CHALLENGE THEME PAPER 2: SUSTAINABLE SEED SYSTEMS

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Overall Challenge: How do we assure the timely supply of adequate quantities of quality sweetpotato planting material, including improved varieties, to smallholder farmers in Sub-Saharan Africa (SSA)?

BACKGROUND

Seed systems for vegetatively or clonally propagated crops such as sweetpotato fulfill a number of critical roles, namely:

The timely provision of planting material of appropriate quality for smallholders.

The efficient dissemination of new improved varieties from breeding programs.

The provision of replacement planting material following natural disasters or in times of crisis or unrest.

The provision of improved planting material for clonal crops has a proven track record in poverty alleviation through raising crop productivity, both through improved seed quality and through the dissemination of improved varieties with their associated pro-poor traits. The provision of planting material of appropriate varieties is also often seen as a key intervention to rehabilitate farming systems following natural disasters such as drought, civil unrest or conflict, and in assisting the return of displaced persons. An example of the potential impact of improved seed systems in clonal crops is given by the adoption of the International Potato Center (CIP) sweetpotato seed technology (virus testing and tissue culture) in the Shandong province of China in the period 1988 to 1998. The technology was adopted over 80% of the production area of the province, which represents 12% of global sweetpotato production, amounting to some 17 million tons per annum, and resulted in average yield increases of 30%. The economic impact of this intervention was later estimated as providing an annual productivity increase valued at $145M per annum by 1998 (Net present value [NPV] $550M; Internal rate of return [IRR]of 202%), and the agricultural income of some 7 million smallholder farmers had been raised by some 3-4% (Fuglie *et al.*, 1999).

Recent survey evidence also indicates that the lack of sustainable seed systems is one of the key constraints to improving sweetpotato productivity in Sub Saharan Africa (SSA). For example, a CIP survey of National Agricultural Research Systems (NARS) priorities in 2005 reported that “virus management, seed quality and supply systems” was ranked as the highest priority for future research and development (R&D) against all other listed sweetpotato technologies by 91 respondents from 34 developing countries (Fuglie, 2006). CIP pro-poor research targeting further indicates that research on virus control in sweetpotato through provision of clean planting material alone could yield rates of return of between 56-84%, depending on rate of adoption and adoption ceiling. The anticipated aggregate impact of the technology (assuming a *status quo* adoption ceiling) was calculated to be $74 million per annum, with annual benefits to the rural poor calculated to be $49 million per annum. The maximum potential aggregate benefits and benefits to the rural poor for SSA (assuming adoption on all affected areas i.e. no adoption constraint) were calculated to be $434 million per annum and $287 million per annum, respectively (Fuglie, 2007).

A comprehensive background paper on sweetpotato seed systems, with particular relevance to Eastern Africa, has been prepared by Richard Gibson for this project and provides an excellent account of the biology and agro-ecological requirements of the crop.

The provision of seed systems for vegetatively propagated crops in SSA remains a challenging and controversial subject. Debate continues over the relevant merits of "formal" and "informal" seed systems and important parallels exist with Irish potato and cassava.

PRINCIPAL CHALLENGES

Challenge 2.1. Efficient mechanism(s) for introducing and multiplying new improved varieties?

Sweetpotato planting material is traditionally obtained from previous crops or exchanged between local farmers. Against this background, what is the most efficient mechanism(s) for introducing and multiplying new improved varieties: will farmers ever pay for vines?

Current knowledge

The Sweetpotato Community of Practice survey questionnaire carried out as part of this exercise clearly indicated that respondents ranked "quality and availability of planting material" as the most important limiting factor in developing the sweetpotato crop in all three sub-regions. Interestingly, and perhaps surprisingly, 63% of the same respondents **disagreed** with the premise that commercial vines sales are not sustainable.

Vegetatively propagated crops such as sweetpotato present a challenge as the conventional multiplication rate for vines (15:1) pales in comparison to most cereal crops (200-300:1). Rapid multiplication techniques have been developed (attaining rates of 90:1) and are constantly being improved, but dissemination of these technologies has been limited due to their management intensity. As well, removing viruses from infected materials provides "clean" planting material which can result in impressive yield increases.

It would be attractive to simply extrapolate from what was achieved by Chinese NARS to the sweetpotato situation in SSA. However, it is apparent that the task in SSA is very different from China with its stronger institutions and command economy. Work by CIP and others in SSA, Latin America and South East Asia has demonstrated that smallholder growers will purchase vines where the crop has been commercialized, when only one growing season is available (leading to seasonal shortages of planting material) or where new varieties are available. Work by Agri-Biotech in Zimbabwe has also demonstrated the potential commercial and profitable multiplication of clean vines resulting in very significant yield benefits to smallholders (see Challenge 4). The creation of increased demand for clean planting material is probably also critical to the outcome of achieving the productivity potential of the crop.

The typical three stage public sector/donor financed campaign approach of primary, secondary and tertiary multiplication sites is described in the attached Appendix and also in the Gibson background paper which gives examples from Malawi and Tanzania of successful programs. Recent CIP work on different strategies for sweetpotato vine multiplication and the feasibility of commercial production in SSA was reported by Barker (2008) and these and other programs are also well described in the Gibson background paper.

More recent work (German Agency for Technical Cooperation (GTZ) funded; M. Potts, principal investigator) aimed at giving farmers access to improved varieties, and effective systems for the multiplication and distribution of sweetpotato planting material was undertaken in Kenya, Uganda, Tanzania and Ethiopia. Seven novel strategies of vine multiplication were compared to the conventional strategy of dissemination through individual non-governmental organizations (NGOs) and their farmer groups. Each method had merits and drawbacks but demonstrated the need for a flexibility of approach linked to local conditions. Over 40 million vines were distributed by primary partners during the project and over 600 senior research and extension personnel, "trainers of trainers" and other facilitators were trained in vine conservation and multiplication. Primary multiplication sites were set up and well maintained by commercial farmers in Kenya and Uganda but less well in Tanzania and Ethiopia. Alternative approaches to mass vine production and dissemination involved a variety of actors including large NGOs, five farmer vine producer associations, primary schools, prisons, hospitals and small entrepreneurs (including training unemployed and landless youths). In the end a range of strategies proved successful in large scale vine distribution and the price of improved vines was a major factor in determining success. The high prices paid by many often transitory organizations often disrupted attempts to establish long term prices.

Successful farmer-based vine multiplication schemes have thus been well documented but questions remain over best strategies to promote commercialization of vine production in the sweetpotato crop. Thus, particularly for seed systems that focus on new varieties or farmers who are linked to markets, is it possible to move beyond the so-called "campaign" approach, as characterized by the (albeit very successful) examples described? Banana tissue culture in East Africa has succeeded in part because of the yield advantage both from clean material but also the "juvenile" growth performance associated by being generated from meristems instead of corms. That is, there is a yield advantage that will motivate a clean seed system. Equally there are clear signs of emerging small specialist private Irish potato seed producers in Kenya and Ethiopia and of successful community based seed associations in Uganda. It is also clear for these other crops that a linkage of farmers to markets (such as in Malawi) is a key to promoting more intensive and specialist seed multiplication programs.

