Everything You Ever Wanted to Know about Sweetpotato

Reaching Agents of Change ToT training manual

VOLUME 4

Topic 6: Sweetpotato Production and Management
Topic 7: Sweetpotato Pest and Disease Management

RAC Reaching Agents of Change – Support Vitamin A Sweetpotato

Centro Internacional de la Papa CIP – A member of the CGIAR Consortium

University of Greenwich – Natural Resources Institute

Helen Keller International

Orange-Fleshed Sweetpotato – Rich in Energy & Natural Vitamin A!

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Reaching Agents of Change ToT Training Manual

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Foreword

During the past decade, interest in sweetpotato in Sub-Saharan Africa (SSA) has been expanding, the number of projects utilizing sweetpotato increasing, and the demand for training development practitioners and farmers subsequently rising as well. Sweetpotato scientists at the International Potato Center and national research centres often receive these requests and frequently hold 1-3 day training sessions, drawing on whatever training materials they have or can quickly pull together. The inadequacy of this approach has been quite apparent, but resources to address the problem were not available until now.

The funding of the Reaching Agents of Change (RAC) project in 2011 has changed the situation. Jointly implemented by the International Potato Center (CIP) and Helen Keller International (HKI), RAC seeks to empower advocates for orange-fleshed sweetpotato (OFSP) to successfully raise awareness about OFSP and mobilize resources for OFSP projects. RAC also seeks to build the capacity of public sector extension and non-governmental organizational personnel to effectively implement those projects funded to promote the dissemination and appropriate use of vitamin A rich, orange-fleshed sweetpotato. The goal is to see *sustained* capacity for training senior extension personnel about the latest developments in sweetpotato production and utilization in each of the major sub-regions of SSA: Eastern and Central Africa, Southern Africa, and West Africa. Hence, CIP has identified a local institution to work with in Mozambique, Tanzania, and Nigeria to host an annual course entitled: *Everything You Ever Wanted to Know about Sweetpotato.* During the first cycle of this course, CIP scientists worked closely with national scientists in implementing the course. During the second cycle, the national scientists will lead the training activities and course management with backstopping from CIP personnel. During the third cycle, national scientists will organise and conduct the course with just financial support from the project. In subsequent years, we hope that the course will have become fully self-sufficient on a cost recovery basis.

In developing the course content, a long-time collaborator of CIP, Dr. Tanya Stathers of the Natural Resources Institute (NRI), University of Greenwich, has led the review of existing training material, added in new knowledge from sweetpotato scientists and practitioners, and designed the course with a heavy emphasis on learning-by-doing. Dr. Stathers previously collaborated with CIP, Ugandan sweetpotato scientists from the National Agriculture Research Organization (NARO), and FAO Global IPM Facility in Kenya on a field project which developed a comprehensive Sweetpotato IPPM Farmers Field School manual for Sub-Saharan Africa in 2005. In developing the course, Dr. Stathers has consulted CIP personnel (Robert Mwanga, Ted Carey, Jan Low, Maria Andrade, Margaret McEwan, Jude Njoku, Sam Namanda, Sammy Agili, Jonathan Mkumbira, Joyce Malinga, Godfrey Mulongo) and HKI nutritionists (Margaret Benjamin, Heather Katcher, Jessica Blankenship) and an HKI gender specialist (Sonii David) as well as her fellow NRI colleagues (Richard Gibson, Aurelie Bechoff, Keith Tomlins). She adapted training material from the DONATA project, the Reaching End Users project and many others. After running the course and using the manual in 2012, a review was held and the manual and course were subsequently updated to meet facilitators and participants demands, and a standard set of accompanying Power Point presentations were created. Dr. Stathers has done a tremendous job and we deeply appreciate her commitment to producing this high quality manual.

The level of this course is aimed at senior extension personnel or leaders of farmer organizations who will in turn train others. We envision the course to be improved on an annual basis as new knowledge comes in and based on feedback received from the course participants. In this way, we expect the vibrant and knowledgeable sweetpotato community of practice to continue to grow in the coming years. The *Everything You Ever Wanted to Know about Sweetpotato* course will help us to achieve the major objectives of the Sweetpotato Profit and Health Initiative (SPHI). Launched in October 2009, the SPHI seeks to improve the lives of 10 million sub-Saharan African families in 16 countries by 2020 through the diversified use of improved sweetpotato varieties.

Jan W. Low, Leader of the Sweetpotato for Profit and Health Initiative, International Potato Center
June 2013

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This team has brought together and shared their many years of experience of working with sweetpotato systems and farmer learning processes across Sub-Saharan Africa to compile this *Everything You Ever Wanted to Know about Sweetpotato* resource. None of this experience would have been gained without the partnership of many sweetpotato farmers and other stakeholders (extensionists, national researchers, traders, transporters, NGO staff, nutritionists, media and donors) across the region. We thank you, and hope that this resource can in return offer you support in your sweetpotato activities.

The photographs used throughout this manual come from a wide range of places and we thank Margaret McEwan, Jan Low, Richard Gibson, Erna Abidin, Aurelie Bechoff, Keith Tomlins, Sam Namanda, J. O'Sullivan, Gabriela Burgos, Tanya Stathers, Olasanmi Bunmi, Benson Ijeoma, Grant Lee Neurenberg, Sammy Agili, the late Constance Owori, Ted Carey, Robert Mwanga, Ana Panta, Kirimi Sindi, Frank Ojwang, CIP digital archive, G. Holmes, B. Edmunds, and Nicole Smit for kindly sharing them. Most of the cartoons used in this manual were drawn by Movin Were.

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Acronyms and abbreviations

ACIAR	Australian Centre for International Agricultural Research
AIs	Adequate Intakes
ARMTI	Agricultural and Rural Management Training Institute
ASCII	American Standard Code for Information Interchange
AVRDC	The World Vegetable Centre
BMGF	Bill and Melinda Gates Foundation
CBO	Community Based Organisation
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Centre for Tropical Agriculture
CIP	International Potato Center
DAP	Days After Planting
DFE	Dietary Folate Equivalents
DONATA	Dissemination of New Agricultural Technologies in Africa
DVM	Decentralised Vine Multipliers
EMU	Eduardo Mondlane University
dwb	Dry weight basis
FAEF	Faculty of Agronomy and Forestry Engineering
FAO	Food and Agriculture Organisation of the United Nations
FC	Food Consumption
FW	Fresh Weight
GI	Glycemic Index
HH	Household
HIV/AIDS	Human Immunodeficiency Virus / Acquired Immunodeficiency Syndrome
HKI	Helen Keller International
IBPGR	Bioversity International
IFPRI	International Food Policy Research Institute
IIAM	Institute of Agricultural Research Mozambique
IIED	International Institute for Environment and Development
IIRR	International Institute of Rural Reconstruction
IITA	International Institute of Tropical Agriculture
IMMPACT	International Micronutrient Malnutrition Prevention and Control Program
IPGRI	International Plant Genetic Resources Institute
IPM	Integrated Pest Management
IPPM	Integrated Pest&Production Management
IRETA	Institute for Research Extension and Training in Agriculture
K	Potassium
LGA	Local Government Areas
LGB	Larger Grain Borer
LZARDI	Lake Zone Agricultural Research and Development Institute (Tanzania)
M&E	Monitoring and Evaluation
MAP	Months After Planting
m.a.s.l.	metres above sea level
MM	Mass Multiplication
MRC	Medical Research Council, South Africa
MSC	Most Significant Change
N	Nitrogen
NARO	National Agricultural Research Organisation
NAS	National Academy of Sciences
NBS	National Bureau of Statistics
NGO	Non Government Organisations
NHV	Negative Horizontal Ventilation
NPC	National Population Commission
NPCK	National Potato Council of Kenya
NPK	Nitrogen, Phosphorus, and Potassium
NRI	Natural Resources Institute
OFSP	Orange-fleshed sweetpotato
P	Phosphorous
PMCA	Participatory Market Chain Approach
PMS	Primary Multiplication Site
PPP	Public Private Partnership
PVC	Polyvinyl chloride
QDPM	Quality Declared Planting Material
QDS	Quality Declared Seed
RAC	Reaching Agents of Change
RAE	Retinol Activity Equivalents
RCT	Randomised Control Trial
RDA	Recommended Daily Allowances
RE	Retinol Equivalents
REU	Reaching End Users
RH	Relative Humidity
SASHA	Sweetpotato Action for Security and Health in Africa
SDC	Swiss Agency for Development and Cooperation
SMS	Secondary Multiplication Site
SP	Sweetpotato
SPCSV	Sweetpotato chlorotic stunt virus
SPFMV	Sweet potato feathery mottle virus

SPHI	Sweetpotato for Profit and Health Initiative
SPKP	Sweetpotato Knowledge Portal
SPVD	Sweetpotato Virus Disease
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
TFNC	Tanzania Food and Nutrition Centre
ToT	Training of Trainers
TMS	Tertiary Multiplication Site
Tshs.	Tanzanian Shillings
TSNI	Towards Sustainable Nutrition Improvement
UN HABITAT	United Nations Human settlement Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UNU	United Nations University
USA	United States of America
USAID	United States Agency for International Development
USD	United States Dollar
USDA	United States Department of Agriculture
Ushs.	Ugandan Shillings
USIM	United States Institute of Medicine
VAD	Vitamin A Deficiency
WAP	Weeks After Planting
WFP	World Food Program
WHO	World Health Organisation
WTP	Willingness To Pay

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How to use this manual

This manual contains '*Everything you ever wanted to know about sweetpotato*'. We hope that it will be useful for those involved in training extensionists and NGO staff at different levels, and that they in turn will train farmers in practical ways that help them to build their problem solving and decision-making skills so they can continue to learn, question, test and address different opportunities and challenges relevant to their livelihoods.

The manual consists of fourteen topics which, after the initial two topics on training and the origin and importance of sweetpotato, follow the sweetpotato crop cycle. Each topic discusses the key need to know aspects highlighting the relevant gender issues and then presents suggestions for how this topic might be incorporated in a 10 day ToT course, with step by step guidelines for several hands-on learning-by-doing activities. The last two topics focus on the ToT training course programme and preparations. The fourteen topics are:

Topic 1: Helping Adults to Learn discusses the characteristics of good facilitators, and provides suggestions to help improve one's facilitation skills. It covers how to plan a training course from the needs assessment, through the development of learning outcomes, awareness raising, participant selection, development of the programme, use of discovery-based/ experiential learning approaches, follow-up and long-term monitoring and scaling up and out. The learning-by-doing activities involve the participants practicing their facilitation skills while delivering different sweetpotato topics and understanding the importance of evaluating their training.

Topic 2: Origin and Importance of Sweetpotato describes the historical origins and spread of sweetpotato and presents an overview of the current uses of and production figures for sweetpotato across the world.

Topic 3: Sweetpotato Varietal Selection and Characteristics. Sweetpotato roots range in colour from purple to orange to yellow or white. A wide diversity of leaf shapes, root sizes and shapes, tastes, textures, maturity periods and flesh colours also exist. Farmers use such characteristics to select which varieties to grow. A method for comparing the different characteristics of different varieties on-farm is described.

Topic 4: Orange-fleshed Sweetpotato and Nutrition. An overview of food groups and good nutrition is given, followed by discussion of the consequences of poor nutrition including vitamin A deficiency and the use of conventional breeding to biofortify crops. The benefits of eating orange-fleshed sweetpotato are discussed along with the complexities of trying to create demand for foods that help address frequently unrecognised nutritional problems such as vitamin A deficiency.

Topic 5: Sweetpotato Seed Systems are reviewed including the different seed multiplication levels, the roles of the different stakeholders within the system. The factors influencing decisions on whether to use a single shot or an ongoing planting material dissemination approach, and the level of subsidisation required are discussed. Examples are given for planning different types of planting material multiplication and dissemination strategies. Methods for selecting clean planting materials and then conserving and multiplying them are presented.

Topic 6: Sweetpotato Production and Management covers the importance of advanced planning to ensure sufficient planting materials are available at the start of the rains, land preparation, planting methods, intercropping, nutrients needs, the main growth stages and their associated management tasks.

Topic 7: Sweetpotato Pest and Disease Management explains how recognising the lifecycles of the damaging insect pests and diseases such as the sweetpotato weevil (*Cylas* spp.) and viruses can help farmers learn how to manage them more successfully. The signs and management strategies for mole rats and erinose are also discussed.

Topic 8: Harvesting and Postharvest Management. The physical damage caused during harvest and transport can reduce the shelf-life and value of sweetpotato roots. Over-drying and prolonged storage can reduce the beta-carotene content of dried orange-fleshed sweetpotato products. Good postharvest handling and storage practices for dried products are discussed, and methods for curing and storing fresh roots to increase their quality, value and availability are presented.

Topic 9: Processing and Utilisation. Many delicious, nutritious and potentially profitable food products can be prepared from orange-fleshed sweetpotato. The use of sweetpotato as animal feed is also discussed.

Topic 10: Marketing and Entrepreneurship. The concepts of marketing, market orientation, entrepreneurship, and the 5 pillars of marketing (product, price, price, promotion and people) are discussed in relation to fresh sweetpotato roots and sweetpotato products.

Topic 11: Gender and Diversity Aspects. The importance of recognising gender and diversity issues in agriculture and sweetpotato systems is discussed. Situations where sweetpotato is grown as a female crop, and others where it is grown as a male crop, or grown by both men and women are presented along with the different constraints, needs and priorities of female and male farmers. Best practice suggestions are made for how gender can be incorporated into sweetpotato programmes.

Topic 12: Monitoring of OFSP Dissemination and Uptake. An explanation of the reasons for monitoring and the differences between monitoring and evaluation is provided. This is followed by a range of tools which can be used for monitoring the dissemination, performance and use of sweetpotato planting materials. In order to understand the long-term impacts and reach of sweetpotato training it is important that records are kept on who has been trained. These records can be used for follow up activities.

Topic 13: Using the 'Everything you Ever Wanted to Know about Sweetpotato' ToT course. Detailed programs for a 10 day and a 5 day learning-by-doing ToT course are presented. They describe: the topics to be covered each day; the intended learning outcomes; the sequential activities and their timing; and the materials and advanced preparations required. These programs are not intended to be prescriptive and we hope that facilitators will creatively adjust them to their participants needs.

Topic 14: Reflections. We hope that after field testing this manual trainers and participants will reflect on it and share their ideas for how it could be improved. Please send any suggestions you have to Jan Low j.low@cgiar.org and where possible we will incorporate them into new editions.

TOPIC 6: SWEETPOTATO PRODUCTION AND MANAGMENT

IN

EVERYTHING YOU EVER WANTED TO KNOW ABOUT SWEETPOTATO

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Topic 6: Sweetpotato Production and Management

Sweetpotato has the potential to produce remarkably high yields if given the right growing conditions. Sweetpotato can also yield more reliably under unfavourable conditions than many other crops, which is why it is so important for household food security in many places in Sub-Saharan Africa (SSA). Topic 6 deals with the environmental factors that influence sweetpotato production - soil and nutrients, water, light and temperature – with their management, and with production practices that can help to reliably produce good sweetpotato crops. Development workers should be aware that farmer knowledge of best management practices for sweetpotato may vary between farmers, genders and regions. In regions where sweetpotato is important, many farmers are likely to be highly skilled growers, managing the crop well within their farms and with available resources. In this manual we do not describe how sweetpotato must be grown, but rather try to help the reader (trainer) understand the principles and practices that can contribute to good sweetpotato production.

