CHALLENGE THEME PAPER 5: INTEGRATED CROP MANAGEMENT

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Overall Challenge: Yields of sweetpotatoes are low in Africa and improved crop management will be critical to increases in productivity and yet there is virtually a research vacuum on integrated crop management (ICM) and most farmers have few incentives to intensify crop management.

So the question is: how can quality information related to sweetpotato ICM be generated and how could this information be made available to farmers through appropriate means so that improved crop management can contribute to increased productivity and take advantage of emerging market opportunities?

BACKGROUND

Sweetpotato has several advantages within the context of African cropping systems: i) it produces food in a relatively short time, ii) it gives reliable yields in sub-optimal growth conditions, iii) it requires lower labor inputs (appropriate for vulnerable households) than other staples, vi) it serves as an alternative food source for urban populations, facing increasing prices of cereals and v) it provides a potential option to reduce vitamin A deficiency.

In Sub-Saharan Africa sweetpotato is grown in a few regions as a principal staple food crop but in most countries it is grown as a food security crop. In eastern and southern Africa, the crop is generally cultivated in areas with frequent drought stress where cereal crops produce only marginal yields and farmers seek to exploit their agro-biodiversity to buffer stress events. Sweetpotato produces stable and reliable yields under often marginal growth conditions in a relatively short period of time to serve as a back-up for the main staples or to bridge the time until their harvest. In a few countries in the region, where there is a bimodal rainfall pattern, for example, Kenya, Rwanda and Uganda, sweetpotato makes an important contribution to household food security and is also gaining importance as a cash crop sold as fresh roots on urban markets. Sweetpotato value-added products are on the increase with prospects of reducing post harvest losses and improving household incomes. In West Africa, sweetpotato is found in the moist savannah zone where it is part of more diverse root and tuber cropping systems.

Average root yields are low, ranging between 3 to 6 t/ha (tons per hectare) if water supply is a limiting factor or up to 10 to12 t/ha where natural soil fertility and rainfall are adequate. The potential yield of sweetpotato can be up to 40 to 50 t/ha, or possibly a bit less for high dry matter indigenous land races. As with most other crops in Africa, there is a very large yield gap between what farmers achieve and what is normally attained on the experimental stations. Figure 5.1 presents a preliminary yield gap analysis for Sub-Saharan Africa which shows how present yields could be increased from 6 to 20 t/ha if constraints were managed properly. This analysis is, in fact, conservative given experiments with improved materials in eastern and southern Africa, where an average of 24 t/ha are obtained.

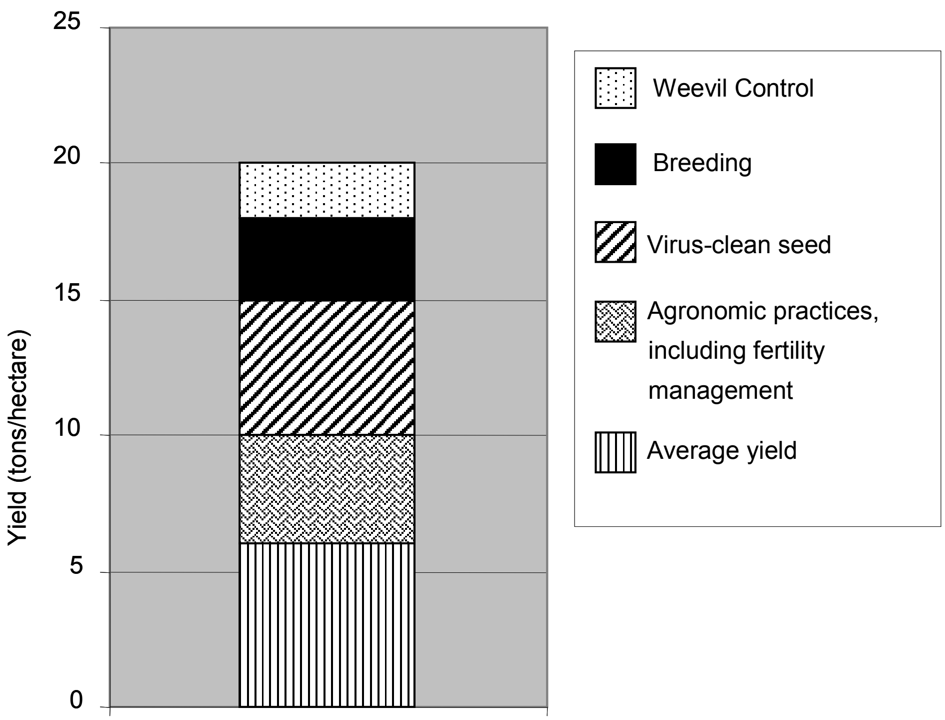

Figure 5.1
Sweetpotato yield gap: Rainfed conditions.

The main constraints to sweetpotato productivity in Africa and, at the same time, opportunities for gains in yield can be summarized as follows:

1) Inappropriate agronomic practices (e.g. planting techniques and spacing, site selection, soil fertility management). Improved management can contribute substantially to increased yields (more than 100% increase). However, facilitating farmer access to fertilizers would not be an easy task, so the estimation of yield gains through better management of local sources of nutrients and other practices is conservatively estimated at 60%.
2) The lack of virus-clean planting material. Most of the local landraces and introduced materials are degenerated because of sweetpotato virus disease. Experts and scientific references indicate that a yield gain of 30% to 50% could be obtained through healthy planting material.
3) Limited yield potential of local land races. Genetic gains in terms of yield are expected to be about 30-40 % compared to healthy local cultivars. Breeding is also the pathway for introducing quality traits (higher micronutrient content, dry matter content, etc.) that do not contribute towards improving yields but are essential for achieving other goals, such as consumer acceptance and improved nutritional status.
4) Sweetpotato weevil. The weevil is an important constraint to sweetpotato in Africa; however, most of the effect occurs when sweetpotato roots are already formed and the principal effect is to reduce the percentage of marketable roots. Published work in Cuba indicates, however, that about 10-20% increase in yield could be expected through a better control of sweetpotato weevil. Improved control could contribute to avoiding losses of yields already formed and increase the value of the roots for potential markets.