A “willingness to pay” study conducted in Mozambique provides important insights into this problem. The study (Labarta, 2008) is an experiment set to elicit farmers’ willingness-to-pay for orange-fleshed sweetpotato (OFSP) vines, conducted in January 2008 in six communities of Mozambique. In these areas, farmers face significant dry seasons and limited access to valley bottoms with residual water supply during the dry season. The availability of adequate quantities of vines at the beginning of the rains is a major constraint. This experiment was conducted in six villages where the 121 participant households had received OFSP vines over two years ago. Given that only 37% had managed to retain their OFSP vines for planting in 2008 is indicative of the difficulty of vine conservation (note that there was a severe drought in 2005). Thus, understanding whether farmers are willing to pay for vines and their varietal preferences is critical for evaluating whether it will be possible to establish de-centralized vine producers with a commercial orientation. The latter is envisioned as a more sustainable strategy than continued reliance on free or heavily subsidized public sector and NGO distribution systems. The “real-choice” experiment with four OFSP varieties and the dominant local variety is currently being promoted in Zambézia and revealed that willingness to pay was higher for any OFSP variety than for local varieties; the latter are considered to be readily available. The two varieties clearly preferred by farmers were Resisto, for its yield and taste properties, and MGCL01 (Persistente), for its yield, taste, and most importantly, its being the most drought resistant of the OFSP varieties. All OFSP varieties were considered to be superior to the local variety in terms of taste. On average, farmers invested 2.1 MTn per kg of OFSP bought but there was a group of five farmers that invested more money than the six MTn received for their participation in the experiment. Seventeen percent of participants decided to invest the total six MTn in vine purchase and 49% invested at least half of the money they received. These results are encouraging, given that the trend was to buy and invest more than the minimum required. Many farmers seem willing to pay more for varieties with characteristics they prefer. Farmers growing the OFSP variety Jonathan are willing to pay 70% more to switch to Resisto, and 71% more to switch to MGCL01. Consistent with economic theory, the higher the difference between alternative prices for varieties, the more likely the farmer is to purchase the cheaper product. Among the third of respondents selecting more expensive varieties in a given scenario, the price difference was about 0.75 MTn. In contrast, in 28% of the scenarios respondents selected the cheaper alternative, with the average difference between varieties being higher: 1.21 Mtn. The prospect for viable de-centralized vine producers of OFSP are encouraging, especially for varieties under demand such as Resisto and MGCL01 (Persistente). The cost of production of these vines will need to be within the range that Zambézian farmers are able to pay, and the demand for OFSP vines will likely be driven by the demand for roots in accessible markets.

In summary, much knowledge has been gained in the mass distribution of sweetpotato vines through conventional as well as rapid field multiplication processes. In moving the debate forwards there is a need to understand how to optimally structure primary multiplication (perhaps including tissue culture), hardening sites, and secondary nurseries, and what mix of private and community based approaches are appropriate. It is likely that different agro-ecologies will have a big bearing, with more willingness to pay likely in drought prone areas as well as when associated with new varieties, and when farmers are linked to markets. Innovative work being undertaken by organizations such as the Catholic Relief Services (CRS) for the dissemination of cassava planting material using voucher based schemes and variants of seed fairs also seem very relevant to future sweetpotato vine multiplication and dissemination activities. Such schemes permit parallel extension and participatory demonstration activities to take place along side dissemination, which should also help build more sustainable systems.

Future areas of work for consideration (not necessarily in order of importance):

1) Systematically study and compare different models of sweetpotato vine distribution including seed fairs, voucher schemes etc., drawing parallels where appropriate with other clonal crops such as cassava.
2) Develop strategies for the wide scale dissemination of successful technologies for farm based vine health conservation (positive and negative selection etc.), developed particularly in Uganda and Tanzania, to other important sweetpotato producing countries in SSA.
3) Understand how major varieties in use in multiple countries have been disseminated – especially Simama (Chingova). The perception is that it has been mostly by farmer-to-farmer spread, but it could be that it has been enhanced (for example in Malawi) by initial project funded dissemination efforts. What is the critical mass for igniting farmer-to-farmer dissemination and what factor does human population density play in making it happen?
4) Analyze under what circumstances small holder growers would invest in quality sweetpotato planting material, particularly in the context of market led production systems, and what role savings and investment schemes could have in providing the necessary capital.
5) Assess the potential role that private and public tissue culture laboratories could have in mass multiplication of healthy sweetpotato planting material.
6) Assess the potential for improved agronomy and rapid multiplication techniques to improve field multiplication and maintain vine quality, including use of floating fleeces, optimizing vine length etc.
7) Fully document, and demonstrate to farmers etc. the yield and economic benefits and degeneration rates of clean seed under different cropping systems in a range of agro-ecologies.

Challenge 2.2. Inadequate supplies of vines at the onset of the rains

Extended dry periods and droughts prevent or hinder conservation of vines and, in turn, the timely supply of adequate quantities of planting material with the onset of rains.

Current knowledge

72% of respondents to the current CIP Sweetpotato Community of Practice survey questionnaire agreed with the premise that timeliness of vine availability is more important than clean planting material, which probably reflects the importance of the need to find solutions to the problem of vine conservation through dry periods. Lack of adequate amounts of material at the beginning of the rains condemns sweetpotato to being produced on a relatively small scale in areas with one major growing season. The threat of impending climate change also gives impetus to this critical work area.

The needs and opportunities for innovation and impact in this area are well described in the background paper presented by Richard Gibson and will not be repeated here. Gibson observes that…"Although the [above] issues remain, the overwhelming constraint is lack of planting material at the beginning of the rains, leading to late planting and limited areas planted. The latter leads to the crop failing to fulfill its potential to be the first major food crop to be harvested, to fill the 'hungry gap' when granaries are empty and to realize high sales and prices." Dissemination of intensive methods of conserving planting material using domestic waste water is currently recommended as a partial solution. More promising is the potential for burying medium or small roots at the end of the rainy season in small nursery beds. These are then watered for 4 – 6 weeks before the expected arrival of the rains. The roots then sprout prolifically, producing large amounts of planting material from a small area in time for the start of the rains. Preliminary results for this technology in Uganda are given by Gibson and the methodology should be prioritized for further development and validation in a much wider range of agro-ecologies and countries.

Other vine conservation strategies are reviewed by Kapinga *et al.*, (2008) and a number, such as pit storage of roots, may also have potential for developing strategies for overcoming preservation of planting material through the dry season and could be systematically compared with the root burial method.

