

PIENING, L. J. (1962) A check list of fungi recorded from Ghana. *Ghana Ministry of Food and Agriculture Bulletin* No. 2. 130 pp.

PIYA GIATONG (1980) *Host Index of Plant Diseases in Thailand.* Mycology Branch, Plant Pathology and Microbiology Division, Bangkok Thailand: Department of Agriculture, Ministry of Agriculture and Cooperation. 2nd edition, 118 pp.

POLE, F. S. (1987) Sweet potato little leaf disease. *Agronomy Advisory Leaflet* No. 1., Tonga: Ministry of Agriculture, Food and Forestry.

PRICE, M. and CISHAHAYO, D. (1986) Ascochyta blight on major food crops in Rwanda, East Africa. *Plant Disease*, **70** : 1159.

PROSHOLD, F. I., GONZALES, J. L., ASENCIO, C. and HEATH, R. R. (1986) A trap for monitoring the sweet potato weevil, *Cylas formicarius* (Curculionidae : Coleoptera) using pheromone or live weevils as bait. *Journal of Economic Entomology*, **79** : 641–647.

PUCKDEEDINDAN, P. (1966). A supplementary host list of plant diseases in Thailand. Department of Agriculture, Bangkok, Thailand, *Technical Bulletin*, **7** : 1–23.

PURSEGLOVE, J. W. (1968) Convolvulaceae pp. 78–88. In : *Tropical Crops. Dicotyledons.* Harlow: Longman.

QUIMIO, T. H. and CAPILIT, A. (1981) *Enumeration and Bibliography of Philippine Fungi (1936–1977).* Philippines: National Institutes of Biotechnology and Applied Microbiology, BIOTECH, UPLB.

RAJAMMA, P. (1980) On some natural enemies of sweet potato weevil *Cylas formicarius* Fab. (Curculionidae : Coleoptera). *Journal of Root Crops*, **6** : 59–60.

RAM KUMAR, SINHA, P. and SINGH, V. (1987) Evaluation of systemic and non-systemic fungicides for control of Cercospora leaf spot of sweet potato. *Pesticides*, **21** : 31–32.

RAMAN, K. V. (1988a) Major sweet potato insect pests : recommendations. pp. 79–81. In : *Improvement of Sweet Potato in East Africa.* Report of a Workshop on Sweet Potato Improvement in Africa ILRAD, Nairobi, Kenya, September–October, 1987, Lima, Peru: CIP.

RAMAN, K. V. (1988b) Major sweet potato insect pests and selection for resistance to the sweet potato weevil *Euscepes postfasciatus* Fairmaire. pp. 83–89. In : *Improvement of Sweet Potato in East Africa.* Report of a Workshop on Sweet Potato Improvement in Africa, ILRAD, Nairobi, Kenya, Sept.-Oct., 1987, Lima, Peru: CIP.

RAMAN, K. V. (1989) Strategies to develop sweet potatoes with weevil resistance in developing countries. pp. 203–211. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in Asia.* Report of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India, Oct. 1988, Lima, Peru: CIP.

RAMSEY, M., VAWDREY, L. L. and HARDY, J. (1988) Scab (*Sphaceloma batatas*) a new disease of sweet potatoes in Australia : fungicide and cultivar evaluation. *Australian Journal of Experimental Agriculture*, **28** : 137–141.

RANGAII, S. S. and KANUA, M. B. (1988) Indigenous technologies and recent advances in sweet potato production. Papua New Guinea Department of Agriculture and Livestock Discussion Paper 88/5.

RANGASWAMI, G. (1975) Sweet potato. pp. 286–287, In: *Diseases of Crop Plants in India*. New Delhi: Prentice-Hall of India.

RAVICHANDRAN, V. and SULLIA, S. B. (1983) Pathogenic fungi from sweet potato. *Current Science*, **52** : 1031.

REINKING, O. A. (1919) Host index of diseases of economic plants in the Philippines. *The Philippine Agriculturalist*, **8** : 38–54.

