CROP PROTECTION PROGRAMME

Extending control of sweet potato diseases in East Africa

R8457 (ZA0681)

FINAL TECHNICAL REPORT

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Executive Summary

R8457 has disseminated information on the control of sweet potato virus disease (SPVD) and SPVD-resistant varieties in both Kagera and Kigoma Regions in northwest Tanzania, largely through maintained and expanded links with other actors in development. It has also developed additional leaflets as part of this activity, again partly through collaboration with others, this time a partner CPP-funded project. It has demonstrated that old foliage of previous sweet potato crops acts as inoculum of Alternaria for new crops, thereby demonstrating the importance of rotation for protection against this disease [the 2nd most important disease of sweet potato in Africa] as well as against SPVD [the 1st].

The participatory breeding work has now identified accessions which are farmer-preferred, high-yielding, resistant to SPVD and other disease and biotic constraints. These have been integrated within the Ugandan Potato Programme activities and planted out in standardized multilocational trials in three major agroecologies across Uganda. A select few of these are already being multiplied by farmers, both for expanded production of roots because of their perceived high marketability and also for sale of vines to other farmers.

The project has also addressed improving sweet potato production in areas where there is a prolonged seasonal drought. Pigeonpea has been identified as a potentially valuable intercrop, being able to become established whilst sweet potato is cropping during the rainy season and then yielding itself during the subsequent dry season. Surveys in Tanzania have identified how massive can be the task of watering propagation material throughout the dry season. Roots have been identified as an alternative means of maintaining sweet potato planting material during the dry season, watering only being required once the roots are stimulated to shoot immediately prior to the onset of the rains.

Background

General: Sweet potato is amongst the most important food staples grown in sub-Saharan Africa and is particularly important in East Africa. Uganda has the largest production in Africa and Tanzania has only a slightly smaller area under sweet potato, though with a relatively low productivity. With good husbandry, sweet potato is amongst the most productive crops but it can also yield on relatively poor soils. It requires few inputs except labour, and its ability to yield rapidly and over a long cropping season if piecemeal harvested provides the flexibility both for it to fit in a range of cropping systems and to yield even with irregular rainfall patterns. Consequently, it is an important daily food for many farmers and their families in Africa, particularly resource-poor farmers growing their food on a restricted area of marginal land. It is also important in disaster relief when other crops fail, for example, when the pandemic of cassava mosaic disease destroyed crops of cassava. Sweet potato is also a cheap food for the urban poor in the growing conurbations of Africa; it is also sold in supermarkets for the growing middle class. By 2020, it is predicted that root crops will have an even more important role in food production in Africa than now and become integrated into a more diverse range of food products (Scott et al., 2000). The International Potato Center (CIP) is deploying high β-carotene, high dry matter content varieties from South America to Africa (see CIP Vitamin A for Africa (VITA A) website) as a means of combating widespread vitamin A deficiencies amongst poor people in Africa, particularly women, young children and HIV AIDS-affected people. CIP estimates that replacing white-fleshed with orange-fleshed varieties could alleviate vitamin A deficiencies in 50,000,0000 children in Africa under the age of six, not to mention the impact on older children and adults, particularly pregnant women and lactating mothers.

Scientific: Previous work has demonstrated the key role of the whitefly-borne crinivirus *Sweet potato chlorotic stunt virus* (SPCSV) in the development of sweet potato virus disease (SPVD), the most damaging disease of sweet potato in Africa. High-yielding and otherwise superior local varieties are often susceptible. Resistance has been identified in African local varieties though resistant ones are mostly low-yielding or possess other adverse characteristics. Field observations coupled with evidence of a lack of diversity in SPCSV at the molecular level predict the resistance is likely to be durable. In Uganda, the National Agricultural Research Organisation (NARO) gives high priority to developing resistant varieties and has released varieties bred at Namulonge Research Institute (NAARI) which combine superior yields and resistance. SPVD is particularly prevalent in western and central Uganda around Lake Victoria including Masaka and Rakai districts; work there funded by R7492 showed that some of these varieties were high-yielding and adequately SPVD-resistant and therefore likely to be appropriate elsewhere in the region. The variety NASPOT 1 was preferred, producing twice the marketable root yield of the best local cultivars in on-farm trials and having good taste and other eating qualities. Although farmers continue to grow most of the varieties they had been given access to, only NASPOT 1 was preferred above local cultivars in a variety ranking exercise, largely because of its massive early yield. NASPOT 1 is being widely adopted in areas around Lake Victoria where SPVD is prevalent. The epidemic of cassava mosaic disease in Kagera District has also resulted in the Tanzanian Department of Research and Development giving high priority to controlling virus diseases of root crops including SPVD in sweet potato in the Lake Zone for the last several years. The high-yielding and SPVD-resistant Ugandan varieties have also been tested in high SPVD-incidence areas bordering Lake Victoria in Tanzania, the field resistance and high yields of some have been confirmed and farmers have enthusiastically begun adopting a few of them, again particularly NASPOT 1. Control of SPVD is also a prerequisite for the success of the VITA A project as exotic sweet potato clones introduced from S. America (where the disease has been rare till recently) are almost invariably very susceptible to SPVD.

Plate 1. The two plants in the foreground are cuttings affected by SPVD

Planting material of high-yielding, SPVD-resistant cultivars bred in Uganda has been distributed to farmers, and extension officers have been trained so that they can disseminate to farmers both the benefits of the resistant varieties and the SPVD control strategies and how best to utilise them. In Uganda, this has been done in districts around Kampala largely through links with the NGO BUCADEF (Buganda Cultural and Development Foundation) funded directly by CPP funds. In Tanzania, this has been done in drought and refugee-affected areas in the south-eastern (Mukeba; Ngara districts) part of the Lake (Victoria) Zone supported by other donors, notably The Norwegian People's Aid (NPA).

However, on-farm trials have shown that nationally released varieties are not high-yielding in all agroecologies in Uganda and Tanzania where sweet potato is important. Farmers there have requested better varieties and a variety ranking exercise identified several characteristics including various storage root quality characteristics and continuous storage root production for piecemeal harvesting, which would seem difficult to assess accurately on station. SPVD is not the only constraint facing sweet potato producers and several of the released varieties including NASPOT 1 were much more susceptible to Alternaria disease than the local cultivars. It was also noted in the FTR for R8243 that drought had affected several of the trials and was identified by farmers as a major factor in determining their ability to retain NASPOT 1 and several other NAARI varieties. There was therefore a demand a) for measures to control SPVD in superior local varieties and b) for new varieties adapted to local conditions and local needs and participatory breeding was commenced with farmer groups in Uganda and Tanzania by R8243. By the completion of R8243, an initial seed population of some 12,000 planted with two farmer groups located in Mpigi and Luwero districts in Uganda, where SPVD is also prevalent, had been evaluated over three generations and 24 genotypes had been selected for further evaluation within R8457. Various natural disasters, particularly drought, devastated the breeding trials based in Tanzania.

SPCSV is transmitted only semi-persistently by whiteflies and most spread of SPVD is local, rates of spread of SPVD into unaffected newly-planted crops being determined by the amount and proximity of old crops within a radius of about 100m and the numbers of whiteflies (R6617; Aritua et al., 1999). SPCSV is transmitted by *B. tabaci* in the semi-persistent manner (Larsen et al., 1991) and this, together with the tendency of *B. tabaci* for short-distance flights (Byrne et al., 1996), would appear to account for this result. Whatever the explanation, the result presented the possibility that individual farmers could also beneficially use local phytosanitation to control SPVD and so be able to continue to grow their best high-yielding local landraces despite some susceptibility to SPVD. Work done under R7492 has confirmed this. On-station and on-farm trials showed that most spread in a field occurs within a few metres of an infection source and roguing out diseased cuttings within one month of planting halved ($P<0.001$) the spread of SPVD, even though unrogued control plots were next to the rogued plots. An EU-funded project (ICA4-CT-2000-30007) has also shown how neighbouring unaffected plants can compensate for either the presence of a diseased plant or the removal of a diseased plant. Small amounts of isolation also had dramatic effects; plots planted just 15m away from a diseased plot had between a third and a quarter the number of SPVD-affected plants than plots adjacent to the diseased plot ($P<0.001$). However, although some farmers realised that SPVD is caused by a “germ”, none realised that SPVD is a disease spread by whiteflies and many thought it is caused by abiotic factors such as drought (interviews done in Uganda and Kenya). Consequently, most farmers ignore cultural control practices such as isolation although most do select their planting material from disease-free parents.