6.1 Planning sweetpotato activities for the farm operation

Timing of operations is critical to farm success. Having sufficient planting materials when needed, usually at the onset of the rains, is one of the biggest challenges to sweetpotato production in SSA. There are, of course, other challenges related to balancing the management of the sweetpotato crop with the other crops on the farm and activities in the household. This is particularly true for resource-poor households dependent on rainfed production, working with declining soil fertility, and facing increasing climatic uncertainty. It is important for the promoter of orange-fleshed sweetpotato (OFSP) to understand the agricultural calendar of the community they work with, and how orange-fleshed sweetpotato will fit into that calendar. Development workers need to know the degree of commercialisation of sweetpotato and understand gender roles and responsibilities along the sweetpotato value chain. Male and female ownership/ management of sweetpotato fields in most parts of SSA can be grouped into three categories:

Completed sweetpotato activity calendar from Ukerewe, Tanzania

- Sweetpotato is traditionally a female crop; few or no men grow it
- Sweetpotato is traditionally a male crop; few or no women grow it
- Sweetpotato is grown by both men and women on individually owned plots, family plots or leased plots

As discussed in Topic 11, gender roles in sweetpotato production are dynamic, varying across regions of a country and changing over time. In many parts of SSA, sweetpotato is largely grown by women for subsistence purposes, with men becoming more involved in production as market demand increases. However, the reverse situation also occurs. In parts of northern Nigeria, where men are the major sweetpotato producers, women are increasingly growing the crop as it becomes

	Month												Who is involved?	Other activities/ crops competing for women's labour at this time
	J	F	M	A	M	Jn	Jy	Ag	S	O	N	D	Men, Women, Male children, female children, Hired male labour, hired female labour	
RAINS														
Tasks														
Land preparation														
Land clearing														
Making mounds/ ridges														
Obtaining vines														
Transporting vines														
Planting														
Weeding														
Applying fertilizer														
Harvesting														
Transport to market														
Selling														
Processing roots														
Conserving vines														

more commercialized. Developing a cropping calendar with farmers, which explores who does each of the sweetpotato activities as well as the other activities which are competing for women's labour at those points in time can help explain the situation.

While all the agricultural activities on the calendar will require some advanced planning, this is particularly so when sweetpotato planting materials need to be multiplied in order for there to be sufficient materials at the intended planting time.

6.2 Selecting and preparing land

Altitude: Sweetpotato grows well from sea level up to 1,700 m above sea level (m.a.s.l.). Some varieties even grow up to 2,500 m.a.s.l. but have poorer taste and lower dry matter.

Soils: Sweetpotato can be grown on many types of soil but does best on deep, moderately fertile, sandy loam soils, which produce high quality storage roots with an attractive shape and appearance. Adequate drainage and soil aeration are important, which is one of the reasons the crop is usually grown on mounds, ridges or beds. Sweetpotato does best on slightly acid soils, with optimal pH 5.6-6.6, but can tolerate soils with higher and lower pH. Descriptions and quick field tests to determine your soil type are given in Appendix 6.1.

Sweetpotato, like other crops, obviously benefits from good soil fertility. As a root crop, sweetpotato has a high requirement for potassium. However, a high soil nitrogen content may lead to excess foliage growth and limited root production, particularly in humid environments. Farmers rarely add fertiliser to their sweetpotato crop, but the crop benefits from residual fertility when it follows or is intercropped with a fertilised crop such as maize. During land preparation, the mounds, beds or ridges may be constructed by heaping soil up and over the residues of previous crops or vegetation from fallow periods, to provide fertility for the sweetpotato crop and to loosen any compressed soil that might hinder root formation. Farmyard manure, compost, or green manures can be very beneficial, if available, but may be more likely to be applied in a kitchen/ backyard garden setting than in a large production field. Ash is rich in potassium, and can be incorporated into soils to help boost sweetpotato root formation.

Crop rotation and plot separation: As with any crop, it is advisable to rotate sweetpotato with other crops, or to have a fallow period between crops, in order to reduce the build up of diseases, such as viruses, and pests such as weevils and nematodes (though there are not many problems with the latter in SSA). Sweetpotato does well following cereals or legumes, but it is not recommended for it to follow other root and tuber crops, particularly cassava, due to their similar nutrient requirements. Sweetpotato has been reported to be a good first and last crop in the rotation following fallow. As the first crop, it leaves the soil easy to prepare for the next crop, although very fertile soils may produce lots of vines but few or no storage roots.

It is also advisable, though not always possible, to try to separate new sweetpotato fields from recently harvested or existing fields, particularly in environments where weevils and viruses are a problem. A barrier crop between old and new plantings, or a gap of >120 m can help prevent weevils from finding the new sweetpotato crop. If there is no choice but to re-use an old sweetpotato field then complete incorporation or removal of the old storage roots and vines (which can be burnt or fed to livestock) may help reduce the spread of pests and diseases to the new crop. If possible sweetpotato should only be grown once every three years on the same soil, in order to limit pest and disease carry over problems. This is particularly important where a new variety is being introduced into an area.

Access to land: In most parts of SSA, men are considered the owners of land and make all decisions regarding land allocation even when the crop such as sweetpotato is largely grown and controlled by women. It is critical for development workers to be sensitive to male control over land and ensure that men are consulted about project activities even where they are not directly involved.

6.3 Planting methods and when to plant

Sweetpotato is planted on mounds, ridges or flat beds. Good soil aeration is needed for storage root initiation and growth, and hence, for higher yields, and so the height of the mound or ridge is important. Mounds and ridges ensure good drainage and make it easier to harvest the mature roots, especially when harvesting is done in a piecemeal fashion as is often the case with sweetpotato.

Sweetpotato planted on mounds

Whether mounds or ridges or beds are used, and their sizes, varies among locations, usually based on what is actually most practical for farmers in that area. Where tractors or ox-ploughs are available, ridges are typically preferred, but ridges, mounds and beds may all be prepared manually. Land preparation for planting is the single most labour-intensive part of sweetpotato production. In households where there are labour shortages, sweetpotato may be planted in flat beds, although this typically results in lower yields than when ridges or mounds are used.

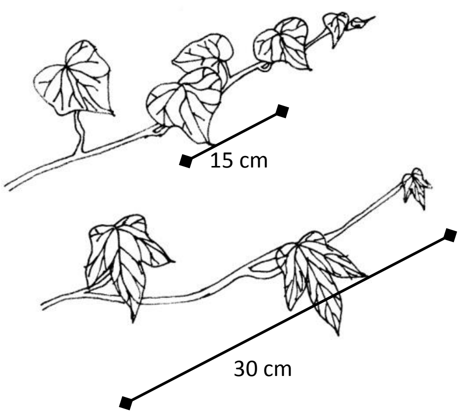


Figure 6.1 Internode lengths may differ between varieties, in some varieties 3 nodes =15 cms, in others 3 nodes =30cm length

Sweetpotato vine cuttings or sprouts, at least 3 nodes (about 20-30 cm [see Figure 6.1]) long are usually planted at a spacing of 25-30 cm between plants and 60-100 cm between ridges, although farmers like to experiment with different spacings and will usually plant varieties with trailing vines wider apart than those with semi-erect or erect vines. Where sweetpotato is grown on mounds, farmers usually plant 3 vines per mound with some space between the vines. At a spacing of 1 m x 1 m between mounds, 30,000 cuttings are required per hectare if 3 cuttings per mound are used. While on ridges 33,333 cuttings are required to plant a hectare at a spacing of 30 cm between plants and 1 m between ridges. Adjustment of spacing can be used to control storage root size, with closer spacing producing a greater proportion of smaller sweetpotato roots, which are preferred by some markets.

Sweetpotato being planted on ridges

To plant, a stick, machete or hoe is used to make a hole that most of the cutting (at least two nodes should be under the soil to enhance establishment and increase the number of roots that form) is placed into the soil, leaving only the tip exposed. The soil is firmed into place to ensure good contact between nodes and the soil. Sometimes lower leaves are removed before planting, but this is not necessary. Farmers sometimes hold cuttings for a day or two in a cool, shady place to encourage root initiation prior to planting. In many places farmers traditionally use two vine cuttings per planting hole, however this requires a lot of extra planting materials, and extensionists recommend

Planting sweetpotato cuttings

using just one cutting per hole and then gap filling any plants that fail to establish. On mounds, the three cuttings are planted towards the top of the mound but equidistant from each other in a triangle configuration. On ridges, the cuttings are planted either vertically or at a slant along the top of the ridge at the required spacing.

Sweetpotato is often planted after the priority cereal crops and other important cash crops, and when sufficient planting materials have been generated by the rains. However, in areas with a short rainy season these delays in planting can end up exposing the sweetpotato crop to drought periods and weevil damage, significantly reducing potential yields.

6.4 Staggered planting to get yield benefits and smooth supply

Planting sweetpotato as early as possible in the rainy season can be beneficial in terms of maximising the growing period and allowing early harvesting for household food consumption or early market sales. However, planting the whole sweetpotato crop at one time may lead to a glut at harvest; albeit there are differences between varieties in terms of their developmental times, and due to the piecemeal harvesting option for sweetpotato the root harvest can still be spread over some months.

Where the growing season permits, staggered planting, that is successive plantings made over a period of weeks or months can also have advantages. These include:

- larger total area planted through ratoon harvesting of cuttings from multiplication plots,
- spreading of risk of yield loss due to unreliable rainy season initiation and prolonged dry spells,
- less likelihood of labour shortage bottlenecks as the labour requirements are spread across a longer period of time,
- a smoother supply of roots over a prolonged period as opposed to a glut of root production across all farms in that area at the same time. The smoother supply has positive market supply and household food security implications, particularly as orange-fleshed sweetpotato becomes important for meeting daily household vitamin A requirements.

However, by extending the planting period, those parts of the crop planted latest may well be exposed to very dry conditions after the end of the rains which may cause yield reductions, weevil infestation, more severe disease incidence and increased likelihood of theft.

Sweetpotato is already a fairly flexible crop, as storage roots can be harvested as soon as they are large enough to eat or market, or can be left in the field to grow for an extended period if the market price is not favourable or the household already has enough food. Staggered planting will further increase this flexibility.

6.5 Intercropping sweetpotato

In some areas sweetpotato is intercropped with other crops, this occurs particularly in areas where land pressure is high or labour for constructing ridges is limited.

Intercropping in addition to improving crop and food diversity, can also: improve labour efficiency; increase soil fertility if nitrogen fixing intercrops are used; and reduce weed growth. Intercropping of sweetpotato is easier when it is grown on ridges. As with all intercropping, the cropping pattern should try and minimise the competition for light and nutrients between the two or more crops being intercropped. If intercropping sweetpotato with beans,

Sweetpotato intercropped with pigeon pea soybeans or peas, sweetpotato can be planted along the ridge and a row of beans on either side of the ridge.

Intercropped sweetpotato with soya beans (top), maize (bottom)

Despite intercropping of sweetpotato being quite common in many situations, very few studies have actually analysed the impacts of intercropping sweetpotato from any perspective. A recent study in Malawi found that yield and profit gains could be obtained by strip intercropping orange-fleshed sweetpotato and maize. Farmer evaluators preferred a planting pattern of two rows of maize with one row of sweetpotato because of the importance of maize in their food culture, although the data suggested two rows of sweetpotato with one row of maize was a more economically profitable design. When intercropped with fertilised maize, sweetpotato can take advantage of the residual fertiliser and there is some evidence that sweetpotato when strip intercropped with maize has less weevil infestation.

Studies in East Africa showed that pigeon pea intercropped with sweetpotato increased productivity. Not only does pigeon pea fix nitrogen, it also initially grows slowly so does not compete strongly with sweetpotato. Pigeon pea has a very deep root system which continues to grow during the dry season after sweetpotato has been harvested, and when nothing else can be planted. In Costa Rica, intercropping two rows of sweetpotato between cassava rows planted simultaneously and continuously over four years was beneficial to both crops and showed no major increase in pests or diseases.

Intercropping of sweetpotato with sugar cane was found to be economically profitable in South Africa. Relay cropping of sweetpotato with maize, with sweetpotato planted as the maize is nearing harvest, has also been used successfully by some commercial producers in Ghana's Central Region.

Sweetpotato can also be alley cropped between lines of agroforestry trees or shrubs, preferably fast growing leguminous species with open crowns that allow the sunshine through. These trees or shrubs are pruned regularly, and as the prunings decay they function as a green manure releasing nutrients and improving the physical properties of the soil. The local species of leguminous shrubs and trees will differ by site, however common species include: the river bean tree (*Sesbania sesban*); the ear leaf acacia (*Acacia auriculiformis*); the kassod tree (*Cassia cajan*); pigeon pea (*Cajanus cajan*); mother of cocoa or Nicaraguan cacao (*Gliricidia sepium*); and elephant ear tree (*Enterolobium cyclocarpum*). Farmers will want to experiment with different spacings, common spacings for the agroforestry species are 4-8 m between rows and 0.3 m within rows.

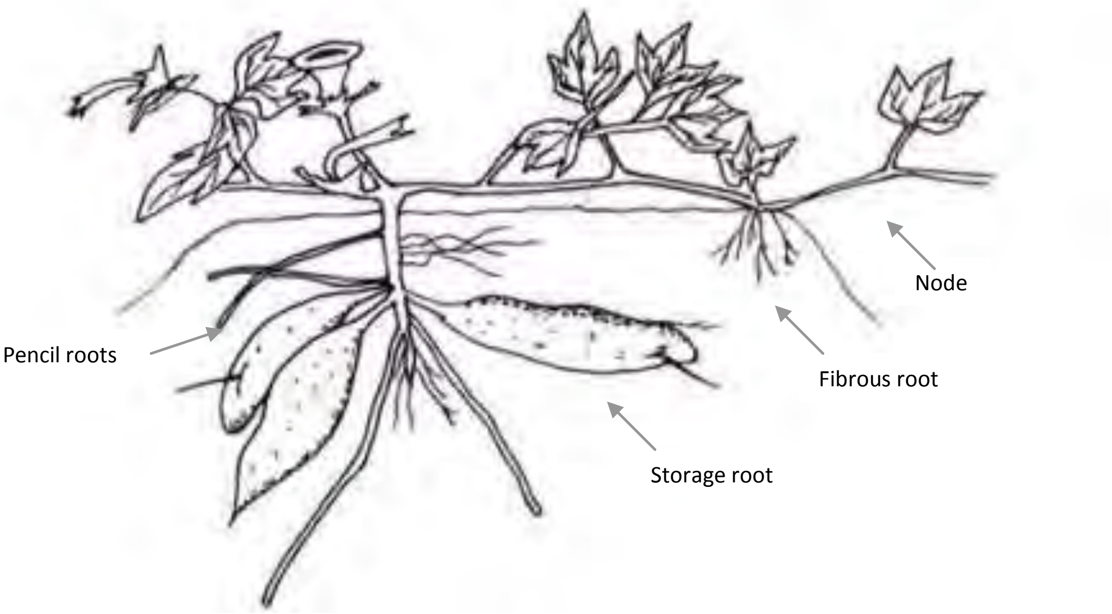
Sweetpotato in a mixed orchard

6.6 Sweetpotato requirements and physiological disorders

6.6.1 The different growth stages of sweetpotato

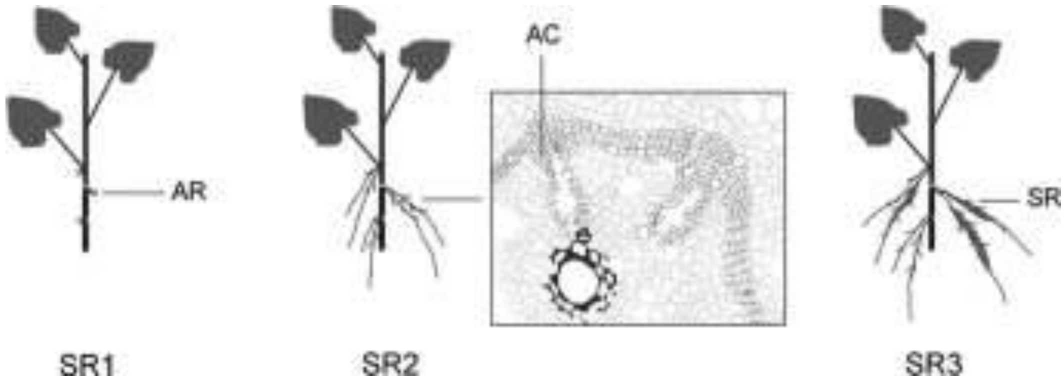
Sweetpotato generally requires a growth season of 4 to 5 months with optimum temperatures of 20°C - 25°C. It can however grow at a wide range of temperatures between 15°C and 35°C. Highest root yields are obtained during day time temperatures of 25 to 30^{0}C and night temperatures of 15 to 20^{0}C. Early maturing sweetpotato varieties can be harvested 3 to 4.5 months after planting, providing an important early source of food during the 'hunger season' in much of Sub-Saharan Africa. Temperature and the number of sunny days strongly affect sweetpotato yields. If temperatures are low the growing period has to be extended to 6-7 months, and if lots of overcast days occur the yield will be reduced and root quality will be poorer. The length of growth period affects the size of roots, a short growth period will result in a high percentage of medium and small storage roots, while the average mass of the roots will be higher if they are harvested later.