Another important area is the quality of the harvested roots with respect to their shape, color, damage etc. Quality is affected by biotic factors such as weevils and diseases, by the genetic background of the varieties, by soil type/structure (compactness) and also by erratic nature of rainfall or availability of moisture. These are causes for outgrowths or secondary growths and cracking.

The quality of the planting material and the genetic background of the varieties, which should have resistance to the main constraints, are the starting points, and a key component of integrated crop management (ICM) strategies. Farmers usually do not manage single problems or constraints; they manage crops under their site-specific conditions. Therefore, developing and making available information about ICM components, using a holistic approach to increase the productivity and quality of field crops, is the most appropriate approach to developing a strategy to overcome these yield-limiting and quality-reducing factors.

In the African context, the ICM approach has often been oriented to the management of one specific crop (the main crop in the system), and in most cases to the management of a few major constraints to productivity of that specific crop. A better concept, however, lies in integrating the management of different factors that influence yields of sweetpotato, but in relationship to the management of other individual crops and livestock activities. This seeks to benefit from the interactions among them and make use of synergies in order to improve, for example, pest control or soil fertility while eventually increasing farm productivity as a whole. The justification for not focusing exclusively on sweetpotato integrated management is that in much of Africa it is a secondary crop and, unless there is farmer motivation to improve yields by, for example, linking farmers to the market, they may not be interested in adopting sweetpotato ICM.

However, options often exist for improving cropping practices in sweetpotato by taking advantage of nutrient applications and improved crop management on other crops in the farming system. In other words, although the main goal is to increase sweetpotato productivity, the entry points for ICM should not only look at sweetpotato management, but also at the management of the cropping system that farmers manage in order to maximize synergies.

Sweetpotato ICM should prioritize the use of low-external input practices for the management of most constraints, particularly in a time of rising prices of purchased inputs. Moreover, ICM is often more knowledge intensive than input-based technologies such as improved varieties or agro-chemicals. Hence, this technology also requires a capacity building and/or strengthening component in order to support local institutions and farmers to fine tune their ICM strategies. Facilitating farmer access to information and knowledge about innovative crop management practices becomes essential for the adaptation of ICM strategies to local conditions.

PRINCIPAL CHALLENGES

The principal challenges of sweetpotato ICM lie in developing or adapting the right combination of technologies for specific agro-ecological and socioeconomic contexts. This is obviously made more feasible when farmers have access to the market where sales provide the returns on farmer investments in labor and knowledge intensive technologies. However, a critical aspect of many ICM-related interventions and innovations is the relative long-term character and payback period of many interventions. For example, there may not be immediate improvement in crop yields or effect on control of pests, but there is an immediate use of resources (time, labor). Hence, the ICM strategy should include a mixture of technologies aimed at both immediate and long-term improvements.

Improving sweetpotato productivity and quality through ICM can be seen as a mixture of scientific, biological, technical and human challenges that require a set of interrelated approaches addressing specific constraints and groups of constraints. Integrating scientific and farmers' knowledge would assist in the design of crop management options and enable farmers to adapt and fine-tune ICM to their specific conditions. This would also allow farmers to be prepared to take advantage of emerging demands or to face changing conditions, such as those created by improved links with the market.

Developing and disseminating suitable ICM technologies is also constrained by inadequate institutional capacity and resources, as many national agricultural research systems (NARS) have very few staff working on ICM for root and tuber crops (and even less so for sweetpotato). They have often no long-term strategy or concept on how to develop sweetpotato-related technologies and create awareness among farmers on the need to employ them. This is variously attributed to lack of staff and staff turnover, lack of resources and other institutional priorities. Moreover, there is need for a strong linkage between research and extension and development organizations. Because knowledge and labor intensive technologies are often the backbone of any ICM strategy, there is need for innovative capacity building and training methodologies based on solid agronomic expertise combined with participatory methods to incorporate farmer local knowledge on ICM development, adaptation and innovation.

Challenge 5.1. Improving crop management practices dependent on farmers' objectives

Farmers manage cropping systems and leaf/root production for different end objectives, including home gardens, integrated crop-livestock systems, relay and intercropping systems, and commercial systems.

Current Knowledge

The short maturity, quick ground cover, relative high productivity, and adaptation to more marginal soil conditions of sweetpotatoes allow farmers significant flexibility in how they incorporate the crop into their farming system. The crop can take advantage of residual moisture and fertility following rice in the inland valley systems of West Africa. It provides a perfect establishment crop in a sweetpotato-cassava relay cropping system in savanna ecologies, and, as such, is the first food to be produced after the “hungry” season. Most farmers cultivate sweetpotato in home gardens or in small field areas ranging from 0.1 ha to 0.5 ha; larger plots are rare and often associated with production for market. Sweetpotato is generally considered a low-input crop, but often grown as a no-input crop. For example, no organic and/or inorganic fertilizers or pesticides are applied and apart from an initial weeding and hilling-up little major field work is being invested in the crop. Moreover, the crop is often planted on the remaining (often exhausted) land after the main field activities for the key crops have been concluded. Fortunately, there are exceptions to this in Uganda and western Kenya, where the crop has a more commercial orientation.

In regions with increasing demographic pressure or in conditions when market access opens new opportunities for revenue generation, land can become a limiting factor to subsistence or commercial sweetpotato production. In these circumstances an intensification of the cropping system might become an important response. In this respect inter- and relay cropping systems which increase output per area and/or per unit input, are suitable options. Sweetpotato is an appropriate crop for these systems because it is flexible in terms of planting dates, robust in its handling but also competitive and has a number of other characteristics which might benefit the associated crop(s), such as protection against soil erosion, weed control etc. There are, however, some caveats. Although these systems often show promising results in experimental settings, their successful management depends on several factors. First, they increase the use of resources and especially if soil water or nutrients are limiting factors, higher plant densities might not be manageable and result in crop failure. Second, sweetpotato is a highly competitive plant, which can suppress the development of other crops, hence time of planting, plant densities, types and growth forms of crops characterize the aptness of crop associations.