The following provisional guidelines for controlling SPVD were drawn up based on results from R8243:

- Collect cuttings for new crops from healthy plants.
- Select cuttings from healthy plants in crops in which few other plants have the disease and avoid collecting cuttings from very old crops because sweet potato virus disease is less easy to see in these than in vigorously-growing crops.
- If possible, choose a variety or local cultivar that isn’t much affected by the disease.
- Plant new crops away from old crops.
- Avoid planting new crops where sweet potato was grown last season because storage roots and cuttings from old diseased plants surviving in the soil will produce diseased plants from which infection will easily spread to your new crop.
- Remove any diseased plants as soon as they appear, especially in young crops.
- Ensure trash from old harvested crops including unwanted storage roots dies.
- All these treatments will work better the larger the area where it is used so: work together with neighbours.

These guidelines have been encapsulated in a multilingual posters and brochures and are included in a general manual for sweet potato farmer field schools. They present a series of choices and, whilst best control will probably be achieved by combining all the practices, adequate control may be achieved, in conditions of only moderate rates of spread of SPVD by whiteflies, by using one or a few. Thus, careful selection of planting material, planting away from old crops and roguing out any new infections may allow a farmer successfully to grow quite susceptible cultivars. Alternatively, growing a very resistant cultivar may also free many farmers from all these restrictions.

An international project on the control of whiteflies and whitefly-borne viruses in tropical agricultural systems [Tropical Whitefly IPM Project (TWIP)] includes a component led by the International Institute of Tropical Agriculture (IITA) on the control of whiteflies and whitefly-borne viruses of sweet potato in Africa. A final phase aiming to utilise knowledge gained in previous phases of this project and in relevant CPP-funded projects commenced in 2005. This project involves NRI scientists contributing to R8457, ensuring a relatively seamless flow of knowledge between the two projects. The TWIP project in East Africa focuses on north-western Tanzania, roughly coinciding with the area there where SPVD is very damaging and where R8243 focused.

R8457 in Uganda aimed mainly to complete the cycles of participatory breeding of sweet potato there and in Tanzania to facilitate the spread of information and means of controlling SPVD.

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Purpose

R8457 aimed to:

1. Increase the breadth of utilisation of knowledge generated by previous projects on SPVD control by:
   - Extending the scope of training materials.
   - Extending its geographical spread around Lake Victoria.
   - Extending the range of social groups.
2. Complete the cycle of participatory breeding, enabling selected superior accessions to be identified, tested by farmers individually and transferred to national programmes.

3. Provide basic information on the control of *Alternaria*, the second most important disease of sweet potato in Africa.

Research Activities

R8457 included three outputs as its main aims. These comprised:

Output 1. Widening the impact of project outputs by collaborating with other actors in development.

Output 2. Complete the first participatory breeding of superior SPVD-resistant sweet potato in Africa

Output 3. Determine the role of phytosanitation for controlling *Alternaria* disease

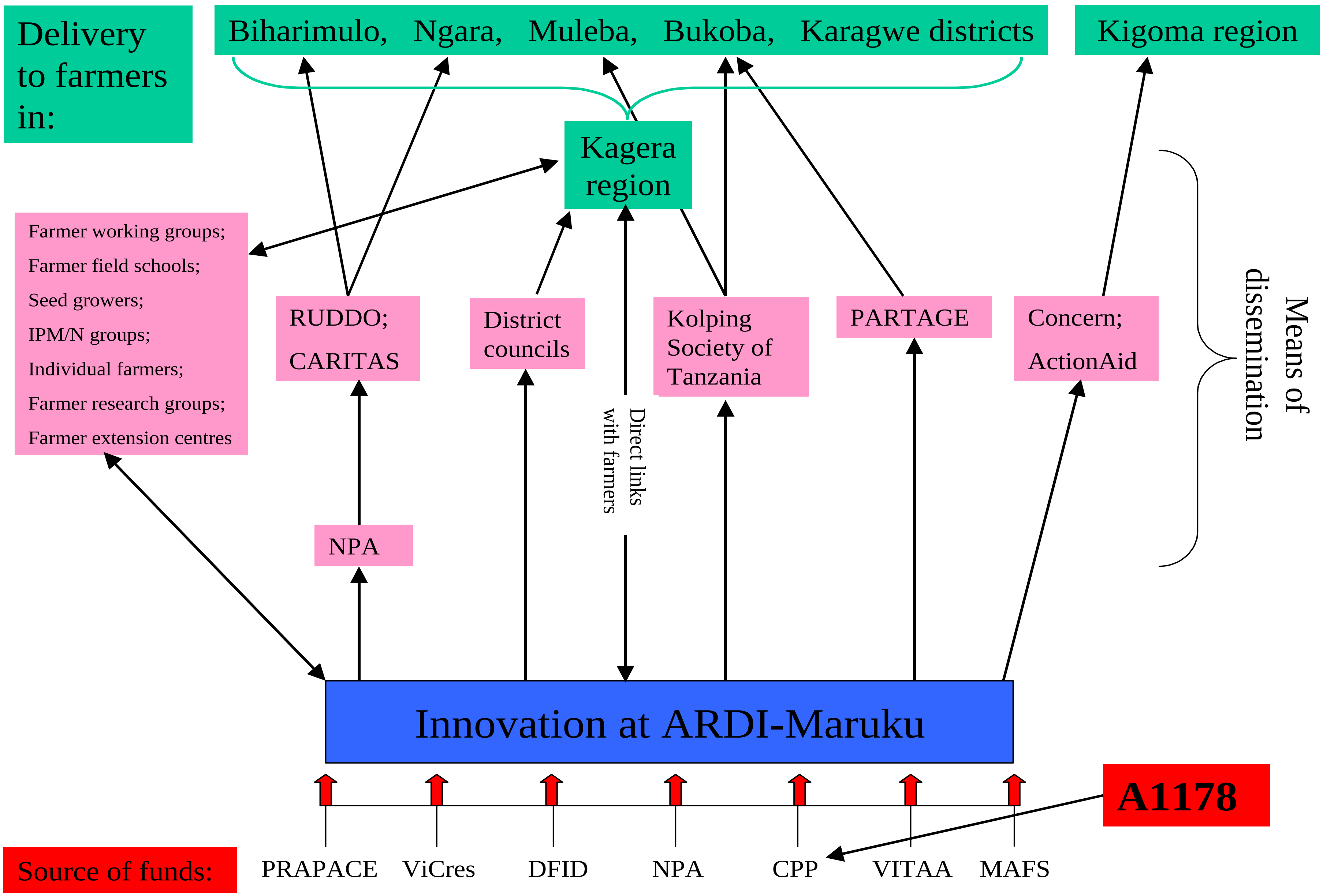
In order to achieve these, R8457 had three main activities:

1. Working with other actors in development to widen impact of project outputs.
In this project activity, the impact of previous project achievements was extended in a cost-effective manner by sharing activities with another CPP-funded project and involving an increasing range of partners with their own funds. The strategy of working closely with other regional actors in development had been found to be particularly effective during the previous phase of the project particularly in the Kagera Region of Tanzania. This approach was expanded still further by project partners at ARDI-Maruku in Tanzania in this extension, increasing the range of NGOs involved and including Kigoma Region as shown in Figure 1.

Additional training material was developed, partly through links with R8458 and Swahili versions by partners at ARDI-Maruku (Figure 2).

2. Complete the first participatory breeding of superior SPVD-resistant sweet potato in Africa
This project activity built on the successful cycles of participatory breeding which have been achieved by R8243 with farmer groups. A further 2 generations of clones selected by three farming communities in Uganda have been planted on-farms. All data collected during the entire breeding programme in Uganda have been entered in three separate Excel spreadsheets, enabling the performance of each genotype to be analysed over 5 generations. This has been done as a first step to publishing the achievements of this activity. Farmer-selected materials have been transferred to the Ugandan Sweet Potato Programme. A process whereby virus-tested material is available for international transfer [with the initial aim of transferring to Tanzania] has been initiated through the auspices of the Ugandan Sweet Potato Programme. Mr S Agili based at KARI-Muguga and the International Potato Center. In the much smaller Tanzanian programme, farmers have grown one further generation and continued to select superior material. ARDI-Maruku scientists have begun propagating material derived from the farmer-selected clones, both as a means of accessing the material and as a means of maintaining it.