RESPLANDY, R., CHEVAUGEON, J., DESLASSUS, M. and LUC, M. (1954) Premiere liste annotee de champignons parasites de plantes cultivees en Cote d'Ivoire. *Institut National de la Recherche Agronomique, Annales d'Epiphyties*, **1** : 1–61.

RILEY, E. A. (1956) A preliminary list of plant diseases in Northern Rhodesia. *Mycological Papers* No. 63.

RILEY, E. A. (1960) A revised list of plant diseases in Tanganyika territory. *Mycological Papers* No. 75.

ROBERTS, P. A. and SCHEUERMAN, R. W. (1984) Managing nematodes in sweet potatoes with resistance and nematicides. *California Agriculture*, **38** : 26–27.

ROLSTON, L. H., BARLOW, T., HERNANDEZ, T., NILAKHE, S. and JONES A. (1979) Field evaluation of breeding lines and cultivars for resistance to sweet potato weevil. *HortScience*, **14** : 634–635.

ROSSEL, H. W. and THOTTAPILLY, G. (1988) Complex virus diseases of sweet potato. pp. 291–302. In : *Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources*. Report of the 1st Sweet Potato Planning Conference, Lima, Peru: CIP.

ROTHWELL, A. (1983) A revised list of plant diseases occurring in Zimbabwe. *Kirkia*, **12** : 233–351.

SALAZAR, L. F. (1988) Procedures for virus indexing. pp 69–72. In : *Improvement of Sweet Potato in Africa*, Proceedings of the Workshop on Sweet Potato Improvement in Africa, ILRAD, Nairobi, Kenya, September–October 1987, Lima, Peru: CIP.

SALAZAR, L. F. (1989) Research activities in CIP on sweet potato virus diseases. pp. 189–194. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in Asia*. Report of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India, Oct. 1988, CIP, 1989.

SCHAEFERS, G. A. and TERRY, E. R. (1976) Insect transmission of sweet potato disease agents in Nigeria. *Phytopathology*, **66** : 642–645.

SHAKOOR, A., KIARIE, J. K., RUTTO, J. K., GITHUNGURI, C. M., GICHUKI, S. T., ABUBAKER, A., OMARI, F. F. and NDOLO, P. J. (1988) Improvement of root and tuber crops in Kenya. pp. 139–153. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in East Africa*. Report of a Workshop on Sweet Potato Improvement in Africa, ILRAD, Nairobi, Kenya, September–October 1987, Lima, Peru: CIP.

SHAW, D. E. (1985) Micro-organisms in Papua New Guinea. *Department of Primary Industry*, Port Moresby, Papua New Guinea, *Research Bulletin* No. 33.

SHEFFIELD, F. M. L. (1953) Virus diseases of sweet potato in parts of Africa. *Empire Journal of Experimental Agriculture*, **21** : 184–189.

SHEFFIELD, F. M. L. (1954) Erinose of sweet potato. *Empire Journal of Experimental Agriculture*, **22** : 97–100.

SHEFFIELD, F. M. L. (1957) Virus diseases of sweet potato in East Africa. I. Identification of the viruses and their insect vectors. *Phytopathology*, **47** : 582–590.

SHEFFIELD, F. M. L. (1958) Virus diseases of sweet potato in East Africa. II. Transmission to alternative hosts. *Phytopathology*, **48** : 1–13.

SHERMAN, M. and TAMASHIRO, M. (1954) The sweet potato weevils in Hawaii, their biology and control. Hawaii Agriculture Experimental Station, *University of Hawaii Technical Bulletin* No. 23. 36 pp.

SHIGA, T. and TAKEMATA, T. (1981) Distribution of sweet potato clones with resistance to root-knot nematode in the Pacific Islands. pp. 64–68 In : *Proceedings of the 3rd Research Planning Conference on Root-knot Nematodes,* Jakarta, Indonesia.

SIDDIQI, M. R. (1972) *Rotylenchus reniformis. Descriptions of Plant Parasitic Nematodes.* No. 5. St. Albans, UK: Commonwealth Institute of Helminthology, 2 pp.