Further intensification will lead to greater use of external resources such as fertilizer, water or mechanization for crop management and might only be feasible and cost efficient for commercial crop production. In these high-input systems sweetpotato will be grown as a single crop to optimize resource use to the demand of the crop. However, the purpose of production might range from leaves for vegetable use, vines for the production of planting material or fodder (in zero grazing systems) to tubers for the fresh market or for processed products.

With the notable exception of South Africa, in Sub-Saharan Africa (SSA) there is little experience with sweetpotato as an irrigated and inorganically fertilized crop and research would have to provide expertise and guidance to make these systems cost efficient and the products meet the required standards for commercialization. This type of research would be rather site specific to be adapted to the locally available resources.

We are interested in how ICM relates to cropping systems. There are basically four different groups of technologies which are used in sweetpotato:
Integrated technologies, which are not crop specific, but are knowledge and labor intensive (soil fertility management, management of drought stress, etc.).
Specific sweetpotato technologies based on external inputs (irrigation, inorganic fertilizer, planting material brought from outside of the farm, etc.).
Specific sweetpotato technologies based on internal inputs (weevil control, irrigation, planting densities, planting materials produced within the farm, etc.).
Varieties (as a specific group according to the importance within the project).

These groups could be further subdivided according to costs in time, labor and information. Generally, cost-intensive technologies are less labor intensive and vice versa, which would suit different cropping systems.

Traditional and new varieties would have to be tested for their nutrient and fertilizer use efficiency (in favorable and marginal conditions) not only for the major nutrients nitrogen, phosphorus, potassium (NPK) but also for their micronutrient requirements, because in many marginal soils these nutrients might also limit crop production, and for their adaptation to the different cropping systems.

Areas of future work for consideration:

1) Characterize and describe the main sweetpotato cropping systems and their needs and potentiality according to the farmers' end objectives (home consumption, market or both);
2) Define and test prototype ICM strategies according to each cropping system, the main constraints and farmers' end objectives (more details in the other challenges of this paper);
3) Define the appropriate agro-ecological conditions for intensified/commercially oriented systems and adapt and fine-tune their management with the participation of farmers

according to the cropping systems, and assess the modified cropping systems in terms of gains in sustainable land use, risks and cost-benefit;

4) Understand the effectiveness of different management practices under on-farm conditions and different cropping systems. Determine if they can be applied singly or if they must be integrated —for example, does soil fertility investment pay without appropriate weevil control?
5) Determine capacity building needs to help local institutions and farmers to conduct adaptive, participatory research and training for fine-tuning ICM alternatives according to local systems and end objectives.

Challenge 5.2. Extending the supply period to meet demands for sweetpotato products

Current Knowledge

The flexibility that comes from sweetpotato's short maturation is unfortunately not matched either by its ability to be stored for extended periods in the ground (as with cassava) or to survive under extended drought or dry season conditions. Thus, to fully develop the market and utilization potential of the crop, including the nutritional benefits from orange-fleshed sweetpotato (OFSP), would require a significant extension of its supply period. Where the growing season is very long, as in Rwanda, or there are extensive wetland or valley bottom areas, as in Uganda, sweetpotato has developed as a principal crop in the food economy, in major part due to the extended supply period.

There are a range of options that can be utilized to extend supply. One important component is the use of varieties with different characteristics. In commercial production areas of Uganda farmers manage a suite of varieties of different maturities and also stagger planting dates. Drought resistance and weevil tolerance are also important traits in extending supply and storage in the ground into the dry season. Other options could also be employed by the farmer in combination with varieties and planting time. These include: 1) exploiting different micro-ecologies, 2) post-harvest storage (see the discussion in the Challenge Paper 4: Value chain), 3) relay or rotational cropping with other crops, and 4) managing vine availability to ensure early planting. In order to achieve the objectives of this challenge, activities would have to link up and be coordinated/integrated with activities related to the seed systems and market chain development themes, and to the ICM challenges included in this paper on integrated pest management (IPM) (5), on cropping systems development (1) and drought management (3).

One crucial aspect of extending the sweetpotato supply period is the timely provision of planting material. The conservation of planting material at farm level during the dry season and the availability of sufficient planting material (with the respective quality characteristics if possible) at planting time are two major constraints to sweetpotato production. This is particularly true for extending the supply period, especially in drought prone and low potential areas. To overcome these problems there is need for adapted or new technologies to improve planting material storage or maintenance conditions. These include, for example, maintaining plants in the field (under irrigated conditions or in specific micro-ecologies) for rapid vine multiplication as well as IPM technologies for weevil control. In this area research in sweetpotato agronomy and physiology could make an important contribution linking to the expertise and experiences generated within the seed system theme (more details in Gibson, 2008).

A second step would be to vary planting dates, varieties and cropping systems. All these farm specific options depend on the availability of resources (land, labor and inputs), the capacity of the farmer to use them efficiently and the incentives to do so. Options would consist in staggered planting, intercropping 'major' crops with sweetpotato and using areas with sufficient moisture supply for off-season production. These operations can compete with or complement other farm activities and food production strategies. Therefore, exploiting the synergies between crops, for example sweetpotato – cassava systems, would improve productivity, stabilize food supply during the year, and provide a system attractive to subsistence farmers.