Fig. 1. ARDI-Maruku strategy for developing and disseminating knowledge and resistant varieties to address need for control of SPVD and for high-yielding and orange-fleshed sweet potato varieties in north-west Tanzania



3. Determine the role of phytosanitation for controlling Alternaria disease
Alternaria is probably the second most damaging disease of sweet potato throughout East Africa yet little is known of its epidemiology and how to control it. It has proved particularly damaging to some of the high-yielding varieties bred by the Ugandana Sweet Potato Programme, notably NASPOT 1 and the highly SPVD-rsistant New Kawogo. Little is known of its epidemiology and an important first step towards understanding it seemed to be to examine whether infected sweet potato debris is a major source of inoculum. This was addressed by conducting replicated on-station trials at NAARI in both the first and the second rains, comparing the development of *Alternaria* disease in plots in which surface debris from previously harvested plots is/is not introduced and in plots in which apparently disease-free/diseased planting material is used.

Additional Activity 4: Developing strategies for the improved maintenance of sweet potato planting material in areas where there is a prolonged drought.
In R8243's FTR, it was noted that failure of sweet potato to survive through drought affected at least one section of each project activity and that this and other observations had led to a perception that survival through drought was a major aspect of sweet potato production in many parts of Africa. Mwanza and Shinyanga are two regions in Tanzania that experience continuous drought for approximately 6 mths – from May to November. A survey was therefore made in these regions in July 2005 of the means farmers there were using to maintain planting material. This was followed up by additional observations there during a short visit in November.

Additional Activity 5: Assessing the potential of intercropping sweet potato with pigeonpea.
Barrier crops were identified by R8243 as a theoretical means of limiting the spread of SPVD from old to new adjacent crops. However, maize was too demanding in terms of planting time to be generally practical and sorghum was too competitive. Pigeonpea was subsequently identified as a possible candidate. This identification then led to an appreciation that intercropping with pigeonpea could have multiple and major practical benefits and this led to shared funding of a Makerere University MSc student (Ms Ruth Kaggwa) with the International Potato Center. A series of replicated field trials testing different management practices for intercropping sweet potato and pigeonpea have as a result been initiated at Serere Agricultural Research Institute. Links have also been established in Tanzania with Vi Agroforestry and with ARDI-Ukiriguru to test this concept.

Outputs

Output 1. Widening the impact of project outputs by collaborating with other actors in development.

In north-west Tanzania, the project has integrated its activities on the development of superior SPVD-resistant varieties with a range of actors including those involved with the development of locally-adapted orange-fleshed varieties. It has also worked with a range of organisations involved in development to transfer both knowledge of how to control SPVD and to multiply superior SPVD-resistant varieties (Figure 1). Activities have been expanded out of Kagera Region into adjacent Kigoma through collaboration with GTZ and with NGOs particularly Concern and ActionAid. In general, the approach has been that collaborators have funded ARDI-Maruku staff travel and costs and the multiplication of improved varieties whilst R8457 has contributed to knowledge and training materials including starting stocks of known superior SPVD-resistant varieties.

Linking with others both at the innovation level [particularly as regards variety development] and at the dissemination level has continued to be an underlying theme of project activities addressing the above output. Most effort has also continued to be expended in north-west Tanzania where farmer knowledge of SPVD is generally less than in Uganda and where high-yielding SPVD-resistant varieties are only recently and patchily become available. A leaflet on SPVD has been produced in Swahili by ARDI-Maruku (Figure 2). The project has collaborated with R8458 to develop a brochure addressing the wider topic of pests and diseases of sweet potato by abstracting and modifying relevant sections of the now-published ‘Manual for Sweetpotato Integrated Production and Pest Management Farmer Field Schools in sub-Saharan Africa’.

In Uganda, links have continued to be maintained with refugees in camps in Mbarara district, supplying extension staff with planting material of SPVD-resistant varieties and linking with them to evaluate results. This is an extremely dry area and drought has continued to limit progress.

Fig. 2. The leaflet in Swahili produced by ARI-Maruku colleagues on the control of SPVD.

Udhibiti wa batobato ya viazi

Panda aina zinazovumilia batobato

Kituo cha utafiti cha Maruku (Kanda ya Ziwa) kwa kushirikiana na wahisani kimezalisha mbegu bora za viazi vitamu zinazovumilia batobato. Mbegu hizi hutoa mazao mengi na baadhi yake zinavumilia hata magonjwa mengine kama vile bakajani. Baadhi ya mbegu hizo ni kama zifuatazo:

Aina	*Kiwango cha uvumilivu*	*Mazao (tani/ha)*	*Vionjo*
NASPOT1	Kikubwa	47-50	Wanga
NASPOT3	Kikubwa	30-35	Wanga
NASPOT4	Kikubwa	38-47	Wanga
NASPOT6	Kikubwa sana	32-40	Wanga sana
JITIHADA	Wastani	35-45	Wanga
VUMILIA	Wastani	35-44	Wanga sana
POLISTA	Kikubwa	30-38	Wanga sana
SIMAMA	Kidogo	34-40	Wanga

Matumizi ya aina za mbegu zinazovumilia ndiyo njia yenye mafanikio zaidi katika kudhibiti batobato. Hii ni kwa sababu aina hizi haziathiriki kirahisi na hata zikiambukizwa ugonjwa, zinapona bila madhara makubwa kwa mazao. Mbegu toka kwenye aina hizi hupandwa na huchipua bila dalili za ugonjwa hata kama mmea mama ulikuwa umeambukizwa. Kwa kawaida, mbegu zisizokuwa na uvumilivu huwa haziponi batobato hata kama zitapandwa na kuchipua upya.

Chagua mbegu toka mimea isiyo na dalili za batobato

Kukata mbegu toka mimea iliyoathirika huendeleza batobato kwa sababu virusi wa ugonjwa huwa wameenea sehemu zote za mmea. Ili kuepuka batobato unashauriwa kuwa mwangalifu na kuchagua mbegu toka mimea isiyo na dalili za batobato.

LZARDI

Kwa maelezo zaidi wasiliana na:
Kituo cha Utafiti, Maruku
S.L.P 127 Bukoba, Tanzania
E-mail:marukuardi@yahoo.com

Ng'oa mimea iliyoathirika

Unashauriwa kung'oa mimea yote inayoonyesha dalili za batobato mara tu baada ya kuchipua. Hii husaidia kupunguza kiwango cha maambukizi hasusani kama zao limepandwa kwa ajili ya kuzalisha mbegu bora. Hata hivyo njia hii ni muafaka kwa maeneo yenye kiwango kidogo cha maabukizi ya batobato.

Panda shamba jipya mbali na la zamani

Utafiti unaoendelea umeonyesha kuwa, kiwango cha maambukizi ya batobato hupungua endapo aina za mbegu zisizovumilia batobato zitapandwa mbali na shamba la zamani (*isolation*) ili kuepuka chanzo cha ugonjwa. Katika maeneo yenye uhaba wa ardhi unashauriwa kuweka uzio wa mazao yenye kimo kikubwa kuliko cha marando. Mazao jamii ya nyasi kama vile mtama au mawele yaliyopandwa karibu hupunguza kiwango cha kuruka/kutambaa cha wadudu viambukizi yaani inzi weupe, wadudu mafuta na utitiri wa manyoya.

Punguza kiwango cha batobato katika eneo lako

Litakuwa jambo la busara na faida endapo wakulima wote watatumia mbinu muafaka za kudhibiti batobato. Wakulima wakishirikiana wote watapunguza kiasi cha ugonjwa katika maeneo yao na hivyo kupunguza kiwango cha maabukizi.

Natural Resources Institute

Kipeperushi hiki kimeandaliwa kwa msaada wa Crop Protection Programme (CPP) kupitia NRI ya Uingereza na IITA.

Maambukizi na udhibiti wa batobato ya viazi vitamu (SPVD)

Kitengo cha Mazao ya Mizizi, Utafiti-Maruku (Kilimo, Kanda ya Ziwa)

Utangulizi

Batobato ya viazi vitamu (SPVD) husababiswa na muungano wa virusi wa aina mbili, *chlorotic stunt virus*(waenezwao na inzi weupe) na *feathery mottle virus* (waenezwao na wadudu mafuta). Virusi huishi katika chembe hai za viumbe. Huathiri majani na mfumo wa maisha wa mimea na kusababisha mazao kupungua. Kipeperushi hiki kinaeleza jinsi ya kutambua mimea iliyoathirika kwa batobato, jinsi virusi wauingiavyo mmea wa viazi (marando) na jinsi ya kudhibiti ugonjwa huo.

Dalili za batobato ya viazi vitamu

Marando yaliyoathirika hubadilika na kuwa na dalili zifuatazo:

- Majani huwa njano iliyochanganyika na kijani. Rangi ya njano hujitokeza kufuatia mishipa ya jani (veins) na kujitokeza mithiri ya unyoya
- Majani hupungua upana na kuwa membamba au huwa na umbile dogo pungufu na lile la kawaida
- Mimea iliyoathirika hukua kwa shida au kudumaa.
- Muhimu zaidi, mazao hupungua au kukosekana kabisa endapo mmea umeathirika ungali mchanga, yaani umri wa chini ya mwezi mmoja.