Future areas of work for consideration (not necessarily in order of importance):

1) Fully assess the potential of promising root/tuber based sweetpotato planting material conservation strategies (late planted roots, pit stored roots etc.) through dry seasons and widely disseminate best technologies to other production areas with extended dry periods and drought prone areas in SSA.
2) Assess and research the potential of small scale irrigation equipment for sweetpotato vine conservation and widely demonstrate the potential of such technology in key production areas.
3) Systematically analyze the potential for extending the use of lake shores and other water sources through water harvesting techniques for the conservation of sweetpotato vine material through dry periods.

4) Undertake climate change vulnerability assessments for key sweetpotato production areas in SSA and develop and disseminate adaptation strategies.

Challenge 2.3. Improving the role of sweetpotato in disaster relief and mitigation

Sweetpotato has played, and will continue to play, a critical role in disaster relief and mitigation. How can these distribution efforts be designed to improve their efficiency, increase levels of permanent adoption and exploit potential opportunities for reaching development, as well as relief objectives?

The humanitarian benefits to be derived from sweetpotato are clear. Sweetpotato produces carbohydrate sources faster than other crops and requires comparably little labor. However, low multiplication rates represent a constraint, as lead times to respond to a disaster situation are necessarily short. The principal need is to have vine material of adapted varieties "ready to go" and capacity to rapidly multiply suitable clean vines for distribution to needy farmers or displaced peoples. Even then, if the process must be started from a small amount of clean material, it can take 5-6 months to have sufficient amounts of material multiplied to serve a large number of households. For immediate emergency response efforts, planting material is often sourced from parts of the country not affected by the emergency and is cut and transported, often with limited concern for quality. In such instances, the varieties selected may or may not be adapted to the environment to which they are going.

Sweetpotato is more commonly employed in efforts where populations are being re-settled in post-conflict situation and in efforts to mitigate future agro-climatic or political shocks through improving food and nutrition security. In many cases, these situations provide opportunities for more highly productive varieties to be introduced to a large number of households – in essence a "disaster" situation can be turned into a "development opportunity". There are many challenges in large-scale distribution efforts. Key lessons learned to date include:

1) A large percentage of vines are not planted or are of poor quality when planted if the communities and farmers are not adequately informed of their arrival. If fields are prepared in advance of distribution, a higher percentage of vines will be planted in a timely fashion.
2) Care must be taken to follow standard procedures for selecting healthy planting material of the appropriate material. In many cases, quantity takes such precedence over quality that the condition of the material used is so poor that survival of the material is a problem.

3) Large trucks are often employed for transporting vines. If the vines are packed too tightly in bags or other materials and/or are stacked on top of one another, rotting and loss of material can be significant.
4) Adequate planning is essential, as, ideally, vines should be cut and planted within 2-3 days. Special training of extension personnel, and often farmers, on how to maintain vines while awaiting field preparation is usually required if there are going to be delays in planting due to lack of rainfall or prior notification, etc.
5) In emergency or post-conflict resettlement settings, vine distribution is typically a public sector or donor funded initiative and farmers receive vines for free. In countries subject to chronic drought or flooding, such free distribution schemes often build up a "dependency" mentality whereby farmers living in disaster prone areas await handouts and don't bother trying to conserve their vines, as they expect the NGO or other agency to return if losses occur.

Given their common use and clear contribution to helping vulnerable communities, there is a clear need to improve these systems.

A good example of the use of sweetpotato to assist disaster affected and prone communities was the multiplication and distribution of cassava and sweetpotato to mitigate the effects of drought and flood emergencies in Mozambique in the period 2001-2003. The project was initiated with a specific aim of mitigating the adverse effects of the floods/drought on food crop production in various districts of the country. Its objective was to increase food supplies through farmer production of superior varieties of cassava and sweetpotato. This was achieved through using rapid multiplication techniques and distribution of healthy planting materials of best-bet varieties.

The project targeted 500,000 farming households, each receiving 200 plantable vines of sweetpotato and 100 plantable stems of cassava. Some 65 selected districts of the 128 districts of the country (50.8%) in 9 of the 10 provinces of the country were targeted as operational areas for the multiplication and distribution of healthy improved planting materials of both crops.

The project made impressive progress and provoked awareness of the use of cassava and sweetpotato in disaster mitigation. Twelve implementing institutions were engaged in widespread partnerships with over 120 field level agencies and NGOs. Together, they planned and executed multiplication and distribution operations involving schools, churches and contract farmers using best-bet clones of cassava and sweetpotato planting materials.

The project established a well-coordinated network of fields and other multiplication sites covering over 200 hectares of conventional and rapid multiplication plots of sweetpotato and over 200 hectares of cassava in different districts. The project distributed sweetpotato and cassava planting materials to some 377,735 families across the country. The project also successfully promoted the utilization and processing of both crops by demonstrating the use of improved tools and machines, as well as extension of improved crop production practices. In this decentralized model, the entry point for the NGOs working on the project was generally through communal nurseries rather than distribution of vines direct to farmers. These communal nurseries also became the focus of demonstration sites and thus served a dual purpose. The campaign was principally designed to serve a relatively short term need for rehabilitation of planting material lost through natural disasters, but capacity and expertise developed has remained in demand beyond the life of the project to serve “normal” seed needs, and remains available in the event of any future disaster (Andrade *et al.*, 2004a, 2004b, 2007; SARRNET/UEM 2003).

Useful experience has also been gained in distributing sweetpotato planting material to regions of Northern Uganda affected by conflict. More than 850,000 OFSP vine cuttings have been delivered to Ugandan farmers in the affected districts of Lira and Apac. This represents the amount of vines needed to plant about 30 hectares and is significant given the escalating violence that has forced many farmers to live in protected camps. During lulls in the fighting, farmers moved from behind the defensive perimeter of the camps to attend fields established from this material. The farmers, who normally grow crops like cassava and millet, apparently prefer sweetpotato because it is earlier maturing than traditional crops. Farmers are also aware that sweetpotato is hardy enough to thrive under the rugged conditions of Northern Uganda and requires little weeding. Moreover, for reasons that are not entirely understood, rebel troops usually raid cassava fields and leave sweetpotato unharmed. Efforts were also undertaken to produce vines that displaced people could carry back to their villages when conditions improve (http://www.cipotato.org/vitaa/archive.htm).

Opportunities currently exist to intervene to combat predicted food insecurity in sweetpotato growing regions of Ethiopia following the failure of the short rains. The infrastructure and capacity that was developed in Mozambique is highly relevant for this emerging situation. One issue is that foundation stocks of virus tested material of appropriate locally adapted varieties are only now becoming available and again highlight the need for such provision to be in place to permit a more timely response to disasters as they emerge.