A third possibility to extend sweetpotato supply is post-harvest conservation and processing and transforming of sweetpotato into new products. There exists a variety of traditional and new technologies ranging from processing at farm level to industrial production (Agona *et al.*, 1998; Owori, 2003). Acceptance and use of these products has been rather limited. Apparently the processing of sweetpotato into chips or flour is not very attractive to farmers as prices are lower than for the fresh product (information from country visit, Malawi). Hence, research would have to exploit options for extended storage of fresh storage roots –farmers claim, for example, that traditional varieties can be stored much longer than improved ones, which rot within 14 days after harvest (Rees *et al.*, 2003)– developing appropriate varieties, methods and physical structures (Van Oirschot *et al.*, 2000). Experience for processing exists for Africa but also for South East Asia, where technologies might be transferred to Africa.

Areas of future work for consideration:

1) Introduction and assessment of sweetpotato varieties with different maturities, which can fit into different cropping systems.
2) Identification of micro-ecologies with sufficient moisture supply and close enough to markets where sweetpotato could be produced for extended periods.
3) Design and assessment of intercropping options and crop rotations that could extend the supply period.
4) Development of alternatives for conserving planting materials and for having planting material on a timely manner, particularly in drought prone areas.
5) Assessment of farmer organizational arrangements that could coordinate sequential sweetpotato planting and harvesting.
6) Development of post-harvest practices that could reduce sweetpotato weevil and disease damage and could extend the storage period for the provision of quality roots for the market.

Challenge 5.3. Managing the crop under moisture constraints

Sweetpotato is a marginal crop in unimodal rainfall areas with long dry seasons and expanding the potential production range of the crop, and its ability to target Vitamin-A-deficient populations, will require managing the crop under moisture constraints, including access to receding river banks, dambos, and inland valley systems.

Current Knowledge

Drought management is an important factor for increasing sweetpotato productivity, given that sweetpotato yields can be severely affected by limited water availability. As vitamin A deficiency (VAD) is much more of a problem in regions with a long dry season and more erratic rainfall, this problem must be overcome to maximize the potential contribution of OFSP to reducing VAD in drought-prone environments. Drought management refers to a range of technologies which are well known but might need some adaptation to sweetpotato cropping systems. They consist of soil preparation and water harvesting technologies which increase water collection and water retention capacity of the soil and are applicable to crops in general. Moreover, sweetpotato is often grown in the dry season in lowland areas with high soil moisture and cropping systems must balance water logging with drought mitigation. Given the increase in climatic variability due to global warming, more specific research will be needed in sweetpotato physiology, as well as new management options to increase drought tolerance and water use efficiency and yield, and also to explore technological options to keep planting material viable during long dry periods.

There are two different approaches to the management of moisture constraints: (i) using the genetic diversity of the sweetpotato plant to identify genetic traits, their expression in plant physiological processes and select cultivars best adapted and most productive under these conditions; (ii) using, adapting and developing technological solutions which either provide alternative sources of moisture or conserve available moisture to increase its use efficiency.

Varietal improvement, focusing on drought resistance (acceptance, tolerance, escape) and on water use efficiency, is complex and has had limited success in the past. The best cultivars are selected on the basis of mechanisms that define the plant's ability to withstand drought conditions (Saxena and O'Toole, 2002). The better a cultivar is adapted to drought conditions, the less intensive needs to be a technological (agronomic) intervention, i.e. drought resistant cultivars can be used in low-input agriculture while with decreasing drought resistance farmers have to invest more resources in 'moisture providing or conserving' technologies to successfully produce a crop.

ICM should provide technological solutions to limited moisture supply (during drought spells, at the end of the rainy season) and to changing moisture conditions. An integrated approach would be especially beneficial in this respect. As Sivanappan says:

There are always strong links between soil conservation and water conservation measures. Many actions are directed primarily to one or the other, but most contain an element of both. Reduction of surface runoff can be achieved by constructing suitable structures or by changes in land management. Further, this reduction of surface runoff will increase infiltration and help in water conservation. Soil and water conservation can be approached through agronomic and engineering procedures. Agronomic measures include open and tied ridges, contour farming, off season tillage, deep tillage, mulching and providing vegetative barriers on the contour (Sivanappan, 2005).

These measures not only improve soil moisture availability but also reduce erosion and improve soil fertility.

Periodically changing water tables in flood plains or inland valley swamps offer opportunities for cropping system diversification and the production of different sweetpotato products such as leaves, vines and storage roots, staggering planting times and varying crop management. This often requires more sophisticated crop and farm management to synchronize field operations and product marketing. These areas have a high development potential but in some regions (West Africa) there are often increased disease burdens associated with working these areas.

Areas of future work for consideration:

1) Increasing genetic diversity of sweetpotato by introducing and selecting cultivars best adapted and productive under drought conditions.
2) Development and adaptation of technological solutions which either provide alternative sources of moisture or conserve available moisture to increase its use efficiency for both the crop and for keeping sources of planting material alive and ready to provide cuttings when rain starts.
3) Study sweetpotato physiology in relation to water availability, so that the effects of water management practices can be better understood.

Challenge 5.4. Improving soil fertility management

There are limited suitable options for improving soil fertility management (which is essential to increase crop and farm productivity) in a crop like sweetpotato that is considered a low-input and subsistence crop and where there are few incentives to use labor and resource-intensive technologies.

Current Knowledge

African farming systems are in general highly nutrient constrained. Apart from the volcanic soils of East Africa, the soils are geologically old and highly weathered. At the same time fertilizer markets on the continent are underdeveloped and where they do exist, fertilizer prices are high by world standards given costs associated with inadequate transport infrastructure, and fertilizer availability is often limited to nitrogenous fertilizers and diammoniumphosphate (DAP). Furthermore, African farmers have limited access to organic manure and in many regions there are very few traditional technologies for the preparation of organic fertilizers based on internal or external resources. Farmers grow higher value, commercial crops on their better soils and concentrate the application of their limited organic and inorganic nutrients on these plots, resulting over time in a mosaic of plots with different nutrient and soil organic matter status. Sweetpotato is often grown on land with poor soil fertility, because farmers know that the crop can still produce an acceptable yield under those conditions, but yields are significantly lower than their actual potential. Even when farmers produce for the market, they rarely apply farmyard manure or other organic fertilizers. Generally sweetpotato production is not an attractive entry point for improved soil fertility management but rather the crop could take advantage of residual fertility from increased nutrient applications in other parts of the farming system through rotational systems, incorporation of vines and crop residues, and potential exploitation of legumes within the cropping system (Fischler and Wortmann, 1999).