Marando yaliyoathirika na batobato hudumaa na kutoa mazao kidogo

Marando yasiyo na batobato hutoa viazi vingi na vikubwa. Pia mazao ni mengi.

Maambukizi na kuenea

Batobato huenea kwa njia kuu mbili zifuatazo:

1. *Inzi weupe na wadudu mafuta*

Inzi weupe (whitefly) na wadudu mafuta (aphids) hubeba virusi katika tezi zao za mate na kuambukiza mimea, kama vile mbu waabukizavyo malaria. Inzi weupe hukaa kwenye upande wa chini wa majani ya marando. Hufyonza majimaji ya majani ya marando kama vile mbu wafyonzavyo damu. Baada ya kuambukizwa virusi huzaliana na kuishi kwenye majimaji ya mimea. Hivyo, mara inzi weupe wafyonzapo majimaji toka mimea iliyoathirika, hunyonya pamoja na virusi wa batobato ya viazi.

Endapo inzi mweupe aliyefyonza majimaji yenye virusi atafyonza toka mmea wenye afya, mate yake huchanganyika na majimaji ya mmea wenye afya na hatimaye kuuambukiza virusi wa batobato. Mimea iliyoambukizwa batobato kwa njia hii huonyesha dalili baada ya siku 5 hadi majuma mawili. Dalili huonekana tu kweye majani ya juu ila ya chini zaidi hayaonyeshi dalili za ugonjwa huo.

2. *Marando yaliyoathirika*

Batobato ya viazi huenea pia kwa kupanda marando yaliyoathirika. Iwapo marando yatakatwa toka kwenye mimea iliyoathirika, mimea mipya pia itachipua ikiwa imeathirika kwa batobato.

Mimea mipya yaweza pia kuchipua na batobato endapo ilitokana na mmea uliokwisha athirika ingawa ulikuwa hauonyeshi dalili za ugonjwa huo (*latent infection*).

Maambukizi ya inzi weupe na aphid:

Ni baadhi ya majani ambayo huonyesha dalili. Ukali wa dalili kwenye majani huzidi kadri marando yanavyokua. Majani yaliyochini huwa ya kijani lakini yale machanga huonyesha

Maambukizi ya mimea iliyoathirika:

Majani huonyesha dalili za batobato tangia wakati wa kuchipua. Marando hudumaa na hayaweki viazi.

Output 2. Complete the first participatory breeding of superior SPVD-resistant sweet potato in Africa

Trials planted in the last few months of R8243 with remaining genotypes of sweet potato selected by farmer groups in Mpigi, Luwero and Kiboga were harvested in July 2005. At all three location, some genotypes outyielded local controls; this was particularly significant in Luwero where the controls chosen by the farmers included NASPOT 1 and the local variety Dimbuka. Both these varieties are very high-yielding.

Plate 2. Farmer showing the highly marketable root of NK 1081

Farmers also considered that several of their selected genotypes were better in other ways. In particular, one coded NK 1081 was considered by all the farmers to have roots with a very attractive and highly marketable appearance and with a good taste. It is also apparently more resistant to Alternaria than NASPOT 1, has a vigorous foliage and may also be more weevil-resistant as its tubers are produced deeper underground. All the selected material appears to be resistant to SPVD. As a consequence, farmers have begun multiplying some of these genotypes (Plate 3), both for their own use and for future sales of both tubers and vines.

Plate 3. Farmers collecting cuttings to take home of genotypes they have selected from their breeding trial as superior. Dr Mwanga, Head of the Ugandan Potato Programme, is the 3rd person from the right.

The Ugandan Sweet Potato Programme provided the initial seed stocks and has continued fully participating in these farmer participatory breeding trials (Plate 4). Farmer-selected material from Luwero and Mpigi have been included in their own multilocational trials at Namulonge, Serere and Katchewekano research stations, respectively in the east, central and in the highlands in the west of Uganda. Farmers in Luwero and Mpigi are also continuing to evaluate and multiply their selected accessions and the Ugandan Programme will maintain links with them. Dr M Potts at CIP has also agreed CIP will facilitate the international transfer of this material through their links with KARI Muguga in Kenya. The breeding activity in Kiboga, where SPVD is least prevalent, is one generation behind that in Luwero and Mpigi because of a delayed start and drought preventing evalutions [other than for drought resistance!]. Further selections will be made there with the Ugandan Programme on the current trial due to be harvested with the start of the next rains. Individual Excel spreadsheets have been prepared for the results in Luwero, Mpigi and Kiboga. These have been arranged so that all assessments on any one genotype occupy a single horizontal line so outcomes can be followed and analysed easily.

Plate 4. Mr Setyabule, the leader of the Luwero farmer group, exhibiting genotypes bred by his group to scientists visiting Namulonge Research Institute

Just one farmer breeding programme remains in Tanzania due to the various natural calamities reported in the previous FTR. This programme is located in highland areas near ARDI-Maruku where SPVD is rare. Farmers and scientists continue to evaluate this material and a replica collection is maintained at ARDI-Maruku both for evaluation and protection against further natural disasters. This material will also continue to be evaluated under TWIP. It is also planned to transfer genotypes selected by farmers in high SPVD-incidence Mpigi and Luwero to Tanzania to test for acceptability in high SPVD-incidence areas such as Kyaka.

Output 3. Determine the role of phytosanitation for controlling *Alternaria* disease

A field trial was set out at NAARI during the first rains to assess whether old sweet potato foliage can harbour and act as a source of inoculum for alternaria leaf spot and stem blight. The trial involved two treatments: debris from sweet potato plant which had had alternaria symptoms was either put or not put in the central part of the plots in a randomised design replicated four times. Plots were assessed monthly for any symptoms developing on either leaves or stems. Incidence and severity of any disease was recorded monthly. A repeat trial was planted in the second rains.

The graph below (Fig. 2) shows new symptoms at each time of recording for this first trial. More plants showed Alternaria symptoms in plots with residues than in those without in the first weeks of disease recording. However towards harvest, presumably as the disease spread, new infections were not significantly different for the two treatments. Yield did not differ among the treatments. This may because the disease only became severe when the crop was at near maturity.

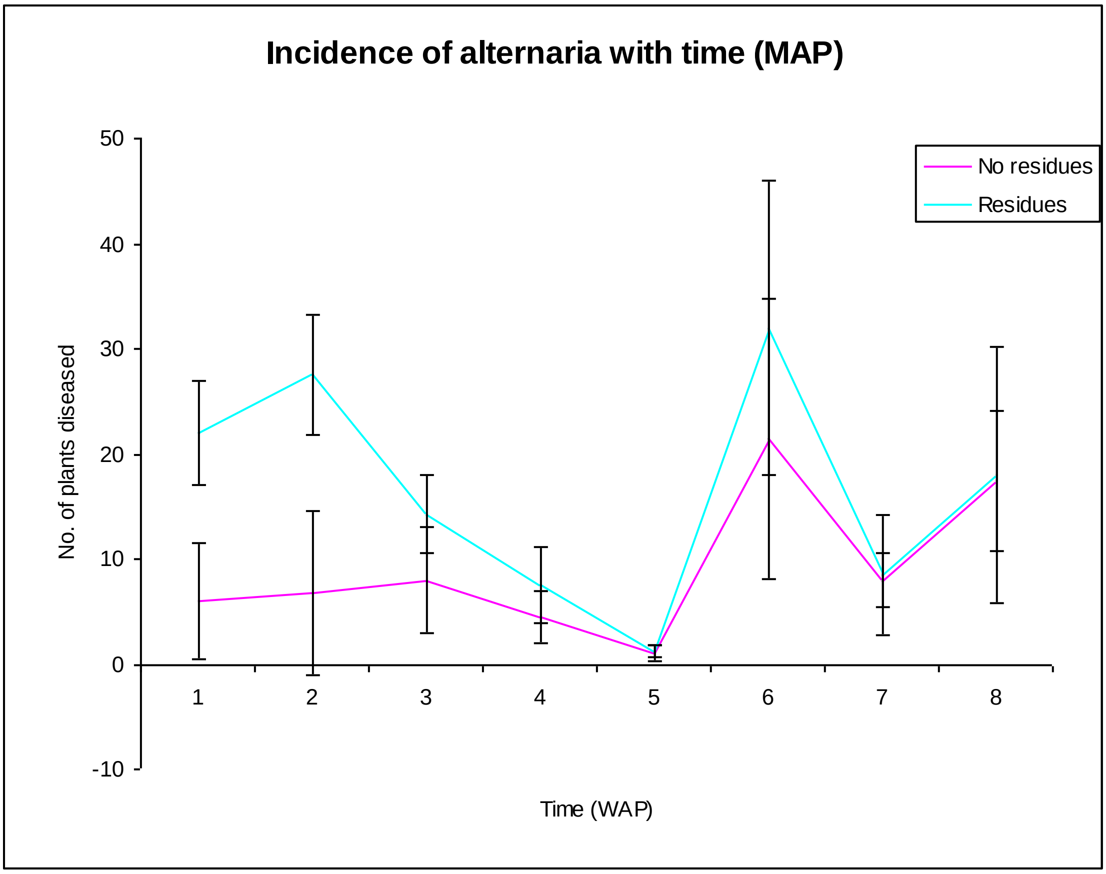


Fig. 2. The occurrence of newly-infected plants in plots in which residues from previous crops had been either added or not added.