Areas for future work:

1) Fully document existing experiences in order to prepare manuals for future use.
2) Better understand the relationship between emergency vine distribution and longer term issues of dependency and sustainable seed systems.
3) Develop methods to speed up response and preparedness for disaster relief interventions using sweetpotato planting material.

Challenge 2.4. Assuring the quality of sweetpotato planting material for purchasers?

Current knowledge

The Sweetpotato Community of Practice survey questionnaire indicated that respondents ranked viruses as the most important factor lowering farmers yields in East and Central Africa by quite some margin, but not so in Southern or West Africa. The sweetpotato virus disease (SPVD) complex caused by mixed infection of *Sweetpotato feathery mottle virus* (SPFMV) and *Sweetpotato chlorotic stunt virus* (SPCSV) is, by far, the most destructive viral disease of sweetpotatoes in Africa (up to 50% in East Africa), and perhaps worldwide (Carey *et al.*, 1999). In many cases, cultivation practices ensure that sweetpotato plants can be infected all year round. Farmer use of cuttings from their previous crop as planting material and the abundance of weed vegetation, which serves as a continually present reservoir of viruses and vectors, make the control of the disease difficult (Karyeija *et al.*, 1998).

Njeru *et al.*, (2006) reported that although most farmers (73%) in Rwanda were able to identify sweetpotato virus disease (SPVD) as the most damaging disease (also confirmed by laboratory testing) the majority (65%) was not aware of what causes the disease and 53% used no control measures against it. Laboratory testing of over 300 fields in Rwanda by the same author (Njeru *et al.*, 2008) revealed that 83% of symptomatic plants and 31% of asymptomatic plants were virus infected, and with mixed infections common in symptomatic plants but not so in asymptomatic plants. Recent virus surveys in Uganda and Tanzania report varying levels of SPVD infection (Ndunguru and Kapinga 2007; Ndunguru *et al.*, 2008; Kapinga *et al.*, 2008). Between 10-40% infection levels were found in Central Uganda where symptoms were recorded as being from mild to moderate. The majority of farmers practice control measures and improved varieties are widely grown. In Tanzania SPVD levels varied from 94% in the NW (West of the Lake), where there was less knowledge about virus control and more local varieties grown, to 54% in the Eastern part of the lake zone (Mwanza). Limited virus testing using samples originating in this Eastern region reported less diversity of different viruses and that in particular, the mixture of viruses responsible for SPVD in Eastern Africa was not found in this particular area. In general there is a lack of current good and systematic virus survey data, particularly from Western and Southern Africa where little is known about virus incidences or the diversity of viruses present. A comprehensive virus survey has recently commenced in Rwanda, Burundi, Uganda and Congo in a CIP coordinated Belgian funded project (Kreuze, personal communication). Initial findings from this survey from Rwanda back up the earlier study and indicate that 62% of farmers believe that the virus problem is increasing or at least not changing (38%). Farmers not practicing any control measures amounted to 47%, 95% and 65% in Rwanda, Burundi and Congo respectively, although most farmers can recognize the disease but very few are aware of its cause.

Anecdotal evidence and that obtained from questioning key individuals and organizations in the recent fact finding missions certainly support the fact that SPVD is still uncontrolled in many parts of Rwanda, Burundi, Ethiopia and parts of Tanzania. Problems associated with the distribution of virus infected planting material by various agencies were also apparent. Potential control measures for SPVD broadly fall into the use of resistant varieties, obtaining clean planting material, or farmers practicing good husbandry or maintaining the health of their own planting material. The use of resistant varieties is reviewed elsewhere (Breeding Challenge paper) and by Gibson (2008). The production of clean sweetpotato planting material for distribution is mostly achieved by initiating a limited generation multiplication cycle, starting with clean planting material, and maintaining the health of subsequent generations through isolation, good husbandry and negative selection (rogueing). An alternative approach would be to plant virus tested ("indexed") material derived from tissue culture plantlets in a manner similar to the Chinese scheme and practiced in Zimbabwe (see below). Sweetpotato propagation schemes in SSA (with the exception of S. Africa) are not currently subject to official regulatory inspections (certification) as is the case with clonal crops in other parts of the world or indeed for Irish Potato in many countries within SSA.

Rather uniquely in SSA, Smith (2004) and Robertson (2006) reported that the use of tissue-cultured sweetpotatoes by smallholder farmers in Zimbabwe has been shown to improve household food security. Farmers who used tissue cultured sweetpotato varieties, such as Brondal, obtained yields of up to 25 tons per hectare against a national average of 6 tons per hectare. Mutandwa (2008) reported that sweetpotato farmers in Zimbabwe were able to achieve net economic returns of $36 per ha using tissue culture derived planting material (which is replaced every 3 years) whereas growers using unimproved planting material made a loss.

Farmer based maintenance of the health of the sweetpotato planting material through positive and negative selection has also shown to be effective, particularly in Uganda and Tanzania (Kapinga *et al*., 2008; Gibson, 2008) in controlling SPVD. Excellent training material has been produced and the techniques are widely practiced. Much work remains to be done to transfer this knowledge to other areas of Tanzania as well as elsewhere in the region. Gibson (2008) asserts that he believes that virus degeneration in locally adapted varieties in Uganda is self limiting (as distinct from introduced improved varieties) through an as yet unknown mechanism, and that virus indexing schemes are not necessary in this context. We believe that a similar mechanism may operate in indigenous native potato seed systems operating in the Andes of South America (unpublished). Gibson also concludes that farmer based health practices can augment this phenomenon. There is then an apparent contradiction in approaches represented by virus indexing schemes practiced in China and Zimbabwe and those practiced in Uganda for local varieties. The contradiction may partly be explained in that two separate approaches are being taken. One relies on the inherent virus “resistance” of local varieties backed by good on-farm husbandry and the other may be based on the considerable yield gains to be had with virus cleaning of high yielding but virus sensitive varieties, which offsets the need to replace the planting material on a regular basis. The question for the former approach is how to improve productivity from this point and close the yield gap and the question for the virus indexing approach is how to make the system economically sustainable without public subsidy in the long term. Certainly, the yield benefits to be gained from planting virus free material (when compared to badly degenerated material) are considerable and have been documented by CIP in China, SSA, Peru, Philippines and elsewhere.

Sweetpotato propagation schemes in SSA are currently not subject to specific regulatory control by National seed authorities, although they may fall into some broad seed regulations in some countries. Seed production of Irish potato, in contrast, is often subject to specific seed regulations, including disease specific tolerance levels, labeling and rotational requirements etc. It is, however, worth pointing out that certified Irish potato seed often only makes up approximately 1% of total seed needs in many African countries. A typical Irish potato seed certification scheme requires two visual inspections of every seed crop by trained staff, followed up by additional tuber inspections and supplementary laboratory testing. The costs in staff time, travel to site and additional laboratory testing, would be prohibitive to an average smallholder sweetpotato seed producer, and the National authorities are unlikely to have the capacity to carry out such a service on a large scale in the short term. It is unlikely that the economic benefits to be had from adopting a formal seed system could carry the additional costs of the scheme. Such concerns are being recognized in many of the newly emerging policy reviews of Irish potato in, for example, Kenya and Uganda, where the important role of informal seed producers is recognized. Some National seed authorities may however see a role in helping to ensure the quality of primary sweetpotato multiplication sites or foundation seed in the future.