Figure 6.1 The sweetpotato plant



After planting, adventitious roots emerge from pre-formed root primordial at the nodes, and become fibrous roots, which under good water, air and mineral conditions have the potential to differentiate into storage roots, within the top 20-25 cm of the soil. Under unfavourable conditions roots may fail to differentiate into storage roots and become lignified pencil roots. Most of the storage roots develop from the initial adventitious root system of the plant, but in some varieties, or if hilling up is done, new adventitious roots (and storage roots) may develop, contributing to an extended piecemeal harvest. Storage root differentiation may begin as early as two to three weeks after planting, and on average between 4-6 weeks, depending on the variety and the environmental conditions. Therefore, favourable conditions during the first month after planting are of vital importance for storage root initiation and will strongly influence yield potential of a plant.

Figure 6.2 Early stages of root formation in the sweetpotato plant



Key: AR = adventitious root, AC = anomalous cambium; SR = Storage root initiation phases 1 ,2, 3

Source: Villardon *et al*., 2009

This early phase of storage root formation can be cut into three critical stages: initial establishment (SR1) and presence of at least one adventitious root (AR), differentiation of storage roots with the development of anomalous cambium (AC) (SR2), and the initiation of storage root bulking (SR3). Since temperatures influence rates of development, a measure of thermal time (growing degree days) is best used to describe how long it takes to get to each stage. In a field experiment with Beauregard, an early maturing US sweetpotato variety, SR1 was reached in 3 days, SR2 in 13 days and SR3 in 26 days. Stress, including excess heat, drought or flooding during these critical stages had the potential to severely reduce yield of this cultivar by resulting in lignified pencil roots, rather than storage roots.

By 8-12 weeks after planting all energy is devoted to the bulking of the storage roots. When many storage roots are formed on a plant, the weight per root is normally low, while few roots per plant normally results in big roots.

Depending on the variety, vine growth of a healthy sweetpotato crop, in which all requirements for maximum development are fulfilled, can be extremely abundant. Normal levels of pest and disease attack will neither result in much loss, nor will the crop suffer from nutrient deficiency symptoms. Although certain pests, such as leaf feeders, may eat parts of the leaves, a healthy plant is able to compensate for such damage. Vine length normally reaches a maximum half way through the final phase. At that stage the foliage of the crop looks most lush. After that, vine density decreases, because the plant uses more and more energy to fill the storage roots rather than to form and maintain the leaves.

A freshly harvested sweetpotato plant

Sweetpotato has three main growth phases, the tasks which need to be done during each of these phases are described in the Table 6.1.

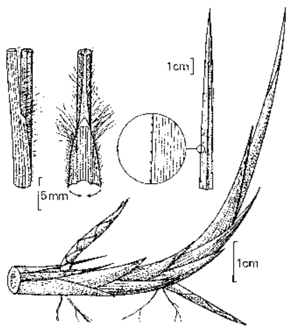
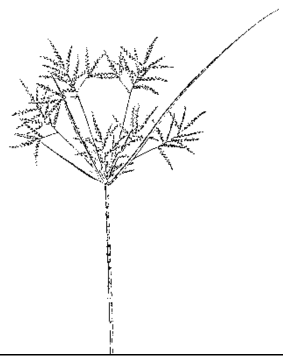
Table 6.1 The different development phases of the sweetpotato plant and associated tasks

Week		Development phase	Characteristics	Tasks
0 1 2 3		I. Establishment phase	• Planting • Fast growth of young roots • Storage roots start to differentiate • Slow growth of vines	• Planting • Gap filling • Avoid stress
4 5 6 7		II. Intermediate phase (storage root initiation)	• Initiation of storage roots • Fast growth of vines • Large increase in leaf area	• Weeding
8 9 10 11 12 13 14 15 16 17 18 ↓ 52		III. Final phase (storage root bulking)	• Growth of vines ceases • Rapid bulking of storage roots • Reduction of leaf area due to yellowing and falling • Harvesting ↓	• Vine lifting • Hilling up • Harvesting

6.6.2 Weed management

If weeds are not controlled during plant establishment and within the first two months after planting, they compete with the sweetpotato plants for nutrients and water and may harbour pests and diseases. The roots of certain spear grasses can even pierce and damage the sweetpotato roots. There are three main categories of weeds:

Table 6.2 Examples of the three main categories of weeds

Grasses	Sedges	Broad leafed plants	
			
Imperata cylindrica	*Cyperus esculentus*	*Lantana camara*	*Solanum incanum*
Spear grass[Eng] Mtimbi[Ksw] Ebiat[At], Lalang, Lusanke[Lg] Tofa[Hau], Ata[Igb]	Nut grass[Eng] Ndaga[Ksw], Ayaya[Hau]	Sleeper weed, wild sage[Eng] Mtululu[Ksw] Akayuukiyuuki[Lg], Omuhuuki[An] Magwagwa[Lo], Mukenia[Ki],	Nightshade, Sodom's apple[Eng] Mtunguja mwitu[Ksw], Entengotengo[Lg], Mutongo[Ki], Ochok[Lo],

Key: Eng – English; Ksw=Kiswahili; Lg=Luganda; At=Ateso; An=Ankole; Ki=Kikuyu; Lo=Luo; Hau=Hausa; Igb=Igbo

Weeds can be useful, some species can be harvested and fed to livestock, some can be slashed and used as a mulch on the soil surface, some can be composter and then dug into the soil to supply soil nutrients and organic matter thereby improving the soil structure.

Weeds are typically removed manually. Once the vines have grown together and covered the ridges, there is little need for further weeding. However, in very wet regions, further selective weeding may be required to remove stubborn or vigorous growing weeds. If these are few and scattered hand pulling can be practised otherwise a hoe is used gently ensuring that any storage roots remain covered by soil. Weeding is easiest when there is no crop to avoid. Removal of stubborn perennial weeds (such as, spear grass (*Imperata* spp.), star grass (*Cynodon* spp.), nut grass (*Cyperus* spp.) and couch grass (*Digitaria* spp.), and burial of annual weeds needs to be done during land preparation. During the making of ridges and mounds any new weeds should be buried under the soil, and then another weeding should be done during the first four to six weeks after planting before the vines cover the soil. Remember it is much easier to remove weeds before they have developed strong roots and stems, and much better to remove them before they disperse a new generation of seeds.

Mulching can reduce weed emergence significantly. Crop rotation also helps prevent the build-up of weed populations. Intercropping two plant types together can reduce weed problems due to the increased shade and crop competition with weeds through tighter crop spacing.

Commercial farmers might wish to use a herbicide such as Glyphosphate to control perennial weeds, this is best done at least two weeks before planting the crop. In Nigeria, Primextra Gold (active ingredients: atrazine and S-metolachlor) applied at 1.5 kg ai/ha 1 to 2 days after planting sweetpotato was found to be an effective herbicide for use in sweetpotato fields. Where the stubborn spear grass weed (*Imperata cylindrica)* is predominant, a mixture of Glyphosate+Prometryn/S-metolachlor at the rate of 3.5+2.0 kg ai/ha was found to control it when applied at 4, 8, and 12 weeks after planting.

Basic safety precautions should be followed when using herbicides; follow the instructions on the label, use the specified application rate, use protective clothing, pregnant or lactating women should not spray herbicides or pesticides, do not spray in windy conditions or the herbicide will drift sideways away from the intended field and possibly onto other crops, rinse the spray equipment after use and pour away the rinsing water into a soak-away pit not into or near to a river. Small-scale farmers may find herbicides costly and have difficulties regarding their accurate and timely application.

6.6.3 Vine lifting and hilling-up

If the soil is moist and the stem of a vine touches it, roots will grow from the nodes. Some producers lift these vines to prevent these roots forming into small non-marketable storage roots. If this is done, care should be taken to just lift the vines and not to turn them over or the leaves may rot.

Hilling-up is done to ensure the developing storage roots are well covered and not exposed to sun or attack by weevils. Soil is hoed up around the base of the plant, closing cracks in the soil caused by expansion of storage roots, or erosion of the ridge or mound away from the crown of the plant.

6.6.4 Physiological disorders

Many factors affect the yield of a sweetpotato crop: quality of planting materials; soil type, land preparation and fertility management; variety; climate; spacing; planting and harvesting dates; virus and pest infestation levels; and irrigation or distribution of rains.

Physiological disorders of sweetpotato can be caused by a range of environmental, physiological and genetic factors, and are often misidentified as pathological diseases. Some common physiological disorders and their symptoms, causes and prevention strategies are highlighted in Table 6.3.

Table 6.3 Examples of physiological disorders of sweetpotato and their prevention strategies

Physiological disorder	Symptoms	Causes	Prevention strategies
Mutations 	Roots have areas of different coloured flesh or skin	Sweetpotato has an unusually high natural rate of mutation	Use positive selection to avoid plants giving such roots, when selecting planting materials
Water blisters (edema) 	Small lumps (enlarged lenticels) on the outside of the roots.	Prolonged exposure of roots to very wet soils leading to lack of oxygen	Plant sweetpotato in well-drained soil. Ensure ridges or mounds are high in wetlands
Sun scalding 	Scalded areas are purplish-brown and prone to secondary infections	Exposure of roots to direct sun at high temperatures	Place sweetpotato roots in shade immediately after harvest
Growth cracks 	Cracks in root skin. More common on large roots. Nematode infested roots are more susceptible.	Cracks develop due to uneven growing conditions, especially uneven watering.	Cultivars differ in their susceptibility to this problem. Irrigation during dry spells.
Flattened stem (fasciation) 	Flattened stem with numerous leaves	Uncertain	Fasciated vines are usually rogued and should not be used as planting material.

6.6.5 Irrigation of sweetpotato crops

Irrigation is rarely used on sweetpotato crops in Sub-Saharan Africa with the exception of South Africa. Although sweetpotato is considered to be fairly drought tolerant, water is one of the most limiting factors for sweetpotato production and drought causes serious yield losses. The effect of drought conditions depends on when during the growth stage the water shortage occurs. The deep (0.75-0.9 m) and branching root system of sweetpotato enables the plant to absorb water in deeper soil layers than occurs in most vegetable crops. A well-distributed rainfall of 500 mm during the growth cycle is sufficient for high productivity. If necessary and available, irrigation can be used to ensure that the sweetpotato crop can be established in moist soil and has sufficient water throughout the growing season. Irrigation can also be used to reduce soil temperatures.

Most irrigation methods (e.g. furrow, drip, flood, and sprinkler) are suitable for sweetpotato. Furrow irrigation where alternative furrows are irrigated can be used when the crop is planted on ridges. Drip irrigation is currently practised under some research environments, and is the most water efficient method. In South Africa, drip irrigation has been found to be only suitable for well-drained soils with 10-15% clay content and high ambient temperatures. There is relatively limited information about the water requirements of sweetpotato, though it is recognized that adequate moisture is important during the first month of the crop, and it is generally agreed that the crop requires between 450 and 650 mm of water (which can be rain) well-distributed throughout the growing season. Once roots are established, they can survive reduced soil moisture regenerating once rains occur. Irrigation requirements are dependent on the soil type, the rainfall, the water quality and availability, the variety and the growth stage. In general irrigation twice a week is recommended up to 20 days after planting (DAP), once a week from 20 to 40 DAP, and once every two weeks from 40 DAP until harvesting. During irrigation the soil should only become wet to the depth of the crop root zone, and not further. Overwatering or prolonged periods of heavy rain can also be problematic as sweetpotato does not tolerate extended periods of very wet soils; reduced storage root development, water blisters and root rot may occur.

In coastal Peru, sweetpotato is frequently irrigated. The irrigation commences before planting in order to loosen the soil for easy land preparation, a light irrigation is then given to help plant establishment, frequent irrigation is carried out in the first 5-6 weeks after planting, and after hilling-up (see Topic 7) and prior to harvesting. A total of 2,000-3,000 m^3 of water per hectare per season is recommended, although this will vary by soil type and variety.

6.7 Nutrient needs of sweetpotato

All crops absorb nutrients from the soil, and when the crop is harvested these nutrients are removed from the soil. In order to maintain the nutrient levels of the soil, nutrients must be returned to the soil. This can be partially done through ploughing crop residues back into the soil and letting the plant materials decompose and return their nutrients to the soil, or by adding fertilisers (which can be in the form of organic manures and composts or chemical fertilizers). In Asia, sweetpotato vines are typically used as green manure. Plants need nutrients not only for their growth, but also to enhance their resistance against diseases.

Sweetpotato, as with most root crops, absorbs more potassium (K) but less nitrogen (N) and phosphorous (P) than maize does.

Potassium is the most important element for storage root development, and so in many places sweetpotato will benefit from extra potassium. This can be provided using ash, as ash is rich in potassium. However, it is not only the amount of potassium that is important, but also the ratio between the potassium and nitrogen to be supplied. The best bulking of storage roots occurs when the nitrogen and potassium are present in the soil at a ratio of about 1:3. Applying potassium during the second half of the crop's growth cycle helps promote development of a strong skin.

Nitrogen (N) if present in too high concentrations can result in abundant vine growth but poor root development. This is particularly damaging if nitrogen is applied after the middle of the crop's growth period. Although sweetpotato does well even on very poor soils, if nitrogen levels are too low the plants have limited vine growth and low yields.

Nutrients can be added to the soil in several ways.

Farm yard manure can be used, and is often more readily available than synthetic fertilizer. Rates of roughly 5 tons/hectare are recommended, but rates this high are rarely applied. As the nutrient content of all manures differ it is difficult to recommend application rates, and it is more sensible for farmers to experiment with a range of different application rates to see which produces the best crop on their field. Manure needs to be added a few weeks in advance of the crop being planted to ensure that it has time to partially decompose before the crop is planted. Uncomposted manure introduces weeds to a field and should be avoided.

Fertiliser mixtures such as NPK are commercially available in different blends. Very general sweetpotato fertiliser recommendations suggest: N (34-45 kg/ha), P_20_2 (50-101 kg/ha), K_20 (84-169 kg/ha) or complete NPK 6:9:15 (560-1,120 kg/ha). In Nigeria, they use NPK 15:15:15 (400 kg/ha). However as all soils differ it is best to experiment with different rates in your field or get a soil analysis done to obtain the fertilizer rate to apply.

Fertilisers (whether organic manures or industrial chemicals) can be applied by spreading the required quantity over the land, and then incorporating it into the soil prior to planting. The most efficient way of applying fertilizer, however, is to side dress in a furrow, applying and incorporating the required amount for each plant.

Research has found that if farmers have sufficient land to rotate their crops and keep some land fallow, the planting of *Mucuna* spp. (a nitrogen-fixing legume, commonly known as Velvet beans or Cowhage) in the field for two years before sweetpotato is grown can increase the storage root yield significantly. In trials this practice increased the root yield more than the addition of an NPK fertiliser, this was likely due to the *Mucuna* improving the soil structure as well as supplying macro and micro nutrients not contained in the NPK fertiliser.

The pH of the soil is also important as it affects the availability of the nutrients in the soil to the plant. Sweetpotato grows best in a slightly acidic to slightly alkaline soil with a pH between 5 and 7.5. If the soils pH is more acidic (e.g. <5) then agricultural lime should be incorporated into the soil before planting, a soil analysis test will determine the pH and amount of lime required.

While soil analyses can be used to determine whether the soil the sweetpotato crop is to be grown in is deficient in any nutrients, in Sub-Saharan Africa it is not common for farmers to access soil testing services. Nutrient deficiency symptoms in the sweetpotato plant can be useful to the farmer and extension agent in helping to identify nutrient deficiencies. If a plant experiences a nutrient deficiency, it will show certain symptoms, mainly in its leaves but its whole growth pattern could be affected.