In the subsequent trial, the second rains ceased unusually early and conditions became dry. Symptoms remained restricted to small lesions on the stem and petiole. However, these symptoms were clearly concentrated on plants in the central part of plots where crop residue had been placed, 22 plants showing lesions in inoculated plots versus only 4 in non-inoculated plots. The photograph below (Plate 5) shows typical lesions developing in close proximity to the old foliage.

These results therefore support the hypothesis that residues of old sweet potato crops harbour Alternaria. These results indicate that farmers should avoid planting a new crop of sweet potato where an old crop has recently been grown. This is consistent with recommendations for controlling both weevils and SPVD as well as for general good husbandry. Where farmers are very short of land, forcing them to grow sweet potato repeatedly on the same land, this result suggests they should burn the residue; perhaps feeding it to grazing animals would be a safe but more productive alternative. It also suggests that farmers in such circumstances should grow Alternaria-resistant varieties – certainly avoid NASPOT 1.

Plate 5. Photograph showing Alternaria lesions developing in proximity to old crop residues

Additional Activity 4: Developing strategies for the improved maintenance of sweet potato planting material in areas where there is a prolonged drought.

The short survey made in Mwanza and Shinyanga Regions of Tanzania in July 2005 [Appendix 1] identified that most planting material was maintained during the long [6mths] dry season around waterholes. This material had to be established in June/July, then further propagated in September so that sufficient is ready for use in November/December when the short rains arrive. This method is extremely labour intensive, particularly as regards watering, and most of the effort for this latter falls on the shoulders of women and girls (Plate 6). The approach is also remarkably 'low-tec', perhaps associated with it being a 'woman's job' – not even watering cans were used [no intermediate technology foot pumps were to be seen!]. This method is restricted to areas where there are waterholes with ample low-lying land around them, and farmers without such access are forced to buy planting material, sometimes travelling considerable distances to do so and at considerable effort and expense.

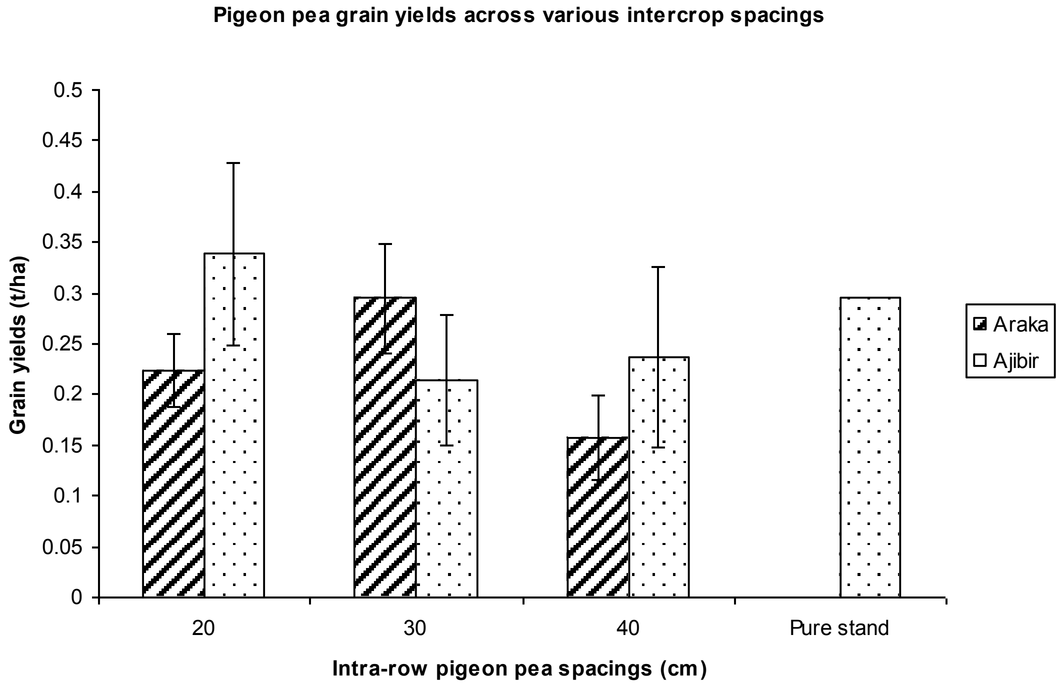
An alternative strategy based on farmers using roots – perhaps growing them especially for the purpose or using small ones less suitable for eating – is suggested (Appendix 1). The roots are planted close together in small beds and watered from about 2mths prior to the onset of the rains. Watering would then only have to be done in a small area for a relatively short time and the roots, which naturally sprout at the beginning of the rains Plate 7), will establish much more easily than shoots exposed to the intense sunlight.

Plate 6. A woman carrying water from a nearby waterhole to maintain her sweet potato planting material

Plate 7. A photograph showing multiple sprouts appearing naturally at the onset of rains from even a small root

Additional Activity 5: Assessing the potential of intercropping sweet potato with pigeonpea.

A trial has been co-funded with CIP to test the agronomic compatibility of sweet potato and pigeonpea. The trial, based at Serere Agricultural Research Institute, involved planting pigeonpea along the furrows between ridges planted with sweet potato.



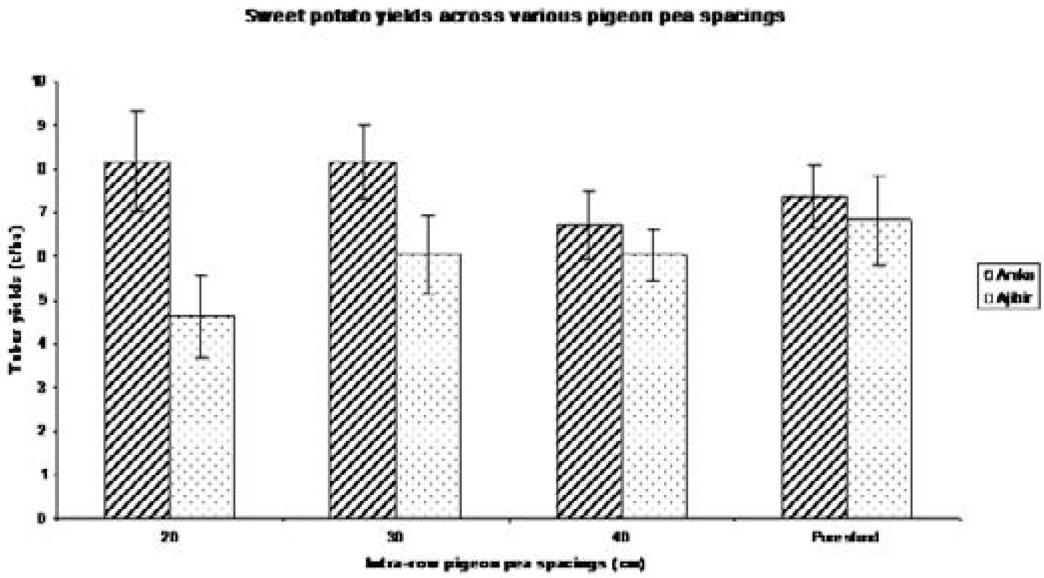


Fig. 3. Yields of sweet potato and pigeonpea when intercropped or monocropped

Two varieties of sweet potato, the vertical-growing Araka and the prostrate Ajibir were grown at normal spacing along the ridge; one variety of pigeonpea, SEP 1, was planted at 20cm, 30cm or 40cm along the furrow. The most impressive outcome was that the yield, particularly of Araka, appeared more-or-less unaffected by the presence of the pigeonpea and the yield of the pigeonpea seemed more-or-less unaffected by intercropping (Fig. 3). This consequently more-or-less doubled the land equivalent value for the two crops when grown together of 1.7 – 1.8, a massive increase in productivity.