Perhaps of more immediate interest would be in developing community based seed quality schemes to improve the quality of vines produced and hopefully add value to the product if it is sold. Developing an awareness of vine quality through local labeling schemes, perhaps based on new Food and Agriculture Organization (FAO) Quality Declared Seed (QDS) protocols currently being developed by CIP and FAO and other partners, could be used to further enhance impact and adoption. The draft sweetpotato protocol (prepared by the National Agricultural Research Organization [NARO] and CIP) is attached as an Appendix. It is envisaged that the QDS sweetpotato seed protocol would provide an achievable but challenging standard for grower groups, perhaps with initial help from an NGO or extension service. The role of the national seed authority in such a scheme could be to nominate only officially released varieties that can be included, and perhaps to maintain a register of authorized producers. Community based seed schemes operating under the QDS protocol could also obtain its starter material from officially certified foundation seed and thus link formal with informal seed producers.

Areas for future work:

1) Research and resolve the conflicting claims made for the need or utility of virus indexing in the production and multiplication of sweetpotato vine planting material, including an economic analysis.
2) Assess the utility of implementing community based vine quality assurance and labeling schemes particularly for market led production schemes.
3) Implement and widely disseminate appropriate vine multiplication quality standards such as the FAO/CIP Quality Declared Seed standard for use by National programs, NGOs, International bodies etc. in large-scale vine distribution programs.
4) Study the possible advantages and disadvantages of extending seed regulations to clonally propagated crops such as sweetpotato in SSA as proposed by a number of National programs and regulatory authorities.
5) Extend virus surveys to Western and Southern Africa.

Challenge 2.5. Efficient and safe germplasm movement programs?

Current knowledge

Sustainable seed systems for vegetatively propagated crops such as sweetpotato require technical capacity to clean-up varieties (thermotherapy being the most used technique) and to test for viruses (diagnostics) and tissue culture labs for maintaining and propagating virus-free stocks. A critical mass of trained technicians and scientists is also a necessary requirement. Financial sustainability of the laboratories is perhaps best achieved through the creation of rotational funds and public-private sector partnerships.

There remain considerable problems in efficiently moving germplasm and breeding material around the region because of a lack of provision of the above basic requirements. This significantly hampers National and International breeding efforts through introducing long delays (several years in some cases) in moving material across national boundaries. Thus many countries are unable to receive in vitro material, and maintain it in tissue culture, both from genebanks and other breeding programs. This material can often only be maintained in the field or screenhouse where it will inevitably become virus infected – a great pity, since it may have taken two years and considerable cost to clean and test the material for viruses prior to it being shipped.

Equally some countries, possessing little or no phytosanitary infrastructure, could be at risk of introducing exotic pests and diseases into the crop. An internal report, based on survey data and laboratory testing, prepared by Ethiopian Institute of Agricultural Research (EIAR) scientists (Abraham, personal comment) in Ethiopia, concluded that recent SPVD epidemics in the country could have originated from one of a number of sources of historically introduced germplasm (although no previous baseline surveys exist to confirm this hypothesis). The findings also include the first possible report of the West African Strain of *Sweetpotato chlorotic stunt virus* in Eastern Africa. Current concerns over the movement of damaging and epidemic diseases of cassava highlight this risk. CIP recently became the first genebank in the world to gain international quality management accreditation through the ISO17025 standard for the worldwide movement and pathogen testing of germplasm, including sweetpotato. Such accreditation provides donors, recipients of germplasm and other interested parties such as governing bodies, independent and internationally recognized assurance that systems in place are "fit for purpose" and perform to the highest possible standards. It is suggested that the skills required to obtain accreditation could be transferred to key institutions within SSA who could then apply for independent accreditation. Such measures would build confidence in enhanced germplasm exchange schemes as national breeding programs become more active in a wider range of countries. Such activities could be underpinned by further developing and disseminating the latest robust and appropriate technological developments in virus diagnostics (Mumford *et al.*, 2006). CIP is currently developing a suite of real-time polymerase chain reaction (PCR) assays for sweetpotato viruses in collaboration with the Central Science Laboratory (UK) and the Danforth Center.

A survey of sweetpotato tissue culture and virus diagnostic capacity was undertaken as part of this current project and will be presented at the forthcoming seed and breeding workshop to be held in Mombasa. Basically only Kenya (Plant Quarantine Service at Kenya Plant Health Inspectorate Services [PQS KEPHIS]), Uganda (NARO), South Africa (Agricultural Research Council [ARC]) and Tanzania (Mikocheni) routinely carry out all of these tasks under one roof and only PQS routinely carries out full virus indexing for sweetpotato for international distribution. Many other countries have some *in vitro* capacity (often used for more commercial crops) ranging from state of the art (Mozambique) to facilities that require considerable attention and investment. Commercial tissue culture companies can be found in Kenya, Uganda and Burundi although none are currently working with sweetpotato. A number of laboratories in the region are capable of testing for sweetpotato viruses but very few routinely utilize modern molecular diagnostic methods and none perform real-time PCR (outside of the Republic of South Africa [RSA]). Investment would seem to be needed throughout the region in greenhouses, diagnostic and tissue culture infrastructure, and all regions need significant capacity strengthening of staff. These initiatives, along with parallel development of virus diagnostic capacity, will need to be aligned with other current initiatives for other vegatatively propagated crops which require broadly similar capacities and capabilities (Bioearn, Donata, BecANet, CIP Buffet etc.). Initiatives such as, for example, the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) Tissue Culture Business Network, are particularly relevant.

A decentralized system of international, regional, sub regional and national nodes for the reception, cleaning, testing and distribution of sweetpotato germplasm with the highest standards of bio-safety, could be set up using current knowledge and expertise. Models such as the enlargement of the European Union ("Plant Passporting") could be looked at for relevance. Such a capacity could significantly enhance the breeding and seed system effectiveness to the ultimate benefit of farmers throughout the region.

Areas for future work:

1) Build regional and national capacities in *in vitro* multiplication and conservation of sweetpotato germplasm and breeding materials across SSA in conjunction with other initiatives.
2) Develop and widely disseminate appropriate sweetpotato virus diagnostics and develop national capacities across the region in key hubs again in conjunction with other initiatives.
3) Implement a strategy for an efficient de-centralized and regional germplasm distribution network to serve international and national breeding programs based on a regional or sub-regional risk-based approach.
4) Implement internationally recognized quality testing standards for the safe movement of germplasm across the region based on the ISO 17025 accreditation standard and the FAO guidelines for the safe movement of sweetpotato germplasm.