SIMBASHIZWEKO, A. and PERREAUX, D. (1988) L'Anthracnose de la patate douce (*Ipomoea batatas* (L.) Lam) au Burundi : Description de l'agente causal et mise au point d'une methode de criblage. pp. 115–120. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in East Africa.* Report of the Workshop on Sweet Potato Improvement in Africa, ILRAD, Nairobi, Kenya, September–October, 1987, Lima, Peru: CIP.

SIMMONDS, J. H. (1966) *Host Index of Plant Diseases in Queensland.* Brisbane, Australia: Department of Primary Industries.

SINGH, K. G. (1973) A check list of hosts and diseases in Peninsular Malaysia. *Bulletin of the Ministry of Agriculture and Fisheries, Malaysia,* No. 132.

SINGH, K. G. (1980) A check list of hosts and diseases in Peninsular Malaysia. *Bulletin of the Ministry of Agriculture and Fisheries, Malaysia,* No. 154.

SINHA, D. C. and SINGH, K. P. (1984) Post-harvest diseases of sweet potato. *Indian Farming,* **34** : 16–17.

SIVAPRAKASAM, K., KRISHNAMAHAN, G. and KANDASWAMY, T. K. (1977) A new leaf spot disease of sweet potato. *Science Culture,* **43** : 325–326.

SMIT, N. (1988) *Sweet Potato Scab Disease Fungicide Trial.* Plant Protection Half-Yearly Report of the Tongan-German Plant Protection Project.

SMIT, N., HOLO, T. and WILSON, J. E. (1988) *A Sweet Potato Seedling Test for Resistance to Scab Disease* (Elsinoe batatas). Plant Protection Half-Yearly Report of the Tongan-German Plant Protection Project.

SMIT, N.E.J.M., HOLO, T. and WILSON, J.E. (1991) Sweet potato seedling test for resistance to leaf scab disease (*Elsinoe batatas*). *Tropical Agriculture* (Trinidad), **68** : 263–267.

SO, I. Y. (1973) Studies on the mycoplasmic witches' broom of sweet potato in Korea. I. Symptoms and pathogen. *Korean Journal of Microbiology,* **11** : 19–30.

SON, K. -C., SEVERSON, R. F., ARRENDALE, R. F. and KAYS, S. J. (1990). Isolation and characterization of pentacyclic triterpene ovipositional stimulant for the sweet potato weevil from *Ipomoea batatas* (L.) Lam. *Journal of Agricultural and Food Chemistry,* **38** : 134–137.

STEWART, R. B. and YIRGOU, D. (1967) Index of plant diseases in Ethiopia. *Haile Selassie I University College of Agriculture Experimental Station Bulletin* No. 30.

STEINER, K. G. (1976) *Les Maladies des Hostes.* Lomé: Bulletin du Service de la Protection des Vegetaux. 45 pp.

STIER, H. and VAN WIJMEERSCH, (1984) *Sweet Potato Varietal Resistance to Scab Disease with respect to various Growing Seasons.* Unpublished Report from Tonga, 8 pp.

STRUBLE, F. B., MORRISON, L. S. and CORDNER, H. B. (1966) Inheritance of resistance to stem rot and root-knot nematode in sweet potato. *Phytopathology,* **56** : 1217–1219.

SUDJADI, M., WARGIONO, J. and TANTERA, D. M. (1977) Reactions of sweet potato clones to scab and brown leaf spot (*Cercospora* leaf spot). *Seri Hama Panyakit LP*, **3** : 78–87.

SULTAN AHMED (1956) *Fungi of West Pakistan*. Biological Society of Pakistan. Monograph No. 1. 126 pp.

SULTAN AHMED (1969) *Fungi of West Pakistan*. Biological Society of Pakistan. Monograph No. 5, Supplement 1. 110 pp.

SUMMERS, E. M. (1951) 'Ishuku-byo' dwarf of sweet potato in the Ryukyu Islands. *Plant Disease Reporter*, **35** : 266–267.

SUTHERLAND, J. A. (1985a) The Sweet Potato Weevil. pp. 28–32 In : Entomological Bulletin No. 17, Port Moresby, Papua New Guinea: Department of Primary Industry.