Growing the two crops together appears also to have many other potential benefits (Appendix 2). Pigeonpea is a legume and therefore can fix N, with potential benefits for subsequent crops. Pigeonpea also has a deep root system – which probably allows it to avoid competition with that of sweet potato – which is reputed to be very effective at mobilising P from the subsoil. This P should be transferred to the upper layers of the soil as the pigeonpea sheds its leaves in the dry season. The pigeonpea itself is a high value export crop but is also high in protein, B vitamins etc, complimenting the high carbohydrate content of sweet potato. Although Serere is an area where SPVD is relatively rare, there also were fewer diseased plants in intercropped plots, though the numbers were too few to analyse statistically.

Contribution of Outputs to developmental impact

Relevance to poor rural families in Africa:
Sweet potato is a crop grown in Africa mainly by relatively poor, mostly women farmers to provide daily food for the family. It is also commonly sold by women as a source of cash, usually for minor family requirements and occasionally as a small business. The project has developed and disseminated control measures for its main disease, SPVD. None of the methods developed require external inputs other than resistant varieties [available] and so are highly appropriate for poor farmers and are sustainable. It has also demonstrated one means [crop hygiene] of controlling the second most important disease (Alternaria), again the low-input, sustainable mechanism making it suitable to benefit these farmers

Although few activities have directly involved orange-fleshed sweet potato varieties [which have the advantage of providing large amounts of vitamin A cheaply to rural families], most of the above activities provide support essential for the success of the VITA A project.

The project has further validated the participatory breeding approach. Once again, the work has been done with farmers growing food mainly for their families plus some cash sales. Genotypes of sweet potato selected in this manner continue to exhibit excellent disease resistance, appropriateness to farmers' conditions, market requirements and for family use. These genotypes have been incorporated within the activities of the two national programmes, ensuring the completion of the work and hence that farmers will fully benefit.

Drought resistance was identified as a key factor in all project activities involving on-farm work and by farmers as a major constraint in survival of planting material essential for the successful production of sweet potato. Drought resistance has probably been selected strongly for by the participatory breeding approach. Improved means of obtaining planting material in time for early planting when the rains arrive have been identified for areas where there is a prolonged seasonal drought. In achieving this, the project has responded to drought resistance and maintaining planting material through dry seasons being under-researched in sweet potato. Areas where there is a prolonged seasonal drought are currently areas in Africa where there are extreme food shortages [e.g., Malawi, Zambia, Mozambique] requiring food aid and are generally extremely poor. In this way, the project is potentially making a major contribution to Millenium Development Goal 1.

The development of a cropping system for sweet potato which involves a legume [pigeonpea] appears to provide the opportunity for farmers to gain massive and multiple benefits. This is considered to offer potentially huge gains for poor rural families farming in marginal, especially relatively arid areas by boosting their food and nutritional security, the fertility of their soil and potentially leading to food surpluses which could generate income.

Development and effective utilization of links with other organizations:
The participatory breeding work has continued facilitating links in Uganda and Tanzania between scientists and farmers and the project has facilitated the overall links between scientists in Uganda and Tanzania based respectively at Namulonge and Maruku research institutes, facilitating technologies to be shared across national borders. This is very cost-effective and hugely to the benefit of both as they share a common agroecology.

The project has also built on an approach seeking to involve the broad range of actors in development present in any one region (Fig. 1), linking organisations involved in disseminating outputs to farmers directly with researchers so that innovations are quickly made available to farmers and scientists are not diverted excessively into delivery of training messages. This has enabled up-to-date training messages and materials to be delivered in a timely manner to farmers. Training in an understanding of SPVD, its causes, means of spread and means of control has been provided to extensionists and farmers in both Uganda and Tanzania. Numbers of government and NGO extensionists trained in Tanzania were particularly large due again to support by external funds. This ability to leverage increased impact is considered to be a major project achievement.

The project has continued to link closely with the activities of the DFID-funded Tropical Whitefly Project (2005 – 2008) in Tanzania and this is seen as a main route for continued impact of project outputs. Plans have been set in motion to enable genotypes of sweet potato selected by farmer groups in agroecologies similar to those of NW Tanzania, including high prevalence of SPVD, to be imported from Uganda. The import of NASPOT varieties bred at NAARI by Dr Mwanga has already had a major impact there and it seems likely that a similarly large impact will be achieved by further imports.

Disseminations

Training materials

Brochure in Swahili on SPVD control [See Output 1]

Scientific Papers

1. Gibson, R. W., Aritua, V. & S Jeremiah. 2005. Factors associated with damage to sweetpotato crops by sweet potato virus disease. In Whitefly and whitefly-borne viruses in the Tropics. Building a knowledge base for global action [Edits: PK Anderson & FJ Morales] CIAT Columbia, 351pp.
2. Aritua, V., Gibson, R.W. & Vetten, J.F. 2005. Serological analysis of sweetpotatoes affected by sweetpotato virus disease in East Africa. In Whitefly and whitefly-borne viruses in the Tropics. Building a knowledge base for global action [Edits: PK Anderson & FJ Morales] CIAT Columbia, 351pp.

Presentations at international conferences

1. Byamukama, E, Mugunda, M., Mutumwinka, M & Gibson, RW. 2005. Occurrence of sweetpotato virus disease in Rwanda. Presentation at the IX International Plant Virus Epidemiology Symposium, April 4 – 7, 2005. Lima, Peru
2. Gibson, RW, Manu-Aduening, JA, Lamboll, RI, Lyimo, NG & Acola, G. 2005. Some farming practices may delay the development of virus-resistant landraces. Presentation at the IX International Plant Virus Epidemiology Symposium, April 4 – 7, 2005. Lima, Peru
3. Rwegesirwa, GM, Marandu, EF & Gibson, RW. Role of vectors and environmental variability on the incidence and severity of sweetpotato virus disease in the Lake Zone of Tanzania. Presentation at the IX International Plant Virus Epidemiology Symposium, April 4 – 7, 2005. Lima, Peru

Internal Reports:

1. Quarterly report to CPP
2. Other reports – see appendices

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Biometric issues

Send reply to:	"Emma Byamukama" <ebyamukama@naro-ug.org>
From:	"Emma Byamukama" <ebyamukama@naro-ug.org>
To:	"GIBSON RICHARD W" <R.W.Gibson@greenwich.ac.uk>
Subject:	**Statistical training**
Date sent:	Wed, 23 Mar 2005 08:42:00 -0000
Organization:	IITA

Dear Richard,

This email is to confirm that, in addition to the statistical training that I received as part of my B.Sc. and M.Sc. at Makerere University, the sweet potato project also ensured that I attended the course on 'Handling data from participatory studies' at the University of Reading in 2003. The training was on aspects like participatory rural appraisal tools, generating qualitative data, dealing with ranks and scores and sampling procedures among others. This has proved very useful and appropriate for ensuring we can handle the kind of data we obtain from the project activities, especially given that I can always get further help if necessary from IITA or Makerere statistician .

Sincerely,

Byamukama Emmanuel

Appendix 1: Notes on visits [20 – 27th July and 17 – 20th November 2005] to Mwanza and surrounding areas in Tanzania to investigate how farmers conserve sweet potato planting material through the long dry season

RW Gibson

Background

Adequacy of planting material involves both qualitative and quantitative aspects. Till now, R8457 and preceding projects have focused on qualitative aspects, notably genetic [disease resistance, high yield, acceptability etc] and freedom from viruses. Drought in particular has, however, been highlighted by national programme leaders as a problem and hindered various activities conducted by R8243, poor retention during drought in particular constraining long-term uptake of superior varieties. Also, sweet potato is less widely grown in countries away from the Equator, perhaps because there the rains are distributed asymetrically with a counterbalancing prolonged dry season. This prolonged dry season is already evident in Mwanza, Tanzania, ca 2.5^{o} south and becomes increasingly so in Shinyanga, 1^{o} farther south. Farmers need to have sufficient planting material at the start of the rainy season to maximise their benefit from it. Ample planting material is also required for farmers to reject diseased material. Sweet potato is a well-established crop in the Lake Zone. How farmers there conserve their planting material may be useful where the crop is newly introduced to farmers in similar or more extreme conditions. An understanding of how farmers currently retain planting material may also enable researchers to suggest improvements and understand how best to distribute new varieties. I visited farmers in this area 20 – 27 July and on 19 Nov., accompanied by Mr Chirimi (ARI-Ukiriguru). We were assisted by DALDOs, particularly at Meatu by Mr Desdery Mushumbusi: email Meatucouncil@Africonline.co.tz).