CONCLUSION

The provision of quality planting material for clonal crops such as sweetpotato and Irish potato in SSA is, and remains, a controversial issue. Opinions differ from workers who advocate (and practice) commercializing virus tested tissue culture derived planting material and others who doubt this can be sustainable or is even needed. A key aspect of this debate revolves around the willingness or even the need for smallholder farmers to purchase quality vines following project funding or agency led vine distribution campaigns; thus, the emphasis in the title of this challenge topic focuses on **"sustainable**" seed systems. Much valuable experience has been gained throughout Eastern, Central and Southern Africa in implementing large-scale sweetpotato vine (and new variety) distribution networks. There is clear evidence of a willingness of farmers to pay for vines under specific instances of distributing new improved varieties (including OFSP), when linked to markets and when vine material is scarce. Large-scale public funded vine distribution campaigns have a tendency to create "institutional" markets and also to distort markets, but have been extremely valuable in replacing lost seed and disseminating new improved varieties, many with important pro-poor traits. Perhaps the important point is that future interventions should evolve toward creating in the long-term economically sustainable seed systems, primarily through the involvement of the private sector, including tissue culture laboratories. A clear distinction should also be made between developing seed systems for the needs of farmers increasingly linked to markets (including OFSP growers) and those who may remain largely subsistence farmers. There is also a need to prioritize the balance of resources invested in virus resistance breeding as distinct from virus testing or other plant health management strategies (Gibson *et al.*, 2004). Concurrent with that is perhaps the clear need to carry out detailed economic analyses and modeling of the benefits (from a smallholder perspective) of differing approaches comparing subsistence farmers with those linked to markets. A case for continued public funding for capacity to aid efficient dissemination of new sweetpotato varieties with pro-poor traits can also be made in the context of subsistence farmers.

A considerable opportunity also exists in building on the very valuable experience in farm based seed systems (positive and negative selection etc.) from Uganda and parts of Tanzania and extending these programs to elsewhere in the region for the control of Sweet potato virus disease (SPVD). It is apparent that the disease represents a very important continuing constraint in East and Central Africa and efforts to spread good management practice and continued development of virus resistant locally adapted varieties (especially OFSP) remain very important. Much interest also exists amongst vine producers, purchasing agencies and national authorities in improving the quality of vines. A balance needs to be struck between appropriate quality systems and possible seed regulations to reflect the needs of the differing categories of vine producers and to reflect the largely informal nature of the crop. The new FAO QDS guidelines could offer achievable yet challenging standards for community based seed schemes, where the role of National regulatory agencies would simply be to monitor and to oversee the scheme in the broadest sense. There is a case for more oversight on primary foundation or breeders' seed in the longer term. An enhanced sweetpotato *in vitro* multiplication, pathogen diagnostic and quality management capacity at the national and sub-regional level to facilitate the efficient and safe movement of elite breeding material and other germplasm would also represent a sound investment of resources. Opportunities exist to integrate any such investment with other planned initiatives for clonal crops, particularly cassava and bananas/plantain, in the region.

Finally there exists a very significant opportunity to continue the development, evaluation, adaptation and eventual dissemination of dry season vine conservation strategies, such as root nursery beds, throughout SSA. The technology could have an enormous impact on increasing productivity and extending the availability of the crop in drier environments and make a significant contribution to future adaptation to expected climate change.

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ANNEX 2.1. DRAFT FAO/CIP QDS PROTOCOL FOR SWEETPOTATO

INTRODUCTION

Origin

Sweetpotato, *Ipomoea batatas* (L.) Lam., belongs to family Convolvulacea (Morning glory). Sweetpotato originated in or near northwestern South America around 8000-6000 B.C. Guatemala, Colombia, Ecuador, and northern Peru have the greatest diversity in sweetpotato germplasm. Secondary centers of genetic variability are Papua New Guinea, the Philippines and parts of Africa.

Modes of propagation

The sweetpotato can reproduce asexually by: a) colonizing an area by production of storage roots which subsequently sprout to give new plants, b) reproducing vines which may form roots at the nodes, producing daughter plants. The sweetpotato can also reproduce sexually by production of seed, but seed is used only in research for breeding. Sweetpotato is a perennial dicot, but it is cultivated as an annual for vines and storage roots. Sweetpotato is sensitive with a photoperiod of 11.5 hr day length or less promoting flowering, while at 13.5 hr day light, flowering ceases but storage root yield is not affected. Short days with low light intensity promote root development.

Estimated reproductive rate using vine cuttings is 1:15 to 1:20. At optimum conditions, from one tissue culture plantlet it is possible to produce 64 000 cuttings from 800 m^2 field plot in one year.

Pests and diseases

A wide range of pathogenic organisms attack sweetpotato, and although most are widespread, damage levels vary. These organisms include viral, fungal and bacterial diseases, and those caused by nematodes. Globally, at least 20 viruses are known to infect sweetpotato. These viruses occur singly or as mixed infections. *Sweet potato feathery mottle virus* (SPFMV) is the most common virus infecting sweetpotato globally. In mixed infections with *Sweet potato chlorotic stunt virus* (SPCSV), SPFMV is associated with the severe sweetpotato virus disease (SPVD), the most important disease of sweetpotato in Africa. Other viruses include: *Sweet potato mild mottle virus* (SPMMV), *Sweet potato latent virus* (SPLV), *Sweet potato chlorotic flecks virus* (SPCFV), *Sweet potato virus G* (SPVG), *Sweet potato leaf curl virus* (SPLCV). Whiteflies and aphids act as vector of some viruses.

Bacterial diseases can be economically damaging in some parts of the world. They include bacterial stem, and root rot (*Dickeya dadantii)* occurs worldwide; bacterial wilt (*Pseudomonas solanacearum*), important in southern China; and soil rot (*Streptomyces ipomoea*), is important in parts of USA and Japan. Use recommended control measures such as good crop hygiene, and resistant varieties.

Root-knot nematodes (Meloidogyne species) occur worldwide. The extensive root-knot nematode (RKN) host plant ranges, and their interactions with pathogenic fungi and bacteria in plant disease complexes, rank RKN among the major pathogens in crops. Nematode attack in sweetpotato causes stunting, yellow foliage, abnormal flower production, round to spindle-shaped swellings (galls), necrotic root system, and low yields. More than 50 species of RKNs have been described, but Meldogyne incognita, M. javanica, M. arenaria, and M. hapla Chitwood account for more than 95% in agricultural soils globally.