Integrated soil fertility management (ISFM) would help the farmer not only to improve soil fertility but also many other agronomic aspects of crop production, such as water retention capacity in the soil and pest and disease control, all of which would contribute to increased crop yields. To establish soil fertility technologies with farmers, they have to be based on available and affordable resources. For example, in a first step, a nutrient inventory of these resources could be produced and their potential studied to be transformed into plant (and soil) available nutrients. In a second more innovative step, methods and technologies would be developed to prepare and treat different kinds of organic fertilizers to improve their efficacy and their effect on crop growth. They range from simple structures for composting to the production and application of beneficial microorganisms to improve aerobic or anaerobic decomposition processes.
Simultaneously known technologies, such as rotations, legumes etc., need to be adapted to local conditions to show the benefits of an integrated approach.

Inorganic fertilizers are out of the reach of most African farmers, even more so with increasing energy prices. Their use could probably only be justified to speed up the growth of vines for planting material. For tuber production other conditions such as water supply or pest control should be in place to optimize resource use efficiency. Research could contribute to the development and evaluation of inorganic fertilizer based cropping systems (see Challenge 5.1). However, it is important to assess if the entry point for improved soil fertility management based, for example, on chemical fertilizers should be sweetpotato or other important crops in the system, so that those farmers who can access this input could make the best use of it. Combinations of chemical and organic fertilizers would also be possible (Alleman, no date).

Developing appropriate and adapted technologies for adequate integrated soil fertility management is only part of the challenge. Other important parts of the challenge are i) how to facilitate farmers' access to appropriate information so that they can improve their decision-making about the usefulness of these methods and technologies, ii) how to generate opportunities (i.e. by linking sweetpotato production with the market) to motivate and encourage them to use technologies for improving soil fertility not only for selected high value crops but for the entire farm in order to improve yields and, even more importantly, to improve yield stability. Hence, approaches to include sweetpotato in ISFM would have to be linked to other challenges in the project, such as the activities related to the production and use of orange-fleshed sweetpotato varieties (OFSP), those related to the market chain development, and the development of innovative capacity building and training methods.

Areas of future work for consideration:

1) Use appropriate methods to elaborate inventories of potential sources of organic and inorganic fertilizers to be used as part of ISFM, according to the variability of cropping systems explained in Challenge 1.
2) Develop methods and technologies to prepare and treat different kinds of organic fertilizers and improve their efficacy and their effect on crop growth and yield. Technologies could range from simple composting methods to the use of beneficial microorganisms to accelerate soil fertility processes, and also if possible, assess feasibility of chemical fertilizers in mixtures with organic sources.
3) Develop or adapt rotational strategies oriented to maintain or enhance soil fertility in the different cropping systems that include sweetpotato and according to farmers' end objectives.
4) Study the influence of soil fertility on parameters that could be demanded by the market, such as root shape, size and quality, also in terms of micronutrient and vitamin A contents.
5) Develop or adapt suitable participatory methods to facilitate farmer involvement in research and training processes oriented to ISFM according to their end objectives (i.e. market or OFSP production and use).

Challenge 5.5. Controlling the sweetpotato weevil

There are limited options to control sweetpotato weevil (the most important pest constraint on yields and root quality in SSA) given that plant breeding has generated only low levels of tolerance; control has to be based on improved cultural practices, but the application of these practices depends on effective returns, usually only possible under improved market conditions.

Current Knowledge

Weevils and viruses are the two most important biotic yield constraints on sweetpotatoes, although severity varies significantly by agro-ecology. Weevils, however, even in small populations, can affect the quality of the storage roots, rendering them commercially less valuable (Ndunguru *et al.*, 1998). They become a problem towards the end of the season when soils are drying up and storage roots are left in the soil for too long. In some areas where weevils are endemic, damage is also recorded during the growth season and production losses reach up to 60-100% (Chalfant *et al.*, 1990; Lenné, 1991; Jansson and Raman, 1991; Mullen, 1984; Smit, 1997). In a recent research priority-setting survey carried out by Fuglie (2007), management of weevils was the highest ranked need in relation to improved sweetpotato crop management. Traditional strategies to avoid weevil damage include early planting and harvest, rotation, submerging the fields at the beginning of the planting season, appropriate and timely hilling-up, and the use of varieties with storage root development deep in the soil. Pesticides are rarely used.

Some research results have shown that late planting is associated with higher levels of damage by sweetpotato weevil (Odongo *et al.*, 1995; Jeremiah *et al.*, 1996, 1998), and that some cultural practices such as appropriate hilling-up, intercropping and crop rotation could also contribute to reducing weevil damage (Muhanna and Kiozya, 1996; Nsibande, 1999; Odongo *et al.*, 2003). The use of pheromone traps to control the weevil has shown mixed results with Downham *et al.*, (2001) indicating that it is possible to reduce damage using this technology but Smit *et al.*, (2001) indicating that no significant difference were found. There would be two points to address regarding this technology: first, find ways to improve its effectiveness (see below) and, secondly, find ways to make the pheromones available at affordable prices.

There have been mixed results regarding tolerance of sweetpotato cultivars to the weevil damage. For example, Stathers *et al.* (2003) found that cultivars with high foliage weight showed lower levels of damage, and Mbilinyi *et al.* (1996) and Jeremiah *et al.* (1996) also found difference in weevil damage across cultivars, but Odongo *et al.*, (1995) found no differences. These mixed results would suggest that continuing screening for tolerance in cultivars may generate interesting results in the future.