Achievements

Agricultural extension officers and farmers in Shinyanga (8), Meatu (9) and Mwanza (1) districts were interviewed using a questionnaire. Opinions were also gathered informally in discussions with these and other farmers. In all districts, rainfall occurred mainly in November and December [short rains] and in March, April and May [long rains]. Sweet potato was an important crop everywhere but particularly in Shinyanga and Meatu. The main time for planting sweet potato was November - December. Despite a dry spell in January and February, pronounced in Meatu, sweet potato could survive till the long rains (whereas maize often failed). Fresh roots were generally available only by February or March – but still making sweet potato the first food staple to become available after the rains. In Meatu, farmers only seemed able to access fresh roots until July but in Shinyanga the season extended even up to October. Otherwise, roots which had been chipped and dried, or chipped, boiled and dried were used; large heaps of these were evident on the roofs of most houses.

It was clear from responses (Table 1) and general discussions with farmers that supply of planting material was a major limiting factor at the start of the rains. Most farmers thought they would plant about twice as much and about 1 mth earlier if planting material was readily available. Most farmers bought planting material; the concept of getting it free from their neighbours was unrealistic to most though three got some free. Some farmers travelled long distances and incurred considerable costs to obtain planting material. In parts of Meatu district, farmers traveled 50 km [Fare, 3,000/- +

700 – 1,000/- extra for transport of cuttings] and paid 3,000/- [Total = 6 USD] for a bundle of cuttings filling a 100 kg maize/fertilizer bag [as described by producers], planting perhaps 10 – 15 ridges each 10 – 20m long [as described by purchasers].

Table 1. Responses by interviewees indicating extent to which access to planting material is a constraint at the start of the rains

District and number of interviewees		Availability of planting material is a problem?					For planting material, do you:	
		No	Small	Main	Limits planting area	Delays planting time	Buy	Sell
Shinyanga	8	3	1	4	7	5	4	3
Meatu	9	0	1	8	9	9	8	3
Mwanza	1	0	0	1	-	-	1	0
Total	18	3	2	13	16	14	13	6

Table 2. Number of farmers using or knowing neighbours using above methods of obtaining planting material

District	No. of interviewees	Method of conserving planting material						
		1	2	3	4	5	6	7
Shinyanga	8	5	4	0	0	1	0	0
Meatu	9	9	0	1	0	4	2	1
Mwanza	1	0	0	0	1	0	0	0
Total	18	15	4	1	1	5	2	1

Farmers mentioned 7 methods of conserving planting material (Table 2):

1. **Growing sweet potato during the dry season in low-lying areas around waterholes and watering**. Nurseries established in June provide cuttings for planting on a larger scale in September to supply planting material for the beginning of the rains in November/December. Watering has to be done throughout; the soil was often heavy clay. Suitable land appeared often to be in limited supply and/or restricted ownership. Sometimes it hardly occurred locally [Meatu]. A few areas had relatively large amounts of such land. An example is Chibe village in Shinyanga district where some farmers were obtaining 100,000 – 150,000/- Tz [90 – 140 USD] by selling to farmers.
2. **Planting a late crop in April that survived until the short rains.** A special soil was required, some suggesting a red soil but a common factor seemed to be that it was sandy. Farmers suggested that such land retained more water but, although root penetration was easy, the soil seemed dry even deep down (>0.5m). Farmers also suggested plants benefited from dew (probable but no logical link to soil type). Some dead plants observed were swollen and tunneled (?by weevils?) at the stem base: better plant survival in sandy soil was probably more to do with weevil damage being less. Farmers weeded the crop with hoes, again limiting access by weevils to stems and tubers. Farmers harvested the larger tubers piece-meal, claiming it helped plant survival.
3. **Establishing a small plot near the homestead that was watered using 'waste' water.** Such plots seemed very small usually, probably because the amount of such water available was limited.

4. **Establishing a nursery bed near the homestead but not watering.** One plot we saw was established in a slight depression and was planted on the flat. This method relied on the survival of the sweet potato foliage as the crop apparently produced few tubers from which the crop could re-establish.
5. **Using shoots sprouting from missed tubers in harvested crops.** No special activities; planting material is generally only available by January.
6. **Wait for regrowth from unharvested sweet potato crops.** Farmers may use a late-planted crop; planting material is generally only available by January.
7. **Plant in the shade.** Planting in the shade of bananas is one of the main methods used in Kagera region [and in drier Uganda] yet it was mentioned only once by farmers in Mwanza and Shinyanga regions. Bananas are rare in these two regions and the native trees mostly shed their leaves in the dry season.

Planting near a waterhole and watering (method 1) was the commonest method. All methods bar 5 & 6 provide planting material for the arrival of the rains. None of these methods, however, provided an ample supply as all farmers interviewed reported a shortage which for most farmers was not alleviated until February or even March. Conserved material had to be protected against livestock.

Table 3. Number of farmers reporting they had lost all their planting material or specific varieties

District and number of interviewees		Using method 1, have lost:		Using other methods, have lost:	
		All planting material	Specific varieties	All planting material	Specific varieties
Shinyanga	8	3	4	2	3
Meatu	9	4	7	-	-
Mwanza	1	-	-	1	1
Total	18	7	11	3	4

Although method 1 seemed likely to be 'fail-safe', it apparently wasn't as some farmers using this method reported losing all their planting material some years. Farmers mentioned that falling sick could mean the entire crop died due to being unwatered. Many farmers had also lost specific varieties: most farmers thought varieties differed in ease of conservation, often mentioning drought or weevil susceptibility as factors. Farmers replanted on an extensive scale in September and October and farmers were watering what were now large areas during my visit in November – it was very hot and dry as there had only been a couple of showers during the last month. It was very obvious that watering the sweet potato planting material was hard work and largely done by women: I counted 22 women and older girls busy watering but, though several men and older boys were present, none were watering. When asked, a woman said her husband had helped her the previous weekend: men apparently sometimes help women but never do it unaccompanied by a woman. Children also helped when not at school (but only young girls were in evidence despite it being a Saturday). Technologies to make watering less arduous/more productive were absent. Buckets were the only tools evident yet cheap hand-, foot- or animal-powered pumps have been developed by NGOs etc and there are also traditional means of raising water. I couldn't help but think that use of such basic equipment (not even a watering can!) was associated with watering being done mainly by women. Watering had to be done from May or June till perhaps December.

Although method 1 in particular might create a circumstance where SPVD would become prevalent, affected plants were only occasionally seen. One farmer explained they selected planting material very carefully. It also may be that the whitefly vectors are rare, as in Soroti and Lira districts in Uganda [apparently similar agro-ecology], perhaps affected by the lack of vegetation during the dry season and lack of trees etc making it windswept

Although farmers used foliage derived from storage roots surviving the dry season [methods 5 & 6], none harvested and stored roots specifically for this purpose. It involves little labour but the roots only sprouted once the rains had arrived and so provided planting material only late in the growing season. My November visit included maincrop fields harvested in April/May, then 'gleaned' in July for any missed roots and finally grazed over. Some 6mths after harvesting, sweet potato sprouts were just breaking through the soil surface (NB, it had rained a couple of times and the soil was damp). When excavated, the roots from which the sprouts originated were all quite small, perhaps 10-15mm diameter yet often had 5-10 sprouts on them. At one location, an obviously late-planted grazed over crop was producing some 20 shoots/hill. At only one location was weevil damage evident on the tubers [This raises the question of whether weevils are only a minor problem for root storage in the soil or whether only the few roots unaffected by weevils survived to sprout. The data from the harvested fields could not provide evidence on this; however, that a high proportion of the hills in the late-planted crop were sprouting suggests it is the former]. The soil at all locations visited was sandy. The main conclusions therefore were:

- Even small roots sprout.
- Very little weevil damage was evident.
- Roots survive and sprout at least 6 months after detachment from the parent plant.

Conclusions
Planting material was a major limiting factor to sweet potato production in these areas with prolonged dry seasons and supplying planting material is a major business enterprise for some. One extrapolation from the survey is the logic of distributing planting material of new varieties in arid areas initially to farmers with access to a waterhole, particularly sellers of planting material. Poorer farmers without such access may be a 'dead-end' for planting material, receiving only temporary alleviation of poverty.

There seem to be two 'best bet' ways forwards:

Improved watering systems: Farmers planting near waterholes should test labour-saving devices for watering. Foot-powered pumps etc have been developed and animals have long been used to raise water using waterwheels, turbines etc. These could increase the area of land that can be watered around a waterhole [and reduce the drudgery], increasing production of planting material and perhaps also increasing the supply of roots for food during the dry season. Increased dry season production of both could be very profitable.