Worldwide there are at least 270 species of insects and 17 species of mites that feed on sweetpotatoes. Insect pests are categorized into defoliators, virus transmitters, stem borers and root feeders. Sweetpotato weevil, *Cylas* spp. is the chief pest of sweetpotatoes. Worldwide there are three main economically important sweetpotato weevils: *Cylas formicarius* occurs globally, while *C. puncticollis* and *C. brunneus* are the main species in Africa. The West Indian sweetpotato weevil, *Euscsepes postfasciatus* occurs in Central and South America, the Caribbean, and the Pacific Islands.

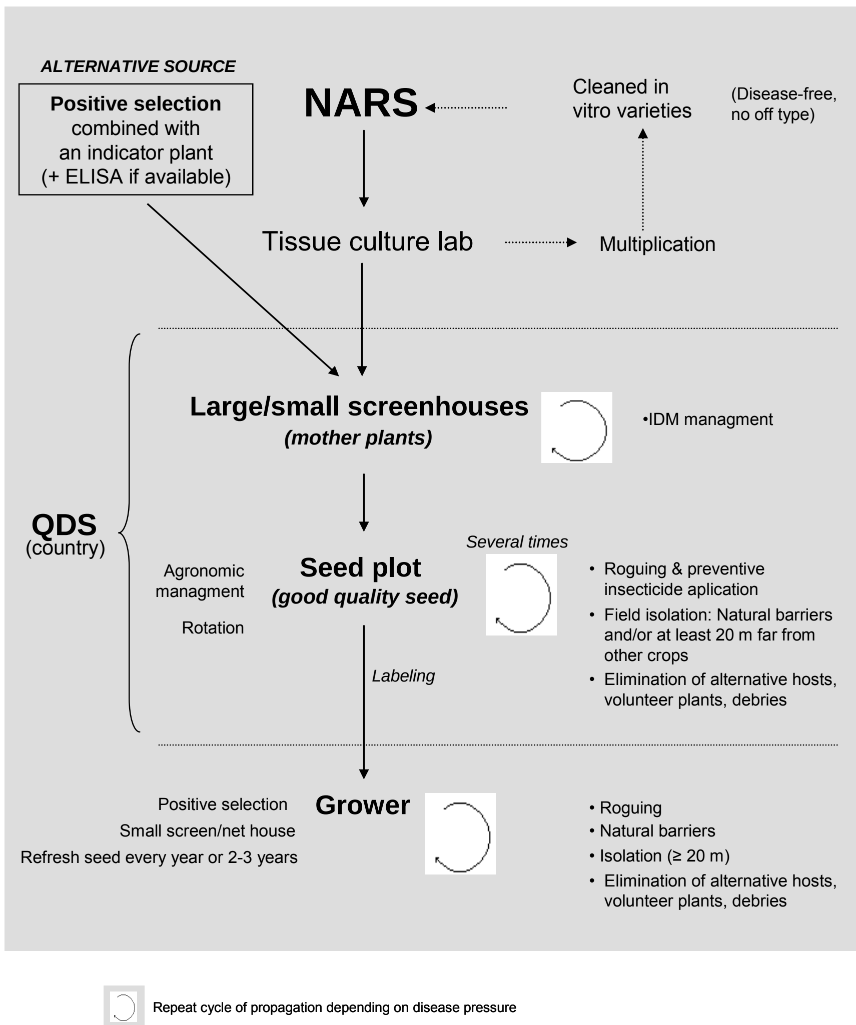
The most damaging stage of weevils is the larval stage. The larvae mainly attack stems and underground parts, although they may also feed on leaves. Adult weevils oviposit in the bases of vines and in exposed roots, while the larvae tunnel through storage roots causing major economic losses. The damage caused by larvae and adults also stimulates the production of terpene phytoalexins, which make the storage roots unhealthy for human consumption. Weevil population and damage is most prevalent during dry seasons, probably because drought increases soil cracking, thus exposing roots to weevils.

PROTOCOL FOR PRODUCTION OF PLANTING MATERIAL

Facilities/equipment

Established protocols specific for region or country or CIP are followed to clean up sweetpotato from different sources, field, screenhouse or tissue culture of all pathogens in tissue culture to produce virus-indexed plantlets for local, regional and international germplasm use (Figures 2.1 and 2.2). Important facilities include well-equipped greenhouses and/or screenhouses, tissue culture laboratories and virus detection equipment and indictor plants for virus indexing. Basic equipment for tissue culture includes: autoclave, lamina flow hood, pH meter, sensitive balances, refrigerators, and heaters. A growth room for in vitro plantlets can be constructed locally. The size of fields for multiplication and increase of stocks of clean plants depends on the demand for clean planting materials and the capacity of the country, organization or agent to meet the demand.

Figure 2.1
Outline of sweetpotato multiplication program.



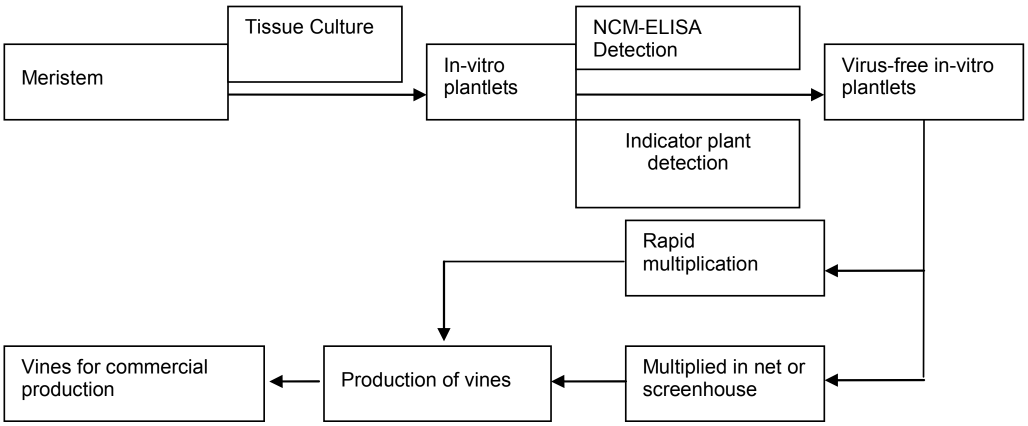


Figure. 2.2
Protocol for virus-free sweetpotato planting material production.

Agronomic practices (including rotations)

Sweetpotato is a perennial but is normally grown as an annual plant. In the tropics it is propagated from vine cuttings, but in temperate regions it may also be grown from rooted sprouts (slips) pulled from bedded storage roots. Apical cuttings, 30-45 cm long are planted by inserting into the soil at an angle. In some parts of East Africa, cuttings may be wilted or left in shade for a few days. In India, the central portion of a cutting is buried in the soil, leaving a node exposed at both ends.