The complete complex of the three weevil species found in Africa needs special attention in the vine nurseries, which cover small plots between the growth seasons, where a food shortage for insects exists and a feeding concentration takes place. Pest management in these plots is especially important considering the high economic value of vines and the need for healthy and pest-free planting material to avoid early crop infestation.

There exists a substantial body of scientific investigations on sweetpotato weevil in Africa, but NARS have not yet developed a consistent IPM program, which reduces weevil damage and controls the pest. However, there are reports from successful programs in Central America (Cisneros and Alcazar, 2001), which used sex pheromones in combination with biological control agents such as the entomopathogenic fungus, *Beauveria bassiana*, produced by cottage industry, and predatory ant colonies in sweetpotato fields and other compatible cultural practices such as the use of pest-free planting material, crop rotation, and others (Lagnaoui *et al.*, 2000). In all these cases a suitable combination of technology development, appropriate training methods and institutional support was present. Although the conditions in African small-holder agriculture might be more complex and a direct transfer of technology not possible, this example shows that IPM can provide sustainable solutions, improving yield in quantity and quality and production efficiency.

A way forward could be the development of an attract-and-kill or "attracticide" strategy, which consists of an insecticide-pheromone co-formulation: the males are attracted by the pheromone and killed through contact with the insecticide (Kroschel and Zegarra, 2007). This strategy is consistent with the aims of IPM because only the target pest is affected, avoiding deleterious effects on beneficial and other non-target organisms. Other areas of research comprise improving the understanding of biotic and abiotic factors affecting the population dynamics of weevils and the development of predictive models, the adaptation of appropriate pest management technologies by farmers, for example, planting early in the season, which is associated with the timely availability of planting material and can help to reduce damage, and capacity strengthening with NARS and other stakeholders in IPM. Other regional important pests should be also considered within an IPM strategy. A more detailed discussion of IPM issues and opportunities is provided in Annex 5.1.

Areas of future work for consideration:

1) Identify, improve, test and provide training about cultural practices that have influence on weevil damage, such as planting dates, which are in turn associated with the availability of planting material;
2) Study innovative control methods based on previous knowledge about pheromone use, for example, develop and assess "attract-and-kill" strategies, particularly for systems where farmers would have to respond to market standards;
3) Develop, adapt or scale-up and out appropriate methods to improve farmer knowledge about biology and behavior of the insects and about the available control practices in a suitable and cost-effective way;
4) Explore the possibility of finding tolerance of sweetpotato cultivars to the damage caused by the weevil;
5) Develop a better understanding of the biotic and abiotic factors that affect the population dynamics of the sweetpotato complex, which could be used for predictive models for better targeting research and development efforts. This effort should be

conducted in close coordination with NARS so that a capacity building process could also take place.

Challenge 5.6. Scaling up and scaling out integrated crop management recommendations

Because sweetpotato ICM recommendations will vary, depending first on market conditions and secondly on cropping systems, the challenge is how to improve the understanding of farmers' driving forces for adoption and developing and scaling-up and out innovative capacity building approaches oriented to farmers, which should be integrated with efforts for new variety assessment and dissemination, and as a part of market development programs or integrated with nutritional education in OFSP promotion.

Current Knowledge

Improved ICM practices in sweetpotatoes are knowledge intensive, usually require increased labor application, and vary depending on the cropping system. Moreover, sweetpotato producers tend to be geographically distributed and not all farmers in a production region grow the crop. Developing and scaling-up and out cost-effective capacity building methods for sweetpotato growers and understanding farmers' decision-making for adoption of ICM are thus a significant challenge. Because of the limited human and financial resources existing in most countries, this challenge should address attempts to maximize the very limited capacities that will be devoted to capacity building for improved sweetpotato ICM through integration into other "change" programs to be included in the project. This would certainly include market development and OFSP promotion programs. Such programs would provide an environment suitable for innovation which would facilitate farmers' decision-making to invest in improved ICM. Nevertheless, there are a range of unknowns in the development of cost-effective programs with the ability to reach an appropriate scale. For example, are farmer field schools (FFS) an appropriate method for this purpose? Are there alternatives to FFS for dealing with knowledge-intensive management practices? The issue of gender in capacity-building methods is critically important in sweetpotato, as it is often considered a woman's crop and integration of nutritional awareness with improved crop management would be a women's role in the household and processing activities.

Farmers are probably more diverse in their attitudes, customs and preferences than the crops they grow or the cropping systems they manage. Therefore to engage farmers in research activities and/or interest them in new technologies depends on a variety of factors, which in their majority cannot be 'controlled' or managed by research or development projects. Apart from creating incentives, considering farmers' preferences and opinions about technological options should be an integral part of the research strategy to improve researchers' and development practitioners' understanding of the driving forces behind technology adoption. For example, there is a consensus that agricultural research has a much higher rate of return (success) in high potential areas or high input systems than in low potential areas or low input systems. In addition, there is an increasing trend to income diversification, especially of subsistence farmers, resulting in a growing portion of the household income coming from non-farm activities. This in turn affects farmers' willingness to adopt new technologies (especially labor and knowledge intensive technologies).

In a first step, a socio-economic analysis of the farming households would indicate with which group of farmers the work should be conducted, either full-time or part-time farmers in the diverse cropping systems indicated in Challenge 5.1 of this paper. Also, it is important to understand if farmers are net food purchasers or surplus food producers. If their activities are subsistence or market-oriented, what kind of resource base is available to the farmers? In addition, whether they have a specific interest in the sweetpotato crop would be extremely important as a starting point for research and capacity-building efforts towards developing and disseminating sweetpotato ICM.

As outlined by the project objectives, commercial opportunities are seen as a major incentive to increase sweetpotato production and for the adoption of more efficient technologies. However, ICM technology development needs to start before the market chain development can actually generate a demand; therefore, there should also be a strategy to work with subsistence farmers.