Typical symptoms of plant nutrient deficiencies include:

- Unusual colours of different plant parts:
    - Chlorosis: leaves turn to a light green, yellow colour
    - Necrotic spots: dry light brown spots on the leaves where tissue has died
    - Purple colouration of leaves
    - Browning
- Leaves drop unexpectedly
- Plants are shorter than normal (stunting)
- Deformation of plant parts: e.g. thin or spindly stems, and curling leaves
- Die-back of stem and root tips
- Similar symptoms on young and old leaves can indicate deficiencies of different elements.
- However, be careful not to confuse deficiency with virus symptoms or plant characteristics.

Specific symptoms of potassium, nitrogen and phosphorous nutrient deficiencies are shown in the Tables 6.4-6.6. Information and photos of other nutrient disorders can be found on Sweetpotato DiagNotes http://keys.lucidcentral.org/keys/sweetpotato. Potassium deficiency is a common cause of low root yield. Root crops have a high requirement for potassium and several successive root crops may deplete the soil of potassium. Nitrogen deficiency is common on soils with low organic matter, or soils which have been cropped for some time without adequate fertilisation or manuring. Applying urea to a test area (e.g. one row within the crop) should make the test area visibly greener if there is a nitrogen deficiency. Volcanic and calcareous soils can bind phosphorous and make it unavailable to plant, and on acid soils aluminium toxicity can induce phosphorous deficiency.

Table 6.4 Symptoms of Potassium (K) deficiency on sweetpotato

Symptoms of Potassium (K) deficiency

- Short vines with short internodes and small leaves are the first symptoms
- Leaves are of a darker colour (dark green), especially at the edges
- Short and pale petioles
- Small, shiny brown spots emerge on the leaves, first on the bottom of the leaves and on old leaves
- Old leaves become yellowish or reddish, starting at the top of the leaves and developing via the edges to the leaf base
- Plants wilt faster and leaves easily fall off
- When experiencing heavy deficiency, the whole leaf becomes yellow except the leaf base and the leaf tissue just next to the veins that become dark green
- Low number of storage roots
- Storage roots are long and thin
- Storage roots are more easily infected by root rots and nematodes

Yellowing appears on the oldest leaves

Plants which received 100%, 14% and 1.7% of optimum potassium supply

Small necrotic lesions following inter-veinal chlorosis on a mature leaf

Spread of chlorosis and necrosis on older leaves

Source: O'Sullivan et al., 1997

Table 6.5 Symptoms of Nitrogen (N) deficiency on sweetpotato

Symptoms of Nitrogen (N) deficiency

- Leaves become light green to yellowish and dull in appearance
- Reduced growth of the vine
- Old leaves become reddish at the edges, yellowish in the middle, then reddish to brown all over
- Stems of old plants become reddish
- Short petioles
- Symptoms develop from the base of the plant to the top

A nitrogen deficient plot (front) compared with a plot fertilized with nitrogen (back)

Healthy (L) and nitrogen deficient(R) plants

Nitrogen deficient crop exhibiting limp yellow older leaves and reddening of veins on lower surface of younger leaves

Red pigmentation of veins on lower surface of younger leaves

Source: O'Sullivan et al, 1997

Table 6.6 Symptoms of Phosphorous (P) deficiency on sweetpotato

Symptoms of Phosphorous (P) deficiency

- Leaves are dark green to bluish with purple veins
- Reduced vine growth
- Premature senescence of older leaves, with a purple discoloration which then becomes yellow
- Interveinal chlorosis turning to necrosis in older leaves
- Small storage roots of irregular shape
- Purple colour on the storage roots is more obvious

Autumnal colours of senescing leaves in a phosphorous deficient crop, and numerous flowers (often a sign of stress)

Healthy (L) and phosphorous deficient (R) plants

Purple pigmentation of young leaves on P deficient plant

Severely stunted P deficient, 6-week old plant, showing purpling and subsequent senescence of older leaves and dark green of young leaves

Source: O'Sullivan et al., 1997

In addition to nutrient deficiencies, sweetpotato can also show symptoms of water deficiency, nutrient toxicity and diseases.

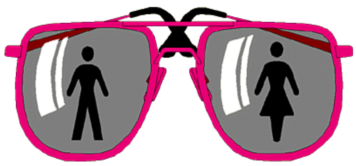
Water deficiency: Sweetpotato is relatively tolerant to drought compared to other crops. However, water shortage, especially at the stage of storage root initiation and for prolonged periods of time, can strongly reduce the capacity of the plants to produce a good yield. The number of storage roots will decrease and roots will be mostly small. Direct symptoms of water deficiency include wilting of the leaves and reduced growth. Drought stress can also make the plants more susceptible to viruses, insect pest attack, and to cracking of the storage roots.

Nutrient toxicity: Most nutrients can cause toxicity in plants when applied in excessive amounts. Too much nitrogen fertiliser causes the vines to grow lushly, but initiation and development of storage roots is hampered. At excessive nitrogen applications, sweetpotato plants will not flower, although it should be remembered that not all sweetpotato varieties produce flowers. Potassium toxicity is seldom a problem. Sweetpotato is fairly tolerant of acid soils.

Symptoms of virus infection: Plants showing symptoms like stunted growth, curly leaves, and/or changed leaf or vein colour are likely to be infected by a virus disease. Viruses are usually transmitted by leaf-sucking insects, such as aphids and whiteflies (see Topic 7 for full details). It can sometimes be difficult to differentiate between disease symptoms and nutrient deficiency or toxicity symptoms. Common differences between nutrient deficiencies and disorders caused by disease, particularly viruses, are that diseases often occur in a patchy pattern across a field, with healthy and diseased plants mixed together, a disease may affect only one variety and a disease may strike suddenly. By contrast, nutrient deficiencies often affect large areas or whole fields from the start of growth.

The lower two plants are infected by virus

6.8 Gender and diversity aspects of sweetpotato production and management



A thorough discussion of gender and diversity aspects in relation to sweetpotato is presented in Topic 11. Key gender and diversity issues relevant to sweetpotato production and management include:

Different people will have different understanding of management practices for sweetpotato, this may be due to experiences they have had while growing sweetpotato, the different roles they have in the production of sweetpotato, the resources they have access to, their information networks and access to training, and the importance of sweetpotato in their livelihoods.

It is important for development workers to understand who typically does which aspects of sweetpotato production and management, when these activities are done, how they are done, what constraints are typically faced by those doing them, and what activities there are that compete for that labour or the land itself. The gender cropping calendar in Appendix 11b can be a useful tool in building this understanding.

In addition to understanding who is typically doing what (and it should be recognised that this may differ by household or based on whether the crop is intended for sale or home consumption), it is also important to understand who owns, controls access to and makes decisions regarding the resources required for sweetpotato production. This would include which area of land the sweetpotato is grown on, the order of priority in planting and caring for different crops, whether the sweetpotato can be intercropped, the labour available for activities such as land preparation, ridge or mound formation, planting, harvesting, transporting and processing, access to irrigation to preserve planting materials, access to manure or fertilisers, and who keeps or can decide on the use of any income generated from sweetpotato sales.

These factors are all relevant in deciding what type of information to share, who to share it with, which people to target and when. The perceived importance of the crop in local livelihoods (which may differ by household type and between men and women), will influence the investment levels farmers are prepared to make in terms or time and resources.

In most parts of SSA, men are considered the owners of land and make all decisions regarding land allocation even when the crop such as sweetpotato is largely grown and controlled by women. It is critical for development workers to be sensitive to male control over land and ensure that men are consulted about project activities even where they are not directly involved.

6.9 Ideas for sweetpotato production learning-by-doing activities

These learning by doing activities have been designed to provide hands-on discovery learning opportunities. The full 10 day ToT course programme is described in Topic 13 of this manual. The following activities occur on day 6 of the 10 day ToT course, an overview of that day is given below.

Day	Topics	Intended Learning Outcomes	Activities
6	Sweetpotato production and crop management	*Participants will:* - Be able to help farmers set up a field experiment to compare different sweetpotato varieties or different sweetpotato management practices - Understand the different stages of the sweetpotato crop cycle and the management implications of each stage	- *Activity 6.9.1: Comparing sweetpotato varieties and management practices.* Setting up a sweetpotato field experiment (see details in 6.9.1) [3 hours] - *Activity 6.9.2: Advanced planning.* Development of their sweetpotato agricultural calendar and identification of the associated advanced planning and crop management activities and discussion of the gender roles associated with these activities and what changes are occurring (see 6.9.2) [75 mins] - *Presentation 6.* to cover the sweetpotato crop cycle (including post-harvest stages), participants then draw the crop cycle in their note books, and after a discussion add in the details of what has to be paid attention to during each stage [45 mins]

6.9.1 Comparing sweetpotato varieties and management practices

Intended Learning Outcome: Participants will be able to help farmers set up a field experiment to compare different sweetpotato varieties or different sweetpotato management practices

Timing: 3 hours

Materials: Flip charts, pens, rope, measuring tape, spades, labels, sticks, nearby field in which they can set up the experiment, Topics 3, 6, and 7 of this manual, pages 20-22 in the handout booklet 'What is damaging my sweetpotato?'.

Advanced arrangements required: Identify a nearby empty field with an area of about 30m * 30m, which participants can use for practising the designing and setting up of a field experiment.

Suggested steps:

1. Ask the participants to get into groups of 5 people. Explain that they are going to plan and design an experiment which they think would be useful to do with the farmers they provide services to. Remind them not to make the experiment too complex, one experiment should only test one topic at a time otherwise the results become too difficult to understand.
2. Ask them to discuss and agree on **the objective** of their experiment, and **what treatments** they will compare (too many or too few will not result in useful information, 3-5 treatments per experiment works well), make sure they remember they need to include a control treatment as well which could be the farmers' normal practice or the recommended practice. Remind them to think about:
    - What they are trying to find out

- What treatments they are going to compare
- Which farmers they should involve in planning, managing and evaluating the experiment *(recognizing that in this particular exercise farmers have not had a chance to participate as fully as would be the case in reality)*
- How often they would need to visit their experiment and what they would observe or measure at each of those visits
- How they could be sure that the results of their experiment were reliable? (e.g., mention the concept of replication, and that they should replicate their treatments at least 3 times to increase their confidence that any differences in results between treatments are due to the treatments and not to the soil type in the corner of the field where that treatment happened to be placed) *[Note: In a community it is also possible to replicate trials over farms. This is the way we do on-farm variety trials.]*
- How large would each of their plot sizes be
- How they would invite other farmers and extensionists to share the learning from the experiment, and how could they best present their experiment to these visitors (e.g. farmer to farmer explanations, clear labels, participatory evaluation by the visitors?)

Give each group a few empty flip chart pages to design their experiment, reminding them that they will need to present it to the rest of the participants [45 mins]

3. Ask each group to present their experiment's objectives, treatments, and design. Then ask the whole group to read through pages 20-22 on Experimenting in their handout booklet, 'What is damaging my sweetpotato?' Let the group discuss whether they need to make any further changes to their experiment [30 mins]
4. Move to the nearby field and ask each group to take one area of their field and set up as much as possible of their experiment, including the labels. Demonstrate to the participants how to lay out a right angle, to produce rectangular or square plots. [Note they will not have sweetpotato planting materials so will need to imagine these, they can lay out the different plots and make clear labels (including pictures) to show what is in each plot]. Explain that they have 1 hour to do this and then the whole group will tour each experiment. The facilitator will move around between groups ensuring they have thought carefully about the layout of the field e.g. any slopes, the size of their different plots, randomizing the treatments, and clear labelling. The facilitator can demonstrate simple field randomization. [60 mins]

5. As a whole group tour the field imagining that you are visitors to the experiments about 3 months after planting. Discuss:
   - any aspects of the layout which do not work well and how you could improve them?
   - when and how you would evaluate the trials with farmers?
   - why it would help farmers to create, visit and evaluate an actual field experiment as opposed to just hearing a presentation about it?
   - why labelling the different treatments is important?
   - why it is important that women as well as men farmers are involved, and that farmers from different wealth groups are involved? [30 mins]
6. Ask the participants to copy the objectives and design of their own experiment, and any of the other experiments they thought might be useful into their notebooks and to highlight the key points they need to remember when setting up experiments with farmers [15 mins].

6.9.2 Advanced planning

Intended Learning Outcome: Participants will understand the different stages of the sweetpotato crop cycle and the management implications of each stage

Timing: 75 mins

Materials: Flip chart sheets, marker pens, pencils, masking tape

Suggested steps:

1. Ask the participants to get themselves into groups of 10 people (preferably all working in the same geographical area so that the timing of their rainy seasons are similar). Ask them to identify two of them to act as facilitators to obtain as full a sweetpotato activity calendar as possible. Remind them:
    - to mark the rainy seasons and months of the year on the calendar,
    - to start by thinking carefully about all the activities they do related to sweetpotato production and postharvest aspects,
    - to include a way of showing who in the household typically does the job, and if it is a combination of the wife and the husband what percentage of the task is done by each (the sweetpotato cropping calendar in Appendix 11b may be helpful),
    - that they can use pictures and symbols as well as words in their calendar,
    - that they will need to present their calendars to the rest of the participants, and
    - to leave about 5 empty activity rows at the bottom of the calendar [30 mins]
2. Now ask the participants if they were to carefully conserve their healthy planting materials during the dry season, when they would need to select their planting materials and how they might conserve them during the dry season. Ask them to think about the process of multiplication of their planting materials in advance of the rains in order that they have sufficient planting materials for planting their whole field (they should specify the size of their field) at the start of the rains. They need to discuss and think about, and then add onto their calendar (in the empty rows at the bottom):
    - when they would select their healthy clean planting materials from their previous crop
    - how they would conserve those planting materials during the dry season, including their watering
    - preparation of their multiplication nursery bed,
    - taking of and planting of clean healthy cuttings from their conserved planting materials,
    - maintenance of their multiplication plot
    - harvesting of their cuttings (note this may include ratoon harvesting (several subsequent harvests) [20 mins]
3. Now have all the participants, move around each group's calendar one by one, as the owning group makes a brief presentation regards it. Encourage questions and discussions about:
    - problems the participants foresee with the need for advanced planning and conservation of planting materials
    - gender aspects of the labour and market returns currently involved in sweetpotato production, and what these gender roles mean regards who they need to train on sweetpotato production
    - other activities for which it is crucial to plan in advance
    - other aspects of farm and household operations and labour availability, as a reality check [25 mins]

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Notes on: ***Sweetpotato Production and Management***

TOPIC 7: SWEETPOTATO PEST AND DISEASE MANAGEMENT

IN

EVERYTHING YOU EVER WANTED TO KNOW ABOUT SWEETPOTATO

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Topic 7: Sweetpotato Pest and Disease Management

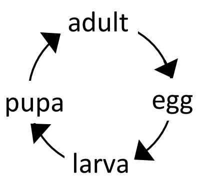
7.1 Where do sweetpotato pests and diseases come from and how do they spread?

In order to manage pests and diseases, it is important to know where they come from, how they spread, when they typically arrive and of course how to recognise and manage them.

It is important to understand the typical lifecycles, behaviours and modes of movement of pests and diseases in order to be able to: recognise them during different stages of their lifecycles, be aware of their populations building up to damaging levels, and in order to break their lifecycles and transmission patterns.

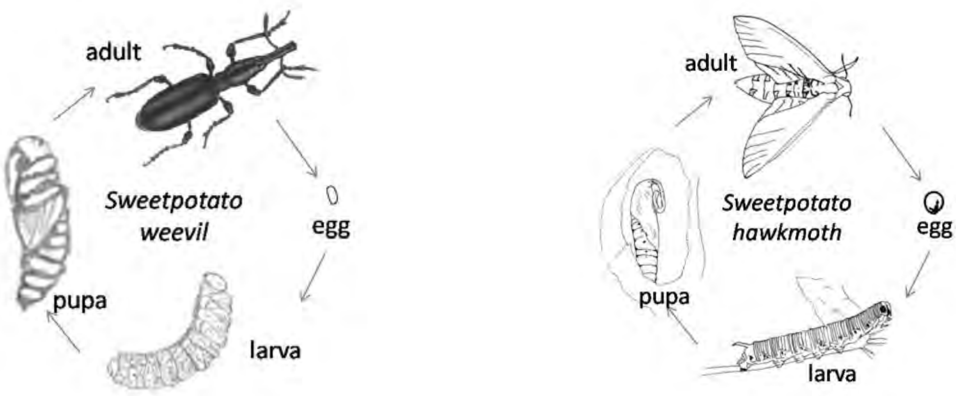
7.1.1 Insect lifecycles

During the course of their lives, insects pass through a number of stages. Often we are only familiar with one of the stages and cannot recognise the other stages. The adult stage is responsible for reproduction and may or may not feed. After mating, the female adult insect deposits her eggs in selected places (e.g. under leaves, on the soil surface etc.). The eggs hatch and the immature insects feed and grow and eventually become adults. However, for many insects the form of the immature insect looks completely different to the adult insect, and it can be difficult to imagine they are even related. The transformation process that an insect goes through as it changes from one form to the next during its lifecycle is called metamorphosis. Some insect species go through a complete metamorphosis whereby there are larval and pupal forms which do not resemble the adult insect. Other insect species go through an incomplete metamorphosis whereby a juvenile form called a nymph hatches from the egg, and then gradually gets bigger until it reaches adult size. These two types of metamorphosis are described below.