SUTHERLAND, J. A. (1985b) The chemical control of *Cylas formicarius* (Fab.) using insecticides at low volume rates with some considerations on the economics of control. *Journal of Plant Protection in the Tropics*, **2** : 97–103.

SUTHERLAND, J. A. (1985c) Occasional pests of sweet potato. pp.94–98. In : Entomological Bulletin No. 18, Port Moresby, Papua New Guinea: Department of Primary Industry.

SUTHERLAND, J. A. (1986a) Evaluation of foliar sprays, soil treatment and vine dip for the control of sweet potato weevil, *Cylas formicarius* (Fab.). *Journal of Plant Protection in the Tropics*, **3** : 95–103.

SUTHERLAND, J. A. (1986b) A review of the biology and control of sweet potato weevil *Cylas formicarius* (Fab). *Tropical Pest Management*, **32** : 304–315.

SUTHERLAND, J. A. (1986c) Damage of *Cylas formicarius* Fab. to sweet potato vines and tubers, and the effect of infestations on total yield in Papua New Guinea. *Tropical Pest Management*, **32** : 316–323.

SWAIN, R. B. (1943) Nematode parasites of the white-fringed beetle. *Journal of Economic Entomology*, **36** : 671–673.

TAKAGI, H. (1988) Sweet potato collections in Papua New Guinea. pp. 147–158. In : *Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources*. Report of the 1st Sweet Potato Planning Conference, February, 1987, Lima, Peru: CIP.

TALEKAR N. S. (1982) A search for sources of resistance to sweet potato weevil. pp. 147–156. In: *Sweet Potato, Proceedings of the 1st International Symposium, AVRDC*, Shanhua, Taiwan.

TALEKAR, N. S. (1983) Infestation of a sweet potato weevil as influenced by pest management techniques. *Journal of Economic Entomology*, **76** : 342–344.

TALEKAR, N. S. (1987a) Influence of cultural pest management techniques on the infestation of sweet potato weevil. *Insect Science Applicata*, **8** : 809–814.

TALEKAR, N. S. (1987b) Feasibility of use of resistant cultivars in sweet potato weevil control. *Insect Science Applicata*, **8** : 815–817.

TALEKAR, N. S. (1987c) Resistance in sweet potato to sweet potato weevil. *Insect Science Applicata*, **8** : 819–823.

TALEKAR, N. S. (1988a) *How to Control Sweet Potato Weevil : a Practical IPM Approach*. International Co-operators Guide, AVRDC, Shanhua, Taiwan, 6 pp.

TALEKAR, N. S. (1988b) Insect pests of sweet potato in the tropics. In : *Proceedings of the 11th International Congress of Plant Protection*, Manila, Philippines.

TALEKAR, N. S. (1989) Development and testing of an integrated pest management technique to control sweet potato weevil. pp. 117–126. In : *Improvement of Sweet Potato* (Ipomoea batatas) *in Asia*. Report of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India, October 1988, Lima, Peru: CIP.

TAN, L. K. and LIN, G. (1970) Fungal diseases of vegetables and ornamentals in Singapore. *Revue de Mycologie,* **35** pp.

TARR, S. A. J. (1963) A supplementary list of Sudan fungi and plant diseases. *Mycological Papers* No. 85.

TAUBENHAUS, J. J. (1925) A new foot rot of the sweet potato. *Phytopathology,* **15** : 238–240.

TAUFATOFUA, P., POLE, F. S. and SMIT, N. (1986) Screening and breeding for sweet potato scab resistance in Tonga. pp. 128–132, In : *Proceedings of the UNDP/FAO/GTZ/IRETA Regional Crop Protection Workshop, Apia, Western Samoa,* September 1986.

TAYLOR, A. L. and SASSER, J. N. (1978) *Biology, Identification and Control of Root-Knot Nematodes* (Meloidogyne *species*). Raleigh: North Carolina State University, 111 pp.

TERRY, E. R. (1976) A review of the major pests and diseases of sweet potato with special reference to plant exchange and introduction. *African Plant Protection,* **1** : 117–133.