Sprouts are obtained by planting small or medium sized roots close together in nursery beds. The resulting spouts, 22-30 cm long, are removed from the storage roots and planted in the field. Cuttings and sprouts are planted on mounds, or ridges, or on the flat if the soil is deep and well drained. Mounds are used extensively in the tropics especially where the water table is high to improve drainage. Mounds up to 60 cm high, about 90-120 cm apart, are planted with three or more cuttings. Ridging is suitable for mechanical preparation of the ground. Ridges are about 45 cm high and 90-120 cm apart, with cuttings planted at 30 cm intervals.

Sweetpotato is often the lead crop in a rotation cycle, except in very fertile soils. In these soils, planting at the start of the rotation should be avoided, as excessive vegetative growth occurs at the expense of storage root formation.

Seed crop monitoring

A sweetpotato crop for planting material (seed) production, when well established, with good vine growth, is carefully inspected by an experienced breeder or seed inspector or other trained personnel to detect off-type plants within a variety. In addition, all plantings undergo inspection for varietal purity by the appropriate authority some time during the growing season.

Inspection methods

Field inspections before and during harvest are conducted to identify high yielding hills, desirable shape, detection of off-type plants, variety mixtures, serious diseases and pests, coupled with positive selection of roots or vines to serve as the breeder seed for planting the next season's crop. Field inspections are conducted at to coincide with the time when diseases are most conspicuous, such as at months after planting when SPVD is vivid. Inspection of one percent of field taken randomly in four different places of a large field is representative, but for smaller fields a higher percentage can be used.

Harvesting

At harvest, roots are dug out of the soil, and each hill is separately handled and graded. Only those hills with a high yield of well-shaped roots and are free of any defects are selected, and only disease-free vines are cut to serve as breeder seed.

Storage: Proper handling after harvest includes curing of seed roots, proper sanitation, including removal of all old sweetpotato and fumigation of the house before storage of new roots. Dust and debris from the grading and packing area must not come in contact with seed roots or vines. Vines must be stored in well ventilated, shaded places before planting. All storage roots and vines for seed must be transported in net bags or well aerated containers to avoid excess heat damage due to respiration and close packing.

Labeling requirements

Each container of seed roots or vines is appropriately tagged to identify them as foundation, registered, or certified. If the container or bundle of vines is not tagged, the seed is not certified. Label information includes, variety name/code, farm location, seed grower name, harvest date, batch number, weight/batch, number/batch, length, inspector name/code, and quality standards-logo. All labeled seed roots or vines should follow quality standards (Table 2.1).

Table 2.1. Maximum tolerances for disease, insect damage, and internal quality standards for foundation, registered, and certified sweetpotato seed.

Standards	Foundation (1st generation)	Registered (2nd generation)	Certified (3rd generation)	QDS (4th generation)
Black rot	None	None	0.1%	0.5%
Root-knot Nematodes	None	0.2%	0.5%	1.0%
Scurf	None	None	0.1%	0.5%
Wireworms	1.0%	2.0%	5.0%	10.0%
Wilt	None	None	0.1%	0.5%
SSR-Pox[1]	None	5.0%	5.0%	10.0%
Sweetpotato viruses				
Mosaic and stunting	None	None	None	1%
Leaf curl	None	None	None	5%
Other (e.g. purpling of old leaves, chlorotic spots, vein clearing)	None	None	None	5%
Other varieties	None	None	None	2%
Storage rot	None	None	None	None
Sweetpotato weevil	None	None	None	None

[1]Seed with pox will be labelled *Sterptomyces* soil rot (pox) below 5%. Other defects are none for foundation, registered and certified seed: other varieties, storage rot.

Multiplication Program Protocol

Breeder seed of all varieties officially released in a country is produced and maintained by the sweetpotato breeder. Breeder seed is the highest quality available of the variety. The breeder seed is carefully maintained until the next multiplication cycle is repeated. Guidelines for production of foundation seed, registered, and certified seed are basically the same. The guidelines relate to land requirements, inspections, and standards for fields, seeds and plants. Sweetpotatoes grown for certification are handled much the same way as the commercial crop except for the following: plants showing any mutations and symptoms are discarded, a 4-year rotation is followed, only vine cuttings may be used for production of foundation seed, and during the growing season fields that are to be certified must have at least one field inspection by the relevant official.

Materials for rapid multiplication

Fertilizer, NPK 17-17-17 at the rate of 42 gm^{-2} is applied after planting. Urea is applied at the rate of 13 gm^{-2} after each harvest of cuttings, followed by light watering. Manure at 2.5 kgm^{-1} is applied as farmyard manure before planting. The manure should be well decomposed.

Insecticides: all cuttings should be dipped in carbofuran (0.05% ai) solution for 20 min before planting. This will kill all stages of the weevil and provide some residual protection for the young plants. Before planting, apply carbofuran at the rate of about 5 gm^{-2}. Mix thoroughly with soil. To control aphids and white flies, and mites, apply weekly acricide or Ambush or available alternative pesticides on market following recommended dosage.

Fungicides: Apply Benlate (4 g in 10 l of water) or other available fungicide on market following recommended dosage when symptoms appear.

Varieties: Identify appropriate varieties for rapid multiplication.

Cuttings: three node cuttings are taken from vines whose leaves were previously removed. Apical or top cuttings are planted separately.

Preparation of nursery beds

The beds are raised, 10 m long, 1.2 m wide and 20 cm height. Fertilizer (17-17-17), manure (2.5 kgm^{-2} and insecticide (carboduran) are applied and mixed thoroughly with soil before planting.

Preparation of planting material: Cuttings are taken from vigorous mother plants of about 3 months. Leaves are removed from the vines. Prepare three node cuttings from all parts of the vine. Apical cuttings with three nodes are planted separately. Deep the cuttings in a solution of carbofuran and water for 20 minutes before planting.

Planting

Density: 50 cuttings m^{-2} (0.2 m between rows x 0.10 m intra-row). The cuttings are planted upright with two nodes below the soil surface.

Cultural practice

Irrigate 2-3 times a day, early morning and late afternoon with a horse pipe or watering can. **Weed** periodically to maintain the nursery beds clean. **Rouge** all diseased plants.

Where there is excessive sunlight and hit, use mats or other locally available material to shade the nursery beds. Remove the mats when the first leaves start developing. Avoid keeping the mats for more than 2 weeks to prevent etiolation.

Cutting (Harvesting) vines: Cut apical cuttings (25 cm long) 5 cm above the soil level leaving some nodes on the stems to enable further production of cuttings from the axillary buds. The procedure of cutting above the soil surface ensures a 98% chance of selecting weevil-free plants.

Data to be collected in rapid multiplication beds includes, % sprouting or establishment (2 weeks after planting), harvesting (cutting) dates of apical cuttings, number of apical cuttings harvested, % rooting success (survival in the open field), and reaction of cuttings in the open field related to the yield.

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