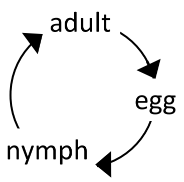


Complete metamorphosis (adult ⇨ egg ⇨ larva ⇨ pupa ⇨ adult): Some insects go through complete metamorphosis whereby a larva (e.g., a caterpillar or maggot) hatches from the egg, and usually feeds on the plant material surrounding it for a period of time, shedding its skin as it becomes larger; it then stops moving, and changes into a pupa. Although the pupa does not move around, internally there is a huge amount of change going on as its tissues are reorganised so that, when it emerges as an adult, it looks completely different, e.g., as a beetle, a moth or a butterfly and also behaves quite differently. This complete change of appearance and behaviour often makes it very difficult for farmers to associate the few small black beetles they see crawling on their sweetpotato plants with the mass of feeding tunnels and many small soft white larvae they find inside their sweetpotato roots a week or so later.

Figure 7.1 Lifecycles of the sweetpotato weevil and the sweetpotato hawkmoth, showing their complete metamorphosis from egg to larva to pupa to adult

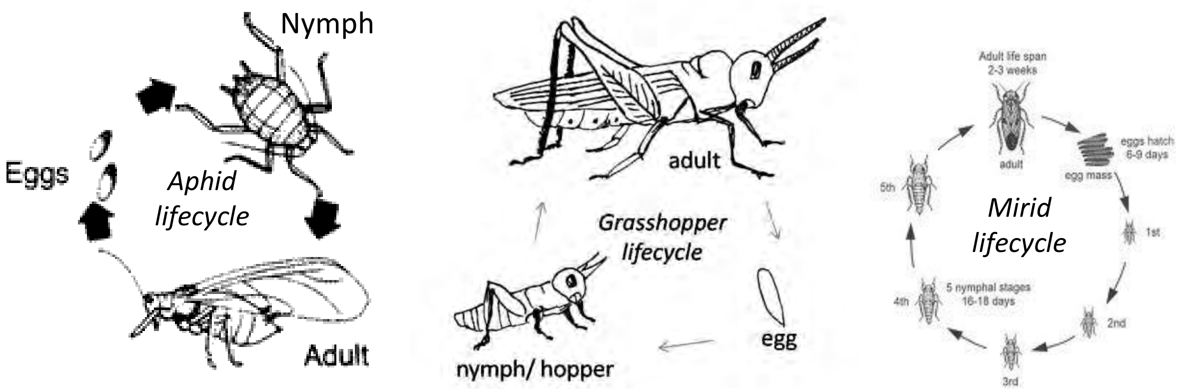


Helping farmers make this link between the adult and the egg, larval and pupal forms of an insect is the first step in helping them to recognise pest presence and damage before it reaches more serious levels. It is much better to try and prevent the adult insects from arriving or laying eggs than it is to have to try and deal with a large scale infestation of larvae chewing their way through your roots! The sweetpotato weevil *Cylas* spp., the rough weevil *Blosyrus* sp., the clear wing moth, the sweetpotato butterfly, the sweetpotato hornworm and armyworms are examples of sweetpotato insect pests which go through complete metamorphosis, where the adult and immature forms look completely different from each other.



Incomplete metamorphosis (adult ⇨ egg ⇨ nymph ⇨ adult): Some types of insects develop through a process of incomplete metamorphosis, whereby a nymph (as opposed to a larva) hatches from their egg. The nymph looks very similar to the adult insect, just smaller and lacking the wings and sexual organs, and feeds in the same way. Nymphs feed and grow through a series of moults, eventually becoming adults. Aphids, whitefly, grasshoppers and sucking bugs such as mirids are examples of sweetpotato insect pests which go through incomplete metamorphosis. Aphids and whiteflies can spread sweetpotato virus diseases. Grasshoppers can consume the leaves of sweetpotato plants, but are usually only considered a minor pest of sweetpotato. Sucking bugs such as mirids, typically feed on the young shoots and leaves causing black lesions and leaf puckering, severe damage can arrest plant growth if all tips are killed.

Figure 7.2 Lifecycles of the aphid, grasshopper, and mirid bug showing their incomplete metamorphosis (egg to nymph to adult)

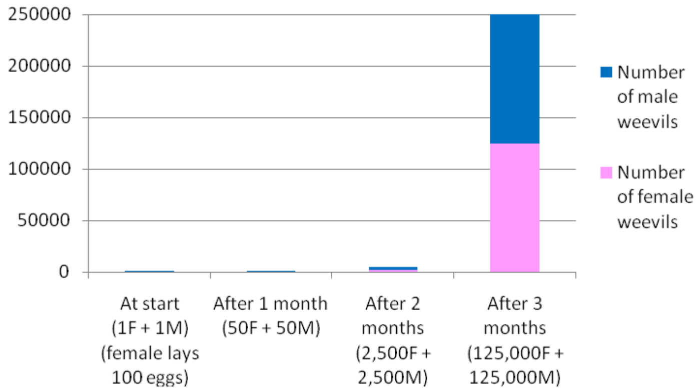


Insect development times and pest population build ups: The period of time it takes for an insect to develop from an egg to an adult is influenced by the environment. Warmer temperatures typically lead to faster development in insects, until the temperature become so hot that it actually prevents insects from developing and surviving. The type of food that the immature insect feeds on will also affect its rate of development. Some insects can feed on a number of different plants and plant parts during their lifecycle, and we refer to these plants as alternative host plants. For example: the sweetpotato weevil can also feed on the water spinach plant, *Ipomoea aquatic*, and can shelter on this plant between sweetpotato crops, and then infest the newly planted sweetpotato crop.

Rapid population growth of insects: Due to their short development times, whereby insects can often go from an egg to an adult that is laying yet more eggs within a month, high populations can build up over very short periods of time.

If one sweetpotato weevil lays 100 eggs that all hatch and develop into adults within a month, this would mean there would then be 50 female sweetpotato weevils who could mate and each lay 100 eggs, and one month later there would be 2,500 female sweetpotato weevils to feed and lay eggs on your crop plus 2,500 male ones. If these females all laid 100 eggs each, within a month there would be 125,000 females ready to mate and lay their eggs on your sweetpotato crop!

Figure 7.3 Rapid population growth of sweetpotato weevils



Whilst spectacular pest outbreaks like this do happen from time to time, many are avoided by the insect pests being killed off by pathogens/ diseases, predators or parasites or simply running out of food.

Pathogens: are micro-organisms such as bacteria, fungi or viruses that cause disease. They enter the body of the insect and live and multiply within it, weakening and finally killing the insect. Insects attacked by pathogens are usually swollen, a different colour, move more slowly than usual and stop eating. These pathogens are sometimes grown for use in insect biological control programs. The bacteria *Bacillus thuringiensis*, better known as 'Bt' is an example of a pathogen that is produced as a biological pesticide.

Predators: are animals or insects that hunt, kill and eat other creatures. Spiders, ants, ground beetles, earwigs, ladybird beetles, lacewings, and flower beetles are insects that are commonly found in sweetpotato fields and are helpful to farmers as they kill and eat sweetpotato insect pests. Therefore, we don't want to kill them off with insecticides!

Parasites: are organisms that enter the body of their victims and feed on them before eventually killing them. The parasites that attack insects are usually species of tiny wasps or flies. They lay their eggs on their victim and, when the eggs hatch, the larvae start to bury into and feed on their host.

Spread of insects: We have all seen insects crawling and flying and it is obvious that pest problems can spread when an insect flies or crawls onto a new plant. However, what is often less well understood is that insect pests can also be transported long distances by being blown in the wind or through the accidental movement of infested soil, plant materials (including human food), tools and shoes, and by getting a secret lift on livestock or vehicles. This is why phytosanitary officers inspect samples of food and other plant materials that are transported within and between countries to try and reduce the chances of pest problems spreading to new areas.

7.1.2 Lifecycles of plant diseases

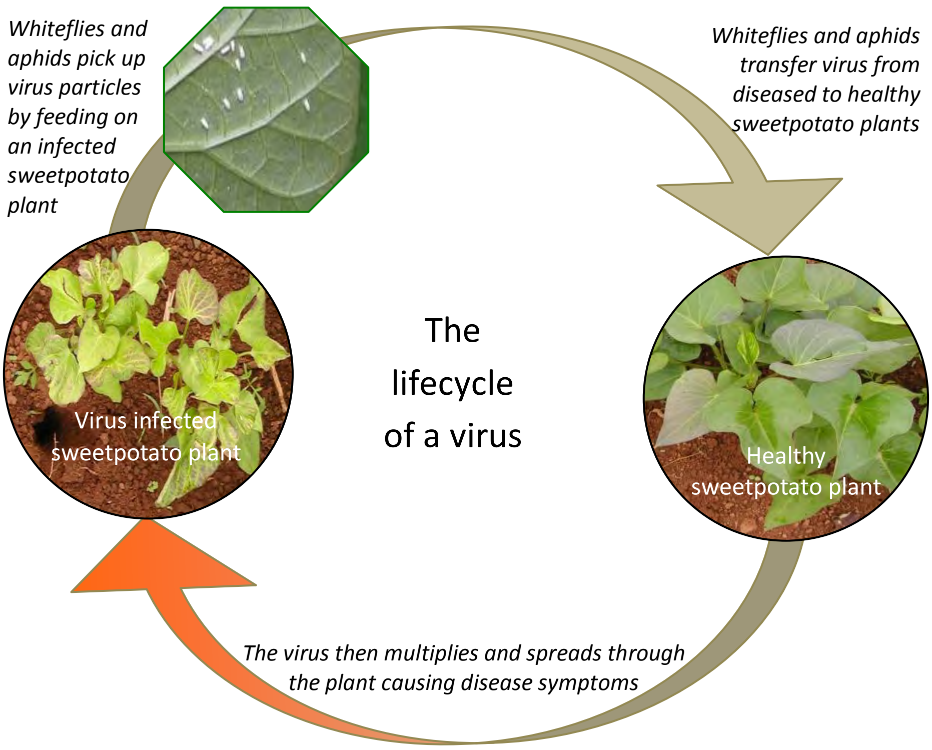
Plant diseases have varied and often complex lifecycles. But, as with the insect pests whose lifecycles and population build up start with an egg laying adult, so a plant disease's life cycle and population build up have to start with a previous infection of the same disease. Hence the importance of not using disease-infected planting materials or transporting disease-affected plants.

Fungal and bacterial diseases usually have special resting stages in which the disease organism can survive for long periods of time, often in dead leaves, and may be blown in the wind onto young, previously unaffected crops. These resting stages, when they arrive on a new host plant, can germinate and penetrate into the new host plant. With fungal diseases, you can often see their resting stages or spores as a fine dot at the tips of fine hairs often sticking out as a mat from the surface of a diseased leaf. Occasionally, as with smuts, these fruiting bodies can be quite massive and the spores form a very obvious fine dust. Common ways by which plants get infected by fungal and bacterial diseases are:

- by spores blown about in the wind from older diseased crops;
- by spores splashed up by heavy rain from leaf litter;
- from diseased planting material, especially if the crop is propagated vegetatively as sweetpotato is.

Virus diseases are unusual in that they do not have a form that by itself can penetrate the skin of a new host so as to infect it. Instead, they rely on another organism, often a plant-sucking insect that feeds on the crop such as a whitefly, leafhopper or aphid, to carry the virus from one plant and to insert it into another plant. We call the organism that plays this role, a vector. Just as the mosquito has first to feed on a human with malaria in order to transmit the disease to another healthy human, so the aphid or whitefly has first to feed on a diseased plant in order to transmit the disease to a healthy plant. In this way, the insect acts in much the same way as mosquitoes act in transmitting malaria in humans. So, if we can stop such insects feeding and moving from an old diseased crop to a new crop, this can prevent plants in the new crop becoming diseased. Also, just as only the Anopheline mosquito species can transmit malaria, so only one type of insect can transmit a particular virus. Thus, only whiteflies can transmit cassava mosaic disease or *Sweet potato chlorotic stunt virus* and only aphids can transmit *Sweet potato feathery mottle virus*. Once the plant is infected by the virus, the virus then multiplies and spreads through the plant so every part is infected with millions of virus particles (which are so tiny you need a special electron microscope to see them). In this way, the whole plant becomes diseased, an aphid or whitefly can pick up virus from any part of the plant and cuttings taken from even a healthy-looking part of a newly-diseased plant are probably infected.

Figure 7.4 Lifecycle of sweetpotato viruses



7.1.3 Integrated Pest Management

Integrated Pest Management (IPM) integrates an understanding of the ecology of the pest organism with a variety of tactics that prevent, avoid or reduce the crop losses caused by the pest. It combines monitoring, crop sanitation, and cultural, mechanical and biological control methods to discourage the development of pest populations and limits the need for pesticides in order to minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

The IPM practices are likely to differ by farm in their specifics as a result of the crops grown, the climate, the soil and surrounding landscape. However in general, biodiversity will be enhanced (temporal and spatial inclusion of different plant species and beneficial organisms) so that the farm is less susceptible to pest outbreaks, and a variety of pest management approaches will have been combined. If pesticides are being used they will be used only when pest densities have reached a particular level, the types of pesticides being used will be those which are less harmful to human and environmental health, and they will be being used in a way that reduces the risk to the applicator, other humans and animals including beneficials and minimises pollution of local water courses.

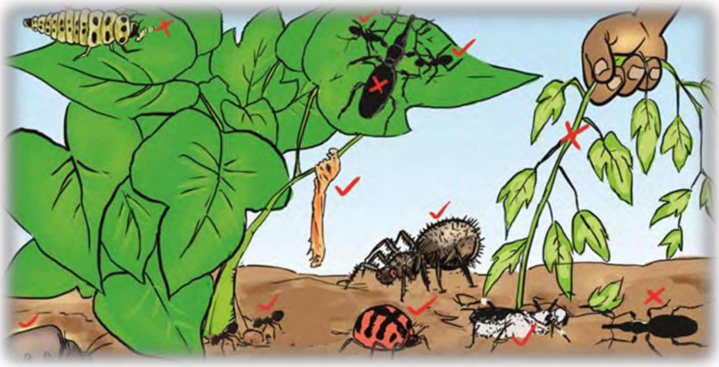
Monitoring includes regular scouting of the crop for signs of pest or disease damage, combines these findings with an understanding of how the different pests and diseases and beneficials develop and behave under various environmental conditions, and examines the effectiveness of control measures.

Crop sanitation aims to prevent or eradicate sources and vectors of pests and diseases. Planting materials should be healthy and pest and disease-free. Old plant materials, weeds or volunteer plants which could act as a source of infestation for the new crop should be removed and burnt, buried or used as fodder. Care should be taken not to damage healthy plants as this may facilitate the entry of pests or diseases. Care should be taken to work from the clean towards the more infested part of the crop to lessen the spread of pests and diseases to clean areas of the crop, and field workers should be made aware of the possibility of spreading harmful organisms on shoes, tools, clothes, livestock and through irrigation water. Crop rotation can help prevent the build up of crop specific pests and diseases in one area of the field.