TERRY, E. R. (1982) Sweet potato (*Ipomoea batatas*) virus diseases and their control. pp. 161–168. In : *Sweet potato, Proceedings of the 1st International Symposium,* Shanhua, Taiwan: AVRDC.

THEBERGE, R. L. (Ed) (1987) *Common African Pests and Diseases of Cassava, Yam, Sweet Potato and Cocoyam.* Ibadan, Nigeria: IITA, 108 pp.

THOMAS, R. J. and CLARK, C. A. (1983) Population dynamics of *Meloidogyne incognita* and *Rotylenchus reniformis* alone and in combination and their effects on sweet potato. *Journal of Nematology,* **15** : 204–211.

THOMPSON, A. and JOHNSTON, A. (1953) A host list of plant diseases in Malaya. *Mycological Papers* No. 52.

THONGJIEM, M. and PIRIYATHAMRONG, S. (1989) Sweet potato in Thailand. pp. 99–104. In : *Improvement of sweet potato* (Ipomoea batatas) *in Asia.* Proceedings of the Workshop on Sweet Potato Improvement in Asia, Trivandrum, India, Oct., 1988, Lima, Peru: CIP.

THONGJIEM, M. and POOLPERM, N. (1988) *Status of the Sweet Potato Industry and Proposed Research Program in Thailand.,* Paper presented at the SAPPRAD Sweet Potato Meeting, Bangkok, Thailand, 13 pp.

THOTTAPPILLY, G. and ROSSEL, H. W. (1988) Virus diseases of sweet potato in Nigeria. pp. 53–64, In : *Improvement of Sweet Potato* (Ipomoea batatas) *in East Africa.* Report of the Workshop on Sweet Potato improvement in Africa, ILRAD, Nairobi, Kenya, September–October 1987, Lima, Peru: CIP.

THROWER, L. B. (1958) Observations on the root-knot nematode in Papua New Guinea. *Tropical Agriculture,* **35** : 213–217.

TINDALL, H. D. (1983) *Vegetables in the Tropics.* London: Macmillan.

TREHAN, K. N. and BAGAL, S. R. (1957) Life history, bionomics and control of sweet potato weevil (*Cylas formicarius*) with short notes on some other pests of sweet potatoes in Bombay state. *The Indian Journal of Entomology,* **19** : 245–252.

TRUJILLO, E. E. (1982) Spot anthracnose. *University of Hawaii Cooperative Extension Service Plant Disease Series* No. 4.

TURNER, G. J. (1971) Fungi and plant diseases in Sarawak. *Phytopathological Papers* No. 13.

VAN BRUGGEN, A. H. C. (1984) Sweet potato stem blight caused by *Alternaria* sp. : a new disease in Ethiopia. *Netherlands Journal of Plant Pathology,* **90**: 155–164.

VAN RHEENEN, H. A. (1963) Breeding research in sweet potato, *Ipomoea batatas* Poir. *Euphytica,* **12** : 245–253.

VAN VELSEN, R. J. (1967) "Little leaf", a virus disease of *Ipomoea batatas* in Papua New Guinea. *Papua New Guinea Agricultural Journal,* **18** : 126–128.

VAN WIJMEERSCH, P. (1986) Root crops production in Tonga. *FAO/SPC RAS/83/001 Field Document* No. 13. 80 pp.

VANDER ZAAG, P. (1985) *Sweet Potato in the South Pacific.* Trip Report (Unpublished).

VASQUEZ, E. A. and SAJISE, C. E. (1990) *Pests of sweet potato: insects, mites and diseases.* Manila: Phillipine Root Crops Information Service, PRCRTC, 65 pp.

VILLAMAYOR, F. G. (1988) Some agronomic tips on how to minimize sweet potato weevil infestation. *Radix,* **10** : 10–11.

VILLAREAL, R. L. and GRIGGS, T. D. (Eds) 1982. *Sweet Potato. Proceedings of the 1st International Symposium,* Shanhua, Taiwan: AVRDC 481 pp.

WADDILL, V. H. (1982) Control of sweet potato weevil, *Cylas formicarius elegantulus,* by foliar applications of insecticides. pp. 157–160. In : *Sweet Potato, Proceedings of the 1st International Symposium,* Shanhua, Taiwan: AVRDC.