Areas of future work for consideration:

1) Develop, adapt and assess participatory research and capacity-building methods suitable for ICM development and dissemination in relation to other challenges included in the project (market development and OFSP production and use). ICM should not be seen as an isolated area of work, but as one that responds to demands according to the cropping system and farmers' end objectives.
2) Develop a better understanding of the typology of farmers who grow sweetpotato in different cropping systems and according to different end objectives, and about their perceptions and the driving forces for innovation related to ICM when having to respond to market or home consumption demands.

Challenge 5.7. Increasing user access to information and improved technologies

In general terms, there are limited investments by NARS and NGOs in sweetpotato research and extension. These organizations usually dedicate their attention to other staple and cash crops. Therefore the development of information and improved technologies (crop management and varieties) for sweetpotato proceeds at a very slow pace and possible productivity gains or other benefits are not realized.

Current Knowledge

The two main actors in agricultural research and development at country level are usually NARS and nongovernmental organizations (NGOs). Given limited resources, research on sweetpotato has been restricted to small grant funded work. During the country visits there was no root and tuber crop program which had major staff time dedicated to on-going ICM research activities for sweetpotato. Breeding has been seen as key to increasing production and overcoming other constraints; hence resources have been invested in this area rather than in the development of crop production technologies.

Apart from the main actors, there are several other stakeholders in the agricultural sector that actively influence directly or indirectly success or failure of research and development activities. A stakeholder analysis could help identify the actors and their interests, constraints, resources and willingness to contribute to the objectives of the project activities within a pilot site or specific country. Using an innovation system's approach (Hall *et al.*, 2004), would help to understand the different stakeholders related to sweetpotato ICM and identify entry points for research and capacity building at institutional level. Their early involvement would be important to the development and advance of project activities.

In addition, NARS, because of their specific role in research and development of SSA countries, would need extra attention to strengthen their capacities, internal structures and institutional memory.

Areas of future work for consideration:

1) Within an agricultural innovation system perspective at the regional, national and local levels, develop an understanding of the drivers of increased performance of public institutions and NGOs in meeting farmers' needs for ICM.
2) Develop suitable capacity building methods oriented to research/development institutions that could use existing resource capabilities and better utilize external

resources in order to develop ICM options that could respond to farmer or system demands.

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ANNEX 5.1. SWEETPOTATO INTEGRATED PEST MANAGEMENT (IPM) IN AFRICA: FURTHER CONSIDERATIONS

Jürgen Kroschel

INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Poir.) is cultivated in over 100 developing countries and ranks among the five most important food crops in over 50 of those countries. One of the most widely grown root crops in SSA, it is particularly important in countries surrounding the Great Lakes in Eastern and Central Africa, in Angola, Madagascar, Malawi and Mozambique in Southern Africa, and in Nigeria in West Africa. In Asia, sweetpotato is the most important root and tuber crop, with China being the largest producer worldwide. In Africa, it is grown predominantly in small plots by poorer farmers, and hence known as the "poor man's food". Increasing sweetpotato production and use is recognized for its role in improving incomes and food security among the rural poor.

Among the major constraints in sweetpotato production are biotic constraints by insect pests (Kapinga and Carey, 2003). For East Africa, e.g. a complex of pests has been described (Skoglund and Smit, 1994):

- stem and root feeders (sweetpotato weevils, *Cylas puncticollis* and *C. brunneus*, and rough weevil, *Blosyrus obliguatus*, all Coleoptera: Curculionidae);
- defoliators (clear wing moth, *Synantedon dasyceles* (Lepidoptera: Sesiidae), striped sweet potato weevils, *Alcidodes dentipes* and *A. erronneus*, long-horned beetle, *Peloropus batatae* (all Coleoptera: Curculionidae), sweetpotato butterfly, *Acraea acerata* (Lepidoptera: Nymphalidae), sweetpotato hornworm, *Agrius convolvuli* (Lepidoptera: Sphingidae), tortoise beetles, *Aspidomorpha* spp., *Laccoptera* spp. (Coleoptera: Chrysomelidae); and
- virus transmitters *Aphis gossypii* (Homoptera: Aphididae) and *Bemisia tabaci* (Homoptera: Aleyrodidae).

The complete pest complex needs special attention in the vine nurseries, which cover only small plots between the growing seasons and during the drought periods, where a food shortage for insects exists and a feeding concentration takes place. Pest management in these plots is especially important considering the high economic value of vines and the need for healthy pest free planting material to avoid early crop infestation. During the cultivation periods widespread infestations by sweetpotato weevils (*Cylas* spp.) are most serious, followed by regional and local yield reductions caused by rough weevils (*Blosyrus obliguatus*) and the sweetpotato butterfly (*Acraea acerata*).

Sweetpotato weevils (Cylas sp.) are the most serious insect pests of sweetpotato in Central America, Africa and Asia; production losses often reach 60-100% (Chalfant *et al*., 1990; Lenné 1991; Jansson and Rama,n 1991; Mullen, 1984; Smit, 1997). In a recent research priority-setting survey carried out by Fuglie (2007), management of weevils was the highest ranked need in relation to improved sweetpotato crop management. Even small weevil populations can reduce sweetpotato root quality. In response to weevil feeding, sweetpotato storage roots produce bitter tasting and toxic sesquiterpenes that render them unfit for human consumption. Studies by Ndunguru *et al*. (1998) have shown that consumers will pay only reduced prices for roots damaged by Cylas spp.