Cultural control includes using pest and disease-free planting materials; growing the crop in ways that increases its resistance against pests and diseases by making sure it is not suffering from soil nutrient deficiencies, or water stress, and growing it in a climate that it is well suited to. If any of the growing factors are sub-optimal the crop will become stressed, and when plants are stressed they have less resistance to pests and diseases. A healthy plant may be more resistant to attack by pests or diseases. Also when you know there is a high likelihood of attack by a particular pest or disease, it may be possible to grow varieties that are resistant. The planting time of the crop can be adjusted so that it does not coincide with the main pest or disease infestation times. High plant densities should be avoided as they can result in weak plants that are more susceptible to pests and diseases. The diversity of plant species being grown in the surrounding area can be increased; intercropping can also help achieve this. Crop rotation can be practiced to reduce the build-up of crop specific pests and diseases.

Mechanical control involves the use of physical measures. Flying insects can be kept away from planting materials and nurseries with the help of net tunnels (see Appendix 5.2). Coverage of the soil with polythene can reduce larval attack of roots. Sticky traps, pheromone traps and insect-o-cutors can be used to trap flying insects. The seeds, bulbs, tubers or cuttings of some plants can be immersed in hot water or treated with hot air to kill some pests, soil can be solarised by covering with transparent polythene for several weeks enabling high soil temperatures to kill pest organisms. Flooding an area for a sufficient period of time can kill off some harmful organisms. Removal and destruction of infested planting materials can reduce spread of pests and diseases.

Biological control methods use natural enemies/ beneficials to control pests and diseases. Natural enemies include: predators; parasites and micro-organisms. Predators are animals that hunt and eat other animals, they generally have strong mouthparts, sharp vision and strong legs. Parasites also consume other organisms but do so by entering the body of their victims and obtaining nourishment from their fluids and tissues, which then weakens or even kills their victim (the host). The parasites that attack insects are usually species of wasps or flies, the adult usually searches for the host and then lays its eggs in or on the host's body (some parasite lay their eggs on the host's eggs, others on the host's larval stage, others on the host's pupal stage and others in the nymphal or adult stage of their host). These parasites' eggs then develop into larvae which feed inside the host, slowly weakening the host and preventing it from developing, while they themselves feed and develop and then pupate either inside or near to the host, the adult parasites then emerge and usually feed on nectar or pollen. Pathogens are micro-organisms (such as bacteria, fungi and viruses) that cause disease. They enter the body of their host, living and multiplying within it and eventually killing it. Insects attacked by pathogens are usually swollen, exhibit colour changes, move slowly, often stop eating and may be covered with a powdery substance. The bacteria, *Bacillus thuringiensis* (or Bt for short) is a well-known insect pathogen that is now commercially produced for use as a biological pesticide. When using natural enemies it is important that they are introduced as early as possible, optimal conditions can be created in the crop to help attract them e.g. attractant plants, or increased humidity. It is helpful to understand the biology of the natural enemies, and if possible to take care when harvesting so as not to eliminate the beneficial populations. To maintain their lifecycles, natural enemies must have some food source. This means that we have to accept the existence of at least a small number of pests in agricultural fields, otherwise natural enemies, especially those that eat only one type of food, cannot survive. If they starve, their disappearance can lead to a rapid increase in pest numbers.



Chemical control within an IPM approach, means selective pesticides are used which are less damaging to beneficials, selective application techniques are practiced such as restricting application to young plants or using seeds treated with a seed coating. Short persistence chemicals can be used. Chemicals must be applied in ways that reduce the risk to the applicator, the neighbouring human and animal populations and the environment – this involves wearing protective equipment, ensuring that pregnant or lactating women, or children, or those who prepare food do not spray pesticides, spraying is not done during windy conditions when the pesticide may drift into nearby areas, spraying equipment should be washed carefully and not rinsed in or near water courses, chemicals need to be well labelled and kept well away from food stuffs. Pesticide containers should be punctured after use to prevent misuse. It should be remembered that pesticides are poisons, not medicines. Pesticide application should be based on pest or disease monitoring observations as opposed to a regular calendar spraying schedule, and pesticide spraying should only occur when the economic threshold is reached (e.g. when the cost of spraying is lower than the cost of expected crop damage if no action were taken).

Most farmers are likely to want to combine a variety of different pest management practices, and will need to experiment with these different practices to find out which best fit their unique circumstances.

7.2 How to recognise and manage sweetpotato weevils

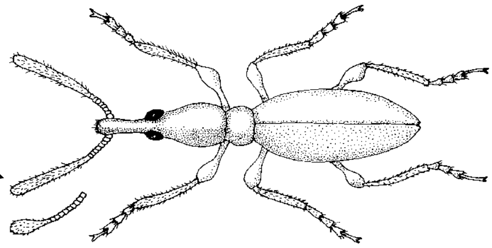
7.2.1 Recognising and understanding the lifecycle and behaviour of sweetpotato weevils (*Cylas* spp.)

The sweetpotato weevil (*Cylas* spp.) is the main pest of sweetpotato; it is found in all sweetpotato-growing regions of the world.

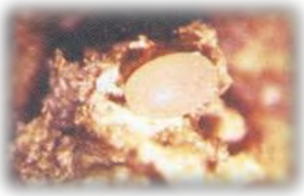
In its adult stage, it is an elongated, small black or metallic blue coloured beetle (5-6 mm long), that looks rather like a large ant. The male and female adults can be told apart by the shape of their antennae, the males' are straight while the females' have a club-shaped end.

Male weevil's antenna is straight

Female weevil's antenna is club-shaped



After mating, the female sweetpotato weevil lays eggs singly in holes that she has chewed into either the vines or exposed and easily accessible storage roots. While the female weevil can survive for up to 4 months, she typically lays all her eggs (50-250) within the first two months. If she arrives on the plant prior to its formation of storage roots, she will lay her eggs in the vines and leaves. If the storage roots have already formed she will search for exposed ones.



Sweetpotato weevil egg

Weevils cannot dig, so they access the sweetpotato roots through cracks in the soil when it dries out or by following the vine down into the soil and moving along the root system until they come across a storage root. The female weevils make feeding punctures and egg-laying punctures in the vines and roots. The punctures containing eggs can be distinguished by their dark colour, as the eggs are covered with a plug of weevil excrement. Whilst the developmental period will be affected by the temperature at that time, the egg typically hatches 3-7 days after it was laid.

The larva that emerges is legless, curved and whitish with a dark brown head. It will start feeding and, as it does so, it tunnels through the vine or root into which it was placed as an egg. It is this tunnelling that is so destructive to the sweetpotato crop, causing the holes and black tunnels so frequently seen in the roots. The feeding punctures and tunnelling reduce the market value of the roots and can act as a source of infestation if the infested root is placed next to undamaged roots. Even low levels of infestation can reduce root quality and marketable yield as the root produces a bitter tasting toxin, a terpenoid, in response to the sweetpotato weevil's feeding. This damage can continue even after the roots have been harvested. The larvae live for 11-33 days before they pupate.

Sweetpotato weevil larva

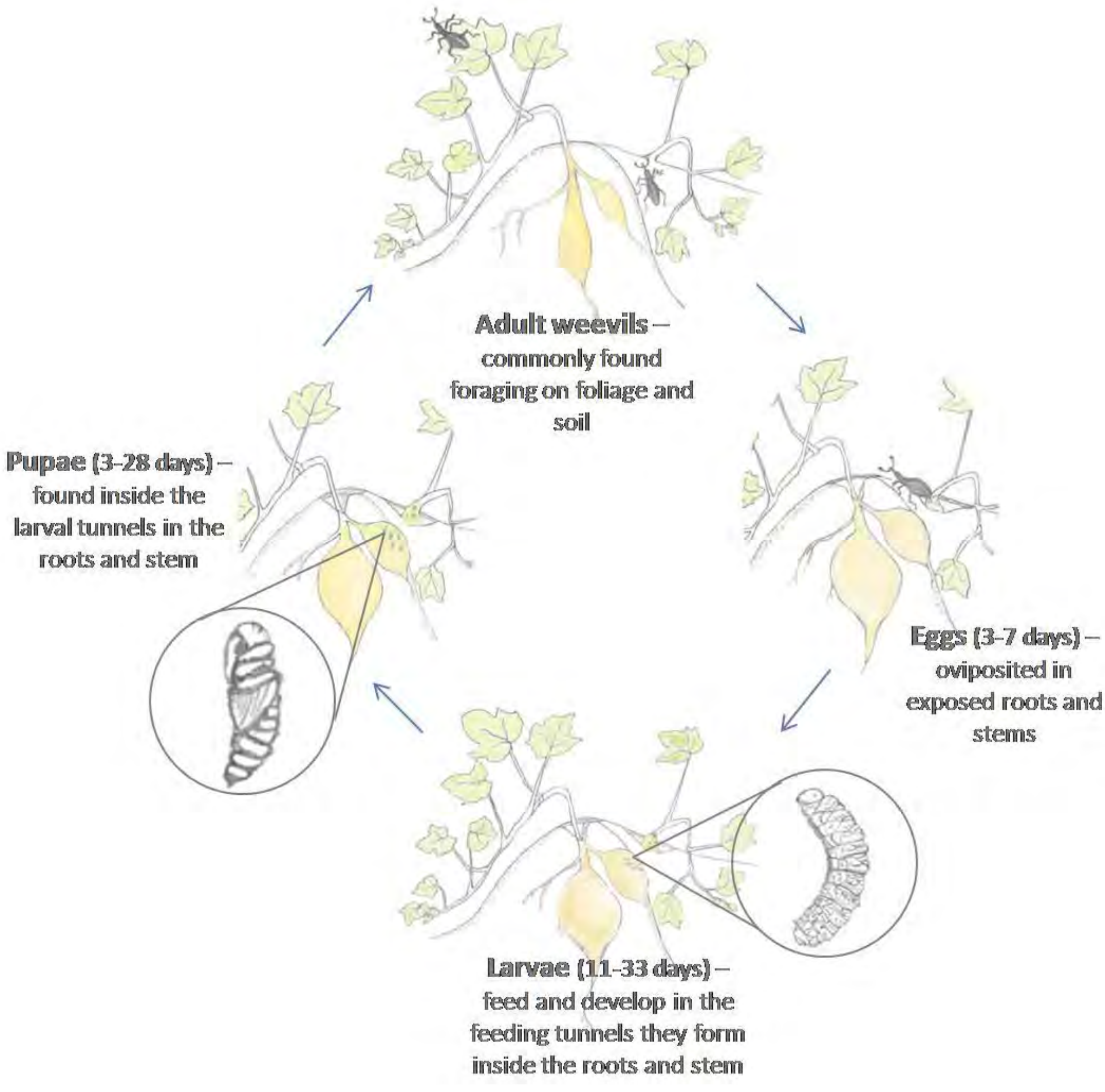
Sweetpotato weevil pupa

Pupation occurs within the larval tunnels, and lasts for 3-28 days after which the adult beetle emerges.

The adult is initially a light brown colour but, after about a week, its skin hardens and becomes dark brown in colour. The adult then leaves the root zone and starts to search for a mate. The female weevil produces a pheromone (*a chemical signal*) to attract the male. Male weevils typically move around on the foliage at night searching for the females, hiding under the leaves or in soil cracks during the day. They mate at night after which the female feeds and lays eggs during the day. The whole lifecycle from egg to adult typically takes 32 days. If many weevils are found on the foliage, this is an indication that the roots are heavily infested.

Adult sweetpotato weevil

Figure 7.5 Life cycle of the sweetpotato weevil, *Cylas* spp.



Source: Stathers et al., 2005

Sweetpotato weevil damaged roots

Sweetpotato weevil damaged vines

7.2.2 Sweetpotato weevil pest management practices

Farmers can integrate as many as possible of the following pest management practices to help reduce crop losses from sweetpotato weevils.

Hilling up: When conditions are dry and the soil cracks, sweetpotato weevil damage can become a serious problem as the insects can more easily reach the roots. The soil pulls away from the plant's stem, allowing easy access to the roots, and the soil of the ridges and mounds often cracks exposing the roots. For this reason, sweetpotato roots, unlike cassava, cannot be stored in-ground in the field for any significant length of time without investing in hilling up. Hilling up soil around the base of the plant and on the sides of the ridges to prevent or fill soil cracks can be used by farmers to give some protection to their crop. Hilling up is typically done during piecemeal harvesting: as the women move from plant to plant checking for large roots which they might take home to cook or sell, they also move the soil back up the ridges or mounds to fill any cracks. This practice can help increase root yields as well as reducing weevil damage.

Field sanitation: Carefully removing and destroying (through burning or feeding to livestock) all old vines or root residues left in the field can help break the sweetpotato weevil's and other pests' lifecycle by preventing them from surviving and moving to a newly-planted field. This is less easy to do in areas where there are two or more sweetpotato crops per year, and weevils can easily survive and find a fresh sweetpotato crop to infest. Highlighting the importance of not planting sweetpotato continuously in the same place (crop rotation), and ensuring the new crop is planted as far away from the earlier crop as possible (plot separation). If vines are typically left in the field to improve soil fertility, then they should be left in the hot sun until they are dead and not able to sprout before they are incorporated into the soil. During piecemeal harvesting, any infested roots which are found should be removed and used as food or feed or destroyed.

Any volunteer plants (sweetpotato plants that have developed from vines or roots accidentally left in the field), and alternative host plants should be removed to try and decrease the weevil population and reduce the chances of carryover of weevils from one season to another.

Using clean planting materials: It is essential to use clean (uninfested) planting materials. Weevils tend to lay their eggs in the older woodier parts of the vine. The feeding and egg-laying puncture holes of weevils are also not easy to see on vines, so it is sensible to take cuttings from the apical end of vines and to strictly avoid using the basal 10cm part of the vine. Planting materials should only be taken from healthy looking plants, as viral disease can be transferred to new areas if viral infected planting materials are used.

Timely harvesting to avoid soil cracking during the dry season: By planting the sweetpotato crop early in the rainy season, you increase the chances of it having been harvested before the dry season causes the soil to crack and exposes the roots to weevil infestation. In Vietnam, harvesting 2 weeks early reduced the loss due to weevils from >30% to <5%.

Crop rotation: It is essential to rotate sweetpotato with other crops, so that one part of your field does not have a continuous sweetpotato crop in it, which would lead to more chances of carry-over of weevils from one season to the next through infested pieces of roots or vines left behind in the field.

Season/Year 1

Sweetpotato	

Season/Year 2

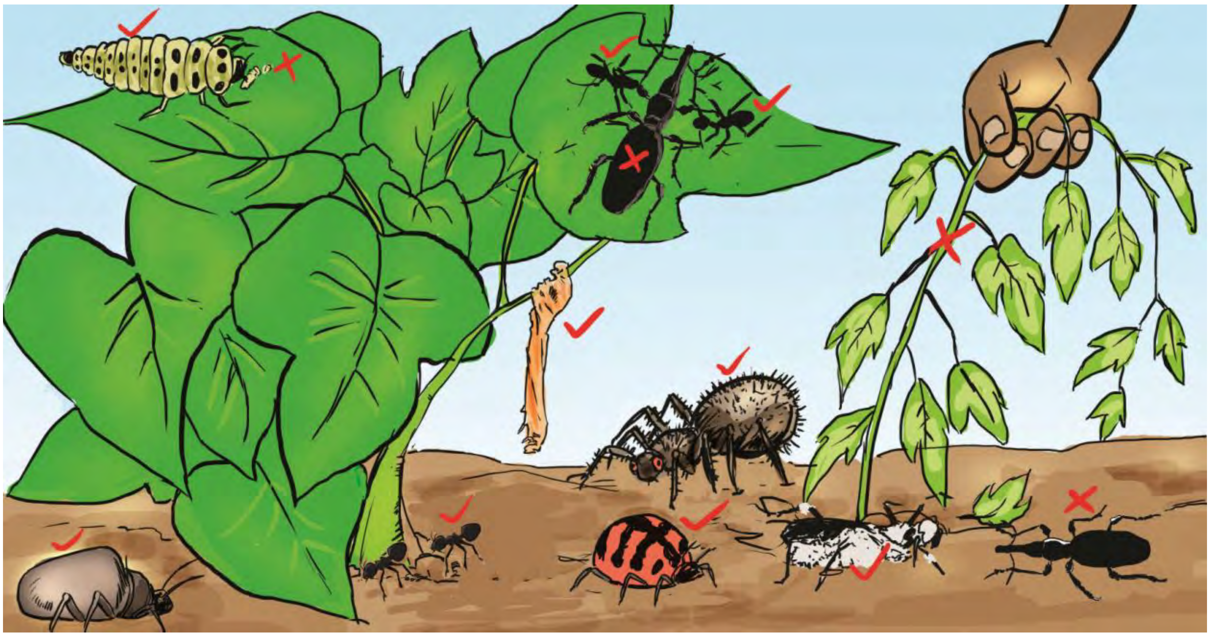
	Sweetpotato

Season/Year 3

	Sweetpotato

Plot separation: As sweetpotato weevils do not fly very often and generally only for short distances of 500m-1000m in order to find sweetpotato plants, planting your new field of sweetpotato some distance from existing and recently-harvested fields of sweetpotato can help reduce the likelihood of many weevils finding your newly planted field.