WALLACE, G. B. and WALLACE, M. M. (1948) A list of plant diseases of economic importance in Tanganyika territory. *Mycological Papers* No. 26.

WALLER, J. (1984) Diseases of Small Holder Food Crops in the Southern Highlands Province of Papua New Guinea. Trip Report (Unpublished).

WATSON, J. E., TAUFATOFAU, P., POLE, F. S. and SMIT, N. (1989) Breeding Leaf Scab-Resistant Sweet Potatoes in Tonga. Unpublished report.

WELLES, C. G. A Provisional List of the Parasitic Fungi of the Philippine Islands. Undated and unpublished report.

WEST, J. (1938) A preliminary list of plant diseases in Nigeria. *Kew Bulletin,* **17** : 17–23.

WEST, S. A. (1977) *Studies on the Biology and Ecology of the Sweet Potato Stem Borer* Megastes grandalis Guen. in Trinidad. M.Sc Thesis, University of the West Indies, Trinidad.

WHEATLEY, P. E. (1961) The insect pests of agriculture in the Coast Province of Kenya. III. Sweet potato. *East Africa Agricultural and Forestry Journal,* **26** : 228–229.

WHITESIDE, J. O. (1966) A revised list of plant diseases of Rhodesia. *Kirkia,* **5** : 87–196.

WIEHE, P. O. (1948) The plant diseases and fungi recorded from Mauritius. *Mycological Papers* No. 24.

WIEHE, P. O. (1953). The plant diseases of Nyasaland. *Mycological Papers* No. 53.

WILLIAMS, T. H. and LIU, P. S. W. (1976) A host list of plant diseases in Sabah, Malaysia. *Phytopathological Papers,* No. 19.

WILSON, D. D., SON, K. -C., NOTTINGHAM, S. F., SEVERSON, R. F. and KAYS, S. J. (1989) Characterization of an oviposition stimulant from the surface of sweet potato *Ipomoea batatas* storage roots for the sweet potato weevil *Cylas formicarius elegantatulus. Entomologica Experimentalis et Applicata* **51**: 71–75.

WILSON, J. E., TAUFATOFUA, P., POLE, F. S. and SMIT, N. E. (1989) *Breeding Scab-Resistant Sweet Potatoes in Tonga.* Unpublished report.

XIE, L. H., LIN, Q. Y. and LIU, W. N. (1983) A study on the pathogens of sweet potato witches' broom disease in Fujian. *Journal of Fujian Agricultural College,* **13** : 85–88.

YAMASHITA, S., DOI, Y. and SHIN, A. (1984) Short rod particles in sweet potato leaf curl virus-infected plant tissue. *Annals of the Phytopathological Society of Japan*, **50** : 438.

YAMAMOTO, W. (1960) Synonymous species of *Alternaria* and *Stemphylium* in Japan. *Transactions of the Mycological Society of Japan*, **2** : 88–93.

YANG, I. L. (1969) Studies on witches' broom of sweet potato in Taiwan. *Journal of Taiwan Agricultural Research*, **18** : 50–60.

YANG, I. L. (1972) Transmission of the feathery mottle virus complex of sweet potato in Taiwan. *Taiwan Agricultural Quarterly*, **8** : 123–124. (Mandarin)

YEN, D. E. (1974) *The Sweet Potato and Oceania.* Honolulu: Bishop Museum Press, 389 pp.

YEN, D. E. (1982) Sweet potato in historical perspective. pp. 17–30. In : *Sweet Potato, Proceedings of the 1st International Symposium*, Shanhua, Taiwan: AVRDC.

YEN, D. E. (1989) The domestication of environment. pp. 55–78. In : *Foraging and Farming : the Origin of Plant Exploration.* (Harris, D. R. and Hillman, G. C. Eds), London: Unwin Hyman.

YIK, C. -P. and BIRCHFIELD, W. (1982) Reactions of sweet potato root tissue to the reniform nematode. *Plant Disease*, **66** : 707–709.

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