In certain areas of East Africa, serious damages of the surface of roots caused by larvae of the rough weevil *B. obliguatus* have gained economic importance. It reduces the marketability and when extensively damaged, roots have to be peeled thickly. The sweetpotato butterfly *A. acerata* can be a serious constraint to sweetpotato production in parts of Uganda, Rwanda, Burundi, eastern Zaire and Southern Ethiopia (Lenné, 1991; Ndamage *et al*., 1992; Girma, 1994). In Southern Ethiopia, frequent outbreaks have occurred in the last decades with tuber yield losses between 31 to 53% in unsprayed control plots. Mostly at the beginning of the dry season, a severe attack can result in extensive defoliation. However, it has been shown that single defoliation at different growth stages does not affect the yield but repeated defoliation is common. This means that farmers also have to learn not to overrate the importance of this pest and to apply control methods only according to the current infestation.

Whereas the two species C. puncticollis and C. brunneus are reported only from Africa, a third species, C. formicarius, is found globally (Wolfe, 1991). Most research has been carried out for C. formicarius, which is the main sweetpotato pest in Central America and Asia. Owing to lack of both funding and entomological capacity, African national research programs have not been able to develop an IPM program to reduce major losses caused by sweetpotato weevils and other regional pests, although the development and implementation of successful IPM programs for sweetpotato weevil management have been reported from Central America. In Africa, the uses of cultural practices such as hilling up or crop rotation are the only tools and recommendations to farmers, but which are not nearly sufficient enough to control this pest effectively.

Management of sweetpotato weevil

Sweetpotato weevil IPM in Cuba – a success story

CIP scientists and national collaborators in Cuba have clearly demonstrated that IPM can successfully control *C. formicarius* (Cisneros and Alcazar, 2001). Site-specific IPM strategies successfully developed and adopted included the use of sex pheromone, which had been made commercially available, for mass trapping of male weevils in combination with biological control agents such as the entomopathogenic fungus, *Beauveria bassiana*, produced by cottage industry, and the setting up of predatory ant colonies in sweetpotato fields, and other compatible cultural practices, like the use of insect-free planting material, crop rotation, and others (Lagnaoui *et al.*, 2000). Pheromone-impregnated rubber septa, suspended in traps 10 cm above the foliage, were distributed at distances of 25 x 25 m. The weevils were killed either by mass trapping in simple water traps placed below the septa or by insecticides or *B. bassiana* applied on the ground around the septa that achieved higher efficacy. Through this collaborative IPM project, covering a six-year period (1993-1999), it proved possible to reduce national mean damage caused by sweetpotato weevils from 45% to 6%, for a production area of 45,000 ha. After 10 years, this project was terminated successfully. The IPM components are still in place today.

Use of sex pheromones

Building on the generally good experience and successful use of sex pheromones in *C. formicarius* IPM, a research collaborative program was initiated in 1997 by the International Potato Center (CIP) and the Natural Resources Institute, UK, to identify the pheromone chemical structure of the two species of African sweetpotato weevil *Cylas puncticollis* and *C. brunneus*. Although sex pheromones were identified and synthesized (Downham *et al.*, 1999), the synthetic pheromones were found to be sufficiently attractive for monitoring weevils but not appropriate for mass trapping or mating disruption. Due to their low efficiency they have not been further researched and used. Recently, the pheromone structure and efficacy of all three *Cylas* species were revisited in a comparative study. Each of the three species scrutinized were shown to produce a distinct bouquet of volatile compounds accompanying the specific major sex pheromone component, which acted obviously as synergists to the major component (Vasquez *et al.*, in prep.). However, also as a single-component, the major sex-pheromone components were revealed to be sufficiently attractive to efficiently lure males in linear olfactometer studies. The two African weevils each required a 10-times higher concentration of the major component for the same level of attractiveness as the synthetic lure for *C. formicarius* to be reached, but nevertheless demonstrating the component's potential use for sweetpotato IPM in Africa. In this context, it is especially noteworthy that this research also resulted in new, cheap and efficient synthesis protocols of the sex pheromones for the three weevil species that could substantially contribute to large-scale production, commercialization and use of the pheromones in Africa.

Opportunities for sweetpotato IPM in Africa

The sweetpotato IPM program developed for the sweetpotato weevil *C. formicarius* in Cuba has several components which could be adapted in an IPM research program for its successful use in Africa. The search for sources of resistance to sweetpotato weevils in the crop's germplasm has not yielded reliable results. Hence no conventional resistance breeding has been possible to date. Instead, the recent results on the sex pheromone structures and synthesis give good prospects for the development of effective lures for the sweetpotato weevil management. Under this project, the synthesis of the sex pheromones of the two African sweetpotato weevils should be scaled up in collaboration with advanced labs using newly-developed protocols, to produce semi-commercial amounts for larger field evaluation and applications. For practical and economic reasons, the numbers of pheromone traps employed per unit of agricultural area has often limited the use and adoption of mass trapping devices in pest management. In order to develop more rational use of sex pheromones, the attract-and-kill or attracticide strategy has already received attention and been successfully used in controlling different insect pests including the potato tuber moth *Phthorimaea operculella* (Zeller) (Kroschel and Zegarra, 2007). This strategy consists of an insecticide-pheromone co-formulation: the male moths are attracted by the pheromone and killed through contact with the insecticide. This strategy is consistent with the aims of IPM because only the target pest is affected, avoiding deleterious effects on beneficial and other non-target organisms.

For this challenging African wide sweetpotato project a systematic and fully ecological-based approach to pest management in sweetpotato should be considered to develop and disseminate site-specific IPM technologies for the main sweetpotato pests based on the following strategic results:

- Sweetpotato production systems and regional occurrence and distribution of sweetpotato pests assessed and understood.
- Abiotic factors influencing population dynamics of sweetpotato pests determined and models developed and validated to predict seasonal occurrences.
- Natural occurrence and influence of biotic factors on pest population determined and use of biocontrol agents evaluated.
- Potential use of sex pheromones in attractants and biocontrol products for IPM in sweetpotato assessed.

- Utilization of appropriate pest management technologies by farmers enhanced using participatory methods; and
- Capacity of national agricultural research systems (NARS) in IPM technology development and transfer strengthened.

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