Natural enemies: Allowing predatory natural enemies such as ants, earwigs, ground beetles and spiders to move through the sweetpotato fields can help keep weevil populations under control. Ant nests can be moved to the sweetpotato field to enhance predation. In some places a solution of a pathogenic fungus, *Beauveria bassiana*, is used for treating planting materials and the soil in order to reduce weevil populations. Not spraying chemical pesticides in your field will help maintain natural enemy populations.



Support natural enemies to help reduce pest problems

Barrier crops: Using a barrier crop such as cassava, maize, bananas or sorghum in strips of at least 3-5m wide between existing sweetpotato fields and your newly planted sweetpotato field, can reduce the number of weevils' migrating to your newly planted crop. However in order for this to be the case, the barrier crop needs to have been planted sufficiently early enough to ensure that it is high enough to act as a flight barrier and one that may stop the weevils sensing attractive volatiles from sweetpotato plants.

Mulching: Adding mulch to the soil surface shortly after planting and maintaining the cover, helps to retain soil moisture and reduce the likelihood of soil cracking and weevil infestation.

Flooding: Flooding the sweetpotato field for at least 48 hours after completing the harvest will drown all the weevils in the soil.

Chemical control: Sweetpotato weevils are difficult to control using chemical pesticides as the egg, larval and pupal stages of their lifecycle are protected within the stems and roots, and not easily reached by insecticides. In some countries, planting materials are dipped into an insecticide prior to planting, which can delay pest infestation for several months.

Weevil resistant varieties: Breeders have not yet developed any sweetpotato varieties that are resistant to weevils. However, deep rooting varieties seem to be less attacked than shallow rooting varieties as the weevils cannot reach the storage roots so easily. Early maturing varieties can also escape weevil damage because they are harvested before the soils start to dry out, crack and provide easy access to the roots.

Pheromone traps: The sex pheromone of the sweetpotato weevil is commercially produced in some countries and lures containing it can be hung in the field above a container of soapy water. When the male adults arrive, attracted by the pheromone, they fall into the soapy water and die. However, in trials in Uganda, use of pheromone traps did not lead to a reduction in weevil damage of roots.

7.2.3 The rough sweetpotato weevil (*Blosyrus* spp.)

The rough sweetpotato weevil is not as serious a pest as the sweetpotato weevil; however, it does cause significant damage to sweetpotato roots in some parts of Africa.

The adult rough sweetpotato weevil is 8-9mm long and appears much larger than the sweetpotato weevil (*Cylas* spp.), its rough body and mottled markings enabling it to be well camouflaged against the soil. It lays its yellow eggs in groups around the edges of sweetpotato leaves and often folds the leaf edge over the eggs. It may also lay its eggs on the ground under fallen leaves. After hatching, the C-shaped larvae roll off the leaves onto the ground and drill themselves into the soil searching for food. When they encounter sweetpotato storage roots, they feed on the surface of them, making deep grooves on the skin. The damage looks similar to that of millipedes and white grubs, and can seriously reduce the market value of the roots, as deep peeling is needed to remove the damage and so yield losses result. However, unlike sweetpotato weevil damage, the rough weevil's feeding does not appear to trigger the production of bitter terpenoids in the root. After about 30 days of feeding the larva pupates in the soil for a period of about 20 days, before the adult emerges. The adults tend to hide under foliage on the ground during the day. Their purple to black excrement (~7mm in diameter), is often the main above-ground indication of rough sweetpotato weevils.

Most of the pest management methods described in section 7.2.2 for managing sweetpotato weevils are also applicable for rough weevil pest management.

Further information about and photos of sweetpotato pests and diseases can be obtained from the 'Manual for Sweetpotato IPPM Farmer Field Schools in sub-Saharan Africa' and the 'Sweetpotato DiagNotes' website https://keys.lucidcentral.org/keys/sweetpotato/

7.3 How to recognise and manage sweetpotato viruses

Viruses are so small you cannot see them. However, you can see their effects as, despite their small size, they are the most damaging group of disease organisms affecting sweetpotato in Africa.

Viruses only survive inside their living hosts and it is inside their hosts that they multiply and cause damage. All plant viruses need somehow to be spread from plant to plant and it is usually by an insect that feeds on the plant's sap. As the insect, such as an aphid or whitefly, feeds on a plant it simultaneously transfers the virus to that plant. Once the virus enters a cell in the new host, it starts to take over the management and control of that cell's processes and forces the cell to produce more viruses identical to itself – instead of the crop yield. These new virus particles then spread through the plant to infect more cells.

Common symptoms of virus infection in plants, including sweetpotato, are:

- diminished growth/ stunting causing the plant and leaves to remain small
- chlorosis (paleness) of the leaf tissue so that the diseased plants stand out from the rest of the crop. This can be general or in a pattern, often either between the lead veins in a mosaic or less well defined mottle, or along the veins to form a chlorotic network.
- misshapen leaves with an uneven or curled appearance
- pigmented leaves, often purple or yellow generally or in spots or rings
- reduced production of sweetpotato storage roots

There are two main sweetpotato viruses that affect sweetpotato in Africa (*Sweet potato feathery mottle virus* (SPFMV)) transmitted by aphids and *Sweet potato chlorotic stunt virus* (SPCSV) transmitted by whiteflies. Each virus by itself may cause only very mild symptoms but when a sweetpotato plant gets infected by both the viruses, a very severe disease results which is known as sweetpotato virus disease (SPVD).

Sweetpotato virus disease (SPVD) affected plant *(bottom left)*

The insects do not spread SPVD over very long distances. But if virus infected planting materials (vines or roots) are transported long distances, then the disease can be spread very widely.

In order to reduce the chances of your crop getting infected with virus disease:

1) **Always use planting materials cut from healthy-looking plants**. In addition:
   - Try and make sure the whole field that you take your planting materials from is healthy, as this will reduce the likelihood of taking cuttings from plants that have just been infected but are not yet showing symptoms.
   - Try to collect cuttings from young or mature crops (3-4 months old), as sweetpotato virus disease symptoms are harder to see in older plants.
2) **Remove and burn or feed to livestock any diseased plants as soon as they appear in young crops**. This practice of removing diseased plants is known as roguing and is very important to

reduce the spread of the virus within your sweetpotato field. Remember, if a plant becomes infected it won't yield very much anyway, so you are improving your chances of harvesting a good yield if you removed infected plants as early as possible. Otherwise, the insects can use them to spread the disease widely in your field and seriously reduce your yields. The neighbours of plants which have been rogued will soon fill up the gap and produce larger roots as a result, or you can gap fill with a new cutting.

3) **Plant sweetpotato varieties that are resistant to the disease**. Some varieties are rarely affected by virus disease. You can set up a replicated trial to test which varieties seem to be resistant to virus diseases.
4) **Avoid planting new sweetpotato crops where you grew sweetpotato last season**. If there are roots or vines from old diseased plants surviving in the soil, they may sprout and produce diseased plants from which infection will easily spread to your new crop. This is also an important aspect of weevil control.
5) **Plant your new sweetpotato crop away from old sweetpotato crops**. This will make it harder for the aphids and whiteflies to reach your new crop and bring the virus disease from the old crop. This is also an important aspect of weevil control.

Remove any diseased plants as soon as they appear, as this helps to reduce the spread of the disease

7.4 How to recognise and control fungal diseases

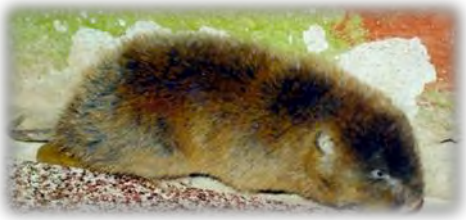
In addition to virus disease, sweetpotato plants can also be attacked by fungal or bacterial diseases. Fungal diseases on the leaves and stems of sweetpotato, typically cause circular brown or blackened areas called lesions. Other symptoms include powdery areas, or masses of filaments. Powdery areas are composed of fungal spores which can then spread the disease to other plants, and the filaments are the means by which the fungus spreads to invade new parts of the plant. *Alternaria*, *Phomopsis* and black rots are serious fungal diseases of sweetpotato (Table 7.1).

Table 7.1 Symptoms, mode of spread and recommended management of three fungal diseases

Alternaria diseases	*Phomopsis* disease	Black rot disease (*Ceratocystis* sp.)
Symptoms: Brown necrotic lesions on leaves, stems or petioles with typical bull's eye appearance of concentric rings and well-defined margins. Spots are usually surrounded by a chlorotic halo. Several lesion fuse, covering the leaf surface, followed by leaf drop. The ground under affected vines is often carpeted with blackened leaf debris. *Spread*: The fungus remains in plant debris on the soil as mycelium and conidia and can be spread by rain splash, irrigation water, wind and insects. High relative humidity is necessary for infection and sporulation.	*Symptoms*: Older leaves have irregularly shaped (~5-10mm wide) whitish to tan brown lesions surrounded by dark purple to brown margin, with black pinhead like structures in the centre. *Spread*: The fungus remains in plant debris on the soil, and its spores are released when the field receives moisture.	*Symptoms*: On storage roots, brown sunken spots (~0.5cm diam.) appear and then become firm, dry and black. They may coalesce to cover the whole root. The root area surrounding the spots has a bitter fruity taste. The plants appear stunted and chlorotic due to the cankers on the roots. Black rot can affect roots, plants and planting materials in field and storage. *Spread*: The fungus survives in soil and plant debris. Wounding increases the possibility of infection, although the fungus also penetrates through lenticels. Infected roots result in infected sprouts.
		
Symptoms of Alternaria *leaf spot*	*Old leaf symptoms of* Phomopsis	*Black rot inside and outside of root*
		
Black lesions on petioles and stems	*New leaf symptoms of* Phomopsis	*Black rot symptoms on roots*
Management: Rotate fields. Destroy and burn crop residues after harvest. Use clean planting materials. Avoid overhead irrigation. Fungicides such as mancozeb, chlorotalonil and dyrene may be effective but need testing. Plant resistant varieties.	*Management*: Rotate fields. Field sanitation should be effective as the fungus survives in affected crop debris left in the field.	*Management*: Rotate fields. Use clean planting materials. Use less susceptible cultivars. Carefully select roots to be stored. Control insects and rodents in stores. Planting materials may be dipped in Benomyl or Thibendazole fungicides, or roots sprayed before storage.

7.5 How to recognise and manage mole rats

In addition to the insects and plant diseases, there are some important vertebrate pests of sweetpotato such as mole rats, rats, porcupines, goats, cattle, guinea fowl, monkeys, baboons, elephants. Hedges or thorn fences can help protect sweetpotato against pests such as goats, cattle, wild pigs, and porcupines. Domestic animals should be tethered during the dry season to prevent them grazing on planting materials, conservation and multiplication plots.



Mole rats burrow through ridges and mounds feeding on the sweetpotato roots. They often spoil more roots than they actually eat. Signs of their damage and presence include: small mounds of freshly dug soil, sweetpotato vines being pulled back down into the soil, holes in the sides of ridges or mounds.

Rodent control works better if done on a large scale, so farmers should work with their neighbours to combine forces.

Stop that mole rat!

Farmers use the following practices to reduce rodent damage in their sweetpotato crop:

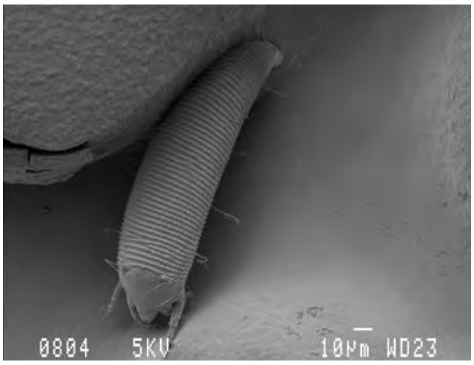
- Destroying rodent burrows.
- Keeping the field and surrounding areas clean of vegetation and rubbish to help reduce rodent populations.
- Digging a deep ditch around the perimeter of their field to prevent rodents from digging tunnels straight into the fields.
- Use of repellent materials inside the rodent's unblocked burrows. The leaves of some plants are repellent, or a mixture of burning cow dung and pepper to smoke the rodent out, or human faeces.
- The planting of deep rooted poisonous shrubs such as *Tephrosia vogelli* in the field as a repellant.

- The planting of sesame all around the perimeter of the field, as the roots are thought to be poisonous to mole rats and so they won't burrow through them.
- Scalding and drowning the rodent by pouring water or a hot water and pounded chilli pepper mixture into the burrow.
- Setting of traps in locations where children will not get hurt by them.
- Poisoning. Poisons are sometimes placed inside rodent burrows and sometimes sweetpotato roots are poisoned as bait. However, it should be remembered that **as rodents are mammals, any poison that is toxic to them will also be toxic to humans and livestock**, so poisoning is not recommended unless it can be very carefully supervised to prevent the baits being eaten by children or livestock.

7.6 How to recognise and manage erinose/ hairiness/ eriophyid mites

Erinose, a condition where sweetpotato leaves and vines become covered with a dense almost felt-like layer of white hairs, is caused by infestation by *Eriophyid* mites and can occasionally be a problem. The leaves and plants are also generally slightly stunted, the leaves and vines thickened, and the plants yield poorly. Occasionally, whole crops are affected but often the symptoms affect just one or a patch of plants, and often particular varieties. The mites feed in the bud and on young foliage of the sweetpotato plant, injecting growth substances into it at the same time so as to make the plant produce the dense mat of hairs (which provide protection for the mites). The adult mites are tiny and look like a speck of dust. The mites invade crops by being blown like dust particles in the wind. Little is known about them or how to control them.

The shoot on the right shows typical erinose symptoms (white hairs and stem thickening). The shoot on the left if unaffected and of the same variety



Scanning electron micrograph showing a highly magnified picture of the eriophyid mite which causes hairiness

The following control measures were developed and are used successfully by Patrick Makokha of the Siwongo Processing Company - OFSP Systems in Western Kenya:

1. Scout fields regularly, looking for hairy shoot tips, the first sign that a mite infestation is underway. Simply removing and destroying the hairy vine tips allows for rapid re-growth of uninfested shoots.
2. If the infestation showed signs of recurring, pruning was combined with a selective foliar fertiliser and miticide (mitigan/dicofol) spray and the new shoots that grew were erinose-free.
3. Erinose on the infested shoot tips has also been controlled by completely burying affected vines at a depth of ~30 cm for 4 to 5 days, during which time the mites die. The vines were then planted, and grew healthily.
4. Other farmer in Western Kenya report having cut the infested vines and then kept them in the shade for some time until the leaves drop off and then planting these vines.

7.7 How to recognise and manage sweetpotato storage pests

Pests and diseases can also damage sweetpotato after harvest. Actions can be taken to help prevent losses during storage of fresh or dried sweetpotato. These include making sure that:

- the product to be stored is in good condition (e.g. for dried products – sufficiently dried; and for fresh or dried products undamaged and uninfested by pests or diseases);
- the storage container in good condition (the storage container should enable the product to be kept: relatively cool; free from rodents [to prevent rodent entry it should be raised 1m from the ground, have rat guards fitted on its legs, and have no overhanging branches], birds, livestock and thieves; free from water damage [under a roof that keeps water out, and not sited in an area prone to flooding];
- good storage hygiene is practiced (the area around the store should be kept clean of rubbish or pests may breed in it; all residues of the previous seasons crop must be removed and the storage container cleaned thoroughly to prevent any carryover of pests to the new crop to be stored [sacks can be turned inside out and brushed and then dipped into boiling water and then hung to dry, stores with mud walls should be re-plastered each year to destroy any insects or spores hiding in the crevices, if storage pests such as the larger grain borer *Prostephanus truncatus* have bored into the wooden parts of the store this wood will need to be destroyed by burning to prevent cross infestation]);
- regular and careful monitoring of the stored produce and store for any signs of damage (such as small feeding holes in the product, large amounts of dust, presence of insects, strange smells) is done.

The main storage insect pests attacking dried sweetpotato are similar to those that attack dried cassava pieces. Adult stages of many of these stored product pests are shown below (Figure 7.6).

Figure 7.6 Stored products insects which attack dried sweetpotato (from top left: *Prostephanus truncatus* [larger grain borer (LGB)], *Rhizopertha dominica* [lesser grain borer], *Tribolium castaneum* [red flour beetle], *Sitophilus zeamais* [maize weevil], *Lassioderma serricorne* [cigarette or tobacco beetle], *Dinoderus minutus*, *Araecerus fasciculatus* [coffee bean weevil])

Stored product pests are generally small, less than 1 cm in length. The adults usually bore holes in the product and lay their eggs, the developing larvae then feed in the product producing feeding tunnels and dust – which causes both quantitative and qualitative losses of the stored product. Pupation usually occurs within the product and the adult insects then emerge, mate and lay the next generation of eggs within the product.

Pest management practices which can be combined to help protect and reduce damage to dried sweetpotato during storage include:

Sun-drying: The product must be well dried before storage to help prevent fungal decay. If the dried product becomes infested by insects during storage, it can be placed in the sun in a thin layer on a mat or sheet of plastic for a few hours to allow the heat of the sun to destroy the developing eggs, larvae and pupae within it. Regular re-drying also helps to reduce the moisture content of the product and enables the farmer to check thoroughly for any signs of infestation.

Parboiling: Freshly sliced sweetpotato chips can be parboiled for 5 minutes or more and then sun-dried, this helps to reduce likelihood of infestation and development of insects in the dried chips. Alternatively fresh sweetpotato roots can be boiled for 30-60 minutes prior to peeling, slicing and sun-drying. The hardness of the parboiled slices helps protect them from insect damage.

Salting: Salt applied at an application rate of 20-30g of salt per kg of freshly sliced sweetpotato chips prior to sun-drying has been found to negatively affect storage pest infestation and development of dried chips.

Rolling and shaking: The periodic rolling or shaking of sacks or containers of sweetpotato chips may kill developing larvae and thus reduce adult emergence and damage. However, it will also break some of the chips into smaller pieces.

Traditional protectants. Ash and plant materials can be added to the dried sweetpotato to repel, reduce the feeding damage or kill storage insect pests. However large quantities of these materials typically have to be added to the stored product to protect it and then later removed from the product before consumption, which can be quite laborious. Some plant materials might be toxic to human and care should be taken in selecting which ones to use.

Insect proof containers: The use of insect proof containers such as clay pots with sealed tops can be very effective in preventing insect damage during storage as long as the product is not infested prior to being placed in the container.

Storage duration: The duration that the dried sweetpotato is to be stored for will affect the control methods used; most storage insect pests take about a month to complete their lifecycle from egg to adult. If the product is only being stored for a few months, pest damage is unlikely to be high unless there was a very high level of infestation at the start of the storage season. However, the larger grain borer *Prostephanus truncatus* causes high levels of damage very rapidly and control measures need to be taken immediately if this pest is found.

Varietal differences: There appear to be differences in susceptibility to storage insect damage between varieties. If farmers are aware that some varieties are more susceptible to insect damage during storage than others the susceptible varieties should be consumed first.

Hygiene: Larvae of some of the insect pests can also survive in sweetpotato flour. If sweetpotato flour is left near the storage environment it may act as an important source of carryover of pests between seasons. The storage container needs to be carefully cleaned, and all the previous seasons' residual stored products removed before the new product is stored, otherwise the insects will move directly to the new product and start damaging it.

Fresh sweetpotato can be stored in pit or clamp stores for several months. Only roots with no damage from wounding during harvest, transport or insect pests should be placed in the store. The stores need to be regularly inspected every 3 or 4 weeks to check the roots for root rotting, rodent or insect damage. If any signs of these problems are found the whole store should be emptied and the affected roots discarded and the other roots used or sold quickly to avoid further losses. If there are no signs of any problems during the inspection the store should be resealed carefully and the shade roof replaced. Care should be taken during inspection as snakes are occasionally found in the stores. More information on fresh root storage is given in Topic 8.

7.8 Gender and diversity aspects of sweetpotato pest and disease management

A thorough discussion of gender and diversity aspects in relation to sweetpotato is presented in Topic 11. However, key gender and diversity issues relevant to sweetpotato pest and disease management include:

Different people will have different understanding, knowledge and experiences of pest and disease management, their information pathways will differ and may include grandparents, parents, neighbours, extension agents and materials, traders, and school. It is important for development workers to understand who is involved in the different sweetpotato production, storage and processing activities as this will influence their experiences and knowledge, and help in deciding who should be targeted for training.

If women are typically involved in monitoring, weeding and harvesting the sweetpotato crop they may have a great deal of experience in having observed pest behaviours in the field or the patterns of disease spread, and may have evaluated different pest management practices. If men have attended extension trainings on pest and disease management, they may have knowledge about appropriate pest management strategies.

It is important to find out who does which activities, what the typical information pathways are, and what understanding of pests and diseases and their management already exists in the focal community. This information can then be used to develop a training programme, targeting those who undertake the crop activities during the periods when pest and disease management strategies can occur and those who make the decisions regards what needs to be done in the field or store. Many farmers are unaware of the different stages of insect lifecycles or how plant diseases spread, by sharing this knowledge and helping farmers to make relevant observations one is empowering them to start experimenting with different practices. In some situations women may have limited access to irrigated areas in which to preserve and produce clean sweetpotato planting materials resulting in delayed planting, use of diseased planting materials, low yields, late harvesting and high weevil infestation. By helping these women and their husbands experiment with use of cleaning planting materials it may help influence decision-making around planting material conservation and quality and lead to higher productivity and reduced losses for the household.

It is generally advised that pregnant or breastfeeding women, those who prepare food and children should not be involved in spraying pesticides. Pesticides are poisons and children should be kept away from them. Children may be especially sensitive to health risks posed by pesticides because: their internal organs are still developing and maturing; in relation to their body weight, they eat, drink and breathe more than adults, possibly increasing their exposure to pesticides in food, water and the air; certain behaviours – such as playing on the ground or putting objects in their mouths can increase a child's exposure. Children exposed to pesticides, either *in utero* or during other critical periods face significant health risks including higher incidence of: birth defects, neurodevelopment delays and cognitive impairment, childhood brain cancers, autism spectrum disorders, attention deficit/ hyperactivity disorder, and endocrine disruption. Care must be taken in storing pesticides and ensuring they are not stored in food or drink containers which children or adults may accidentally consume.

7.9 Ideas for sweetpotato pest and disease management learning-by-doing activities

These learning by doing activities have been designed to provide hands-on discovery learning opportunities for the participants of the 10 day ToT course on '*Everything you ever wanted to know about sweetpotato*'. We hope by learning about sweetpotato in a hands-on way, these trainers will then train others using a practical learning by doing approach.

The full 10 day ToT course programme is described in Topic 13 of this manual. The following activities occur on day 5 of the 10 day ToT course, an overview of that day is given below. However, we hope these activities will also be used by trainers as stand-alone learning activities and as part of other training courses.

Day	Topics	Intended Learning Outcomes	Activities
5	Sweetpotato pests and diseases and their management	*Participants will:* - Be able to find field examples of the key pests and diseases of sweetpotato and explain and show the damage each can cause - Know a range of practical techniques for managing these key pests and diseases	- *Activity 7.9.1: Field hunting for sweetpotato pests and diseases and learning how to manage them.* collection of infested roots, damaged and diseased leaves, some observation of insect activity in the sweetpotato field, group discussion and brainstorming on where these pests and diseases come from and how they spread (including whitefly if possible). Include practice and discussion of hilling up and rouging of SPVD affected plants (*see 7.9.1*) [85 mins] - *Presentation 7a*. Lifecycles of key sweetpotato insect pests and diseases [30 mins] - *Activity 7.9.2: Hidden damage.* Dissection of infested roots to try and identify different lifecycle stages of *Cylas* weevils, and to calculate what percentage of the root is physically lost due to weevil damage. [*Note: facilitator should prepare some weevil infested roots in advance*] *(see 7.9.2)* [1 hr] - *Presentation 7b.* Sweetpotato pest and disease management practices (including mole rats) followed by discussion [45 mins] - *Activity 7.9.3: Training others on key sweetpotato pests and diseases.* Development of training presentations and activities on a range of key sweetpotato pests and diseases. *(see 7.9.3)* [1 hr 45 mins]

7.9.1 Field hunting for sweetpotato pests and diseases and learning how to manage them

Intended Learning Outcome: Participants will be able to find field examples of the key pests and diseases of sweetpotato and explain and show the damage each can cause

Timing: 85 mins plus transport time

Materials: A nearby young crop with SPVD in it, and a field which previously had sweetpotato in it and a mature or old sweetpotato crop which participants can explore and find diseases and pest damaged sweetpotato plants in; 20 digging sticks; 8 buckets for carrying infested roots; 8 sacks; 20 transparent collecting pots or jars with lids with a few small holes in them; 20 magnifying lenses; participants should carry their notebooks and pencils; flip chart and stand; marker pens; tape.

Advanced preparations: Identify one nearby field with a young crop with SPVD in it, a field which previously had sweetpotato in it, and a mature or old sweetpotato crop, which participants can explore and find diseases and pest damaged sweetpotato plants in.

Suggested steps:

1. Split the participants up into small groups of ~6 people, explain that you will be visiting nearby sweetpotato fields in order to identify sweetpotato pest and disease problems. These problems could damage the roots, the vines and leaves, or the whole plant. They should also be trying to find the insects or other types of pests which have caused the damage and collect them in the collection jars to then show to the other groups. [5 mins]
2. Journey to sweetpotato field.
3. Pest and disease hunting. Give each small group a couple of digging sticks and collection jars, and a bucket or sack. Ask each of the groups to cover different areas of the fields. Give them 20 minutes to hunt for insect pests, and signs of pest and disease damage on sweetpotato - which they should collect samples of for the field discussion session. Remind them that they should try and observe the pests in action to gain a better understanding of what the pests do and how they damage sweetpotato. While the groups are hunting, the facilitator must move around between the groups ensuring that each group sees some virus disease, some aphids and whiteflies, and some weevil damaged roots. [20 mins]
4. Call them for the discussion under a shady tree near the fields. Ask each group to display their infested roots, leaves etc. and collection jars on their sack. As a whole group move around from sack to sack hearing about what each of the small groups observed and collected. If they have all collected similar things, speed up the exercise by asking subsequent groups to describe and show anything different they saw or collected. [20 mins]
5. Using open probing questions, the facilitator should ask the participants to share their observations and thoughts on:
   - what the pest was doing when they saw it,
   - how it causes damage,
   - where it might have come from,
   - how it survives during the season when there is no sweetpotato crop in the field,
   - how diseases spread,

   Ask one of the participants to act as a rapporteur and record the suggestions and questions on a flip chart. Pack the plant parts and collection jars containing the insects back into the sacks ready to take to the training room. [20 mins]
6. The facilitator should take the group back into the field, and ask them what they might do to help prevent pest or disease infestations in their sweetpotato field, and what they can do if such infestations do occur to prevent them from spreading and causing further damage. The importance of clean planting materials, resistant varieties, field sanitation, regular monitoring, natural enemies, hilling-up, regular roguing and timely harvesting should be discussed. Each participant should practice some hilling-up of exposed roots and some roguing of virus infested plants. [20 mins]

7.9.2 Hidden damage: the importance of understanding insect lifecycles

Intended Learning Outcome: Participants will understand the different life cycle stages of the sweetpotato weevil, and which stages cause serious damage

Timing: 1 hour

Materials: About 50 weevil infested sweetpotato roots; 20 wooden boards; 20 sharp knives; 20 magnifying lenses; 40 dishes or plastic bags; 1 set of scales for weighing the damaged and undamaged portions of the sweetpotato roots; participant's notebooks and pencils.

Advanced preparations: Collect some weevil infested sweetpotato roots a couple of weeks before the training course. The participants may find some during their field hunt but, in case they do not, the facilitator should be sure they have some for the participants to dissect to see the eggs, larvae, pupae and feeding tunnels. This may require artificially investing roots in the laboratory if field invested examples are not easily available at the time of the course.

Suggested steps:

1. Remind the participants that they saw and collected damaged sweetpotato roots and vines in the field. Working in pairs, you now want them to cut open these roots (and vines) and look for different life cycle stages of the insect pests inside the roots [*Note: they will have just had a lecture on the lifecycles of key sweetpotato insect pests and diseases*]. Each pair should work with at least 5 damaged roots. They need to weigh their roots at the beginning before they start cutting them, and record this total weight in their notebooks. They should then carefully begin to cut open the roots and search for the different lifecycle stages in the root, and investigate them using their magnifying lenses: they can draw a sketch of each of the different life cycle stages they find. As they cut up the roots, they need to keep the undamaged portions on one side and the damaged portions on the other side. The facilitator should move around the pairs helping them to: identify the eggs, larvae, pupae and adult stages of the sweetpotato weevils; ensuring they see the feeding tunnels; helping them to separate the damaged (inedible) parts of the roots from the undamaged parts. [30 mins]
2. When they have finished dissecting their roots they can put all the damaged portions into one bag and weigh them and record the weight. They can then do the same for the undamaged portions of the roots. They should then calculate what % of the total roots was inedible as a result of this insect damage. [5 mins]
3. The facilitator should then ask the groups what they have learnt from the exercise. Areas to probe include:
   - how important it is to understand what the different lifecycle stages of an insect look like so that farmers can link the presence of the seemingly harmless adult stage with the damage that occurs later caused by the larval stage?
   - how might they reduce the spread of these pests and limit the damage they cause?
   - what proportion of the edible roots can be lost due to sweetpotato weevil infestation?
   - what effect does this damage have on the marketing of sweetpotato weevils?
   - if you stored weevil infested roots next to clean uninfested roots, what might happen? [20 mins]
4. Clearing up [5 mins].

7.9.3 Training others on key sweetpotato pests and diseases

Intended Learning Outcome: Participants will have experience in using their field observations to develop training approaches and materials for training others (extensionists or farmers) on sweetpotato pests and diseases

Timing: 1hour and 45 mins

Materials: The root and vine and insect materials they collected during the field hunt that morning; flip charts; 40 marker pens; masking tape; magnifying lenses; 3 packs of stickers/ post-it; participants' notes books and pens

Suggested steps:

1. Divide the participants into small groups (~3 people per group) and allocate each group a sweetpotato pest or disease (e.g. sweetpotato weevil, sweetpotato virus, mole rats, rough sweetpotato weevil, armyworm). Explain that each group has 20 mins to prepare a 5 minute presentation, folk drama or role play about their pest or disease and the damage it causes farmers. Remind them that these presentations they are developing may be useful for them when they come to train others. [25 mins]
2. Ask each group to share their presentation, remind them they have a maximum of 5 minutes only, and ask someone to act as the timekeeper. Ask the other participants to use stickers to make quick notes after each presentation on the things they liked about it, the information that was missing or incorrect in the presentation and a suggestion for how the presentation could be improved (one sticker per presentation). Make a flipchart page for each presentation onto which those watching can stick their review comments (this means at the end each small group will be able to look at all the comments about their presentation and get ideas for how they could have done it differently). [1 hour]
3. The facilitator can use the presentations as a way of assessing understanding of the topic by participants, and to help them start to think about how they will share the knowledge they are developing with others. The facilitator should invite each small group to visit the flip chart page which has comments about their presentation on it, and give them 5 minutes to review and discuss those comments, before opening a 10 minute group discussion on the presentation process. The facilitator must remind participants that we learn continuously, and that listening to and responding to feedback from others is a very important part of improving our performance. [20 mins]

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