Use of storage roots: The swollen storage roots of sweet potato probably evolved as the means by which its wild progenitors survived drought prior to domestication.

Unlike many other plant species with true storage roots (e.g., cassava, dahlia), the roots of sweet potato readily develop adventitious shoots when detached from the parent plant. Farmers in areas where there is a cold winter (e.g., U.S.A.) routinely exploit this to overwinter planting material, storing roots in a frost-free environment until spring and then sprouting them in heated beds. Farmers in dry areas in Africa similarly exploit this characteristic by not harvesting some of the crop: the foliage dies down during the dry season but the surviving roots sprout when it rains. Farmers may also utilize sprouts developing from tubers missed or discarded during harvest. The main problem with this method is that planting material becomes available only 1 – 2mths after the rains [have triggered the tubers to sprout]. The best land may thus already have been planted with other crops, the early part of the growing season is missed and one of the main advantages of sweet potato – to provide food (to eat or sell) quickly – is wasted and total yield is reduced.

Farmers in areas with prolonged droughts need to achieve early growth so that cuttings are available as soon as the rains arrive [Farmers mentioned that, when early thunderstorms enable roots to sprout early, these then provide a valuable source of planting material]. Farmers outside Africa who overwinter the roots achieve timely and efficient production of shoots by planting roots close together in heated beds. In this way, large quantities of sprouts are obtained from a small heated area: each root may produce 5 – 6 shoots and only small roots are needed, achieving some 300 shoots/m^2 [our November observations confirm a minimum of 5 sprouts even from quite small roots]. In areas where there is a prolonged dry season, harvesting and planting the roots in a bed prior to the arrival of the rains would require only a small area to be watered. Storage roots establish easily, partly because they are themselves a water reservoir, and the food reserves in the roots ensure that the sprouts grow quickly so watering is needed for only a short time. Some farmer research is needed to identify the best method to obtain roots for planting in the bed:

1. Farmers could retain roots obtained during the normal harvest over the dry season in a sandy bed. This could be watered once it is necessary to initiate their growth. Use of small low-value roots could make this method especially attractive.
2. Farmers could harvest roots at the time they need to be sprouted in the bed, planting a crop slightly later than usual [as described by Shinyanga farmers] so weevils have less time to build up and large tubers which crack the soil and allow entry for weevils are avoided, perhaps also planting more closely together, to achieve more but smaller tubers. Choosing relatively sandy soil and hoeing may further exclude weevils. There may be need to:
   - protect against rats, goats and other livestock. This could be done by using thorny branches and purposely removing sweet potato foliage.
   - remove any remaining foliage a month prior to harvesting so tubers lose dormancy.
3. An alternative may be to harvest roots at the end of the normal growing season, storing them in clamps or pits and checking regularly to eliminate weevilled roots. This method has already been used as a means of storing roots for sale but it is not clear if it can ensure storage right through till the rains [Mr Celestine Rugutu (a senior technician of Mr Jeremiah Sato at ARI-Ukiriguru; email: rugutu@yahoo.com) intends to test this next growing season].

Farmers in Meatu and Shinyanga districts paid some 6000/- in total for a bag of sweet potato cuttings sufficient to plant 10-15 ridges each 10-20m long. Assuming a planting distance of 30cm along the ridge, this implies some 900 cuttings; perhaps some 100 - 200 tubers could provide the equivalent amount of planting material. Since these tubers would have to be planted towards the end of the dry season, when food is scarce and prices are high, this probably implies that the use of roots will be viable only if small roots, relatively unattractive either for sale or consumption, are used. All methods require the crop to be harvested at some point but the last needs pits to be dug and the roots to be checked regularly, and are the roots safer from attack e.g. by rodents and weevils in pits or when just left in the ground [pits may on average be safer but keeping them in the ground may present less risk of total loss]? We know roots harvested at the normal time can sprout in the pits [but a Mwanza farmer told me sprouting can be delayed if the roots are initially left out for a day or so in the sun]. On sprouted roots, is it better to remove the sprouts before planting in beds so as to get an even regeneration of [?weaker?] sprouts? It is not clear whether roots kept in the ground sprout before it rains. The roots may somehow be rendered dormant in the dry soil or it may favour the multiple sprouting [USA extension report that pre-sprouting results in more shoots] observed during my November visit. The use of roots may also change the epidemiology of viruses, root-borne fungi and bacteria. None of these factors are likely to present major obstacles as the use of sprouts from roots as sources of planting material is widespread both in Africa and in the developed world – but they need some research.

Other methods identified include:

Tissue culture: A 'rustic' method of enabling farmers to propagate virus-free planting material using tissue-culture has been developed in Zimbabwe (http://www.guardian.co.uk/guardianweekly/outlook/story/0,12662,1416752,00.html). This technique still requires 'hi-tec' knowledge and facilities, and only provides small amounts of planting material – so it does not address bulk-shortage of planting material.

Use of waste domestic water: Various initiatives have used waste domestic water, either getting it to run directly into a garden or watering containers, often with sweet potato growing at the top and sides. It should work but the examples we saw had only straggly plants – it didn't seem to generate either vigorous plants or much planting material. Maybe there isn't enough domestic waste water; the soil around the household was compacted and maybe infertile; even if goats are excluded, there are always chickens around houses to peck at it; and repeated use of the same area may build up of pests and diseases.

Growing plants in the shade This method may work best where the dry season is brief and not intense. Where it is extended, bananas do not thrive and most trees – except mangos under which little grows anyway – lose their leaves. It is possible that sweet potato intercropped with something tall – like maize [which dies but the stover could be left] or pigeonpea [which persists] – may also achieve some protection from drought, but farmers didn't mention it.

Appendix 2: Report on potential of intercropping pigeonpea and sweet potato

RW Gibson: December 2005

Introduction The investigation of pigeonpea as an intercrop for sweet potato derives from the value of barriers [R8243] in preventing the spread of *Sweet potato chlorotic stunt virus*, one of the causal viruses of sweet potato virus disease and reports of lower disease incidence in crops intercropped with maize. Pigeonpea landraces tend to be tall, late-maturing and long-lived; ICRISAT has pioneered the development of high-yielding medium-maturity varieties for Africa. Like most pigeonpeas, they have a deep root system, allowing them to tap subsoil sources of water and nutrients, especially P, not available to most crops. Being legumes, they can fix N, making them an ideal companion crop and are initially slow growing (whilst they establish this deep root system?). Since sweet potato yields quickly, such pigeonpea varieties grown between the ridges or mounds of sweet potato may with little effect on the latter and, by tapping residual moisture, yield after the sweet potato has been harvested to gain an 'extra' crop. This could be particularly advantageous where the sweet potato harvest is followed by a prolonged dry season so that no other crop can be planted (as in Mwanza in May). Adding pigeonpea would also provide a nutritionally more complete diet, help maintain the use of the often limited amount of land poor farmers, particularly women, can often access, provide firewood or stakes (e.g., for climbing beans) and spread labour demands into the dry season. In Uganda, Dr Mike Potts [CIP] and I co-sponsor/supervise a Makerere MSc student, Ruth Kaggwa examining mainly agronomical aspects of intercropping at Serere Agricultural Research Institute (SARI). We have also established links with an NGO, Vi Agroforestry and with Ukiriguru Agricultural Research Institute in Manza, Tanzania.

Activities This report derives from visits made in August during a trip to Mwanza [Tanzania] in July 2005 to Catholic Relief Services and, two NGOs promoting pigeonpea to farmers there and to Ruth Kaggwa's trial at Serere Agricultural Research Institute. A brief visit was also made to the ICRISAT regional office in Nairobi whilst travelling back to UK. A further visit has been made to Mwanza in November 2005 and to Uganda in December 2005.

Findings CRS puts high priority on marketing, processing and utilisation of pigeonpea and have identified that most sales of pigeonpea are in India [1], Europe [2], Kenya [3] and local buyers [4]: the last two perhaps act as intermediaries for re-export. It currently has 13 producer/marketing groups in the Lake Zone but will expand these. CRS is promoting medium duration [about 6 mths] ICRISAT varieties, intercropping with maize: the maize initially dominates but then pigeonpea grows away when the maize is harvested. CRS was using the following medium maturity ICRISAT varieties: ICEAP 00068; ICEAP 00554; ICEAP 00557; ICEAP 000850 and ICPL 87051 [listed in apparent order of popularity]. Collaborating farmers seen at Mwasonge village [Bukumbi sub-county] had a beautiful crop of pigeonpea. Planted in December 2004, it already had many dried and green pods of large white seeds and was also still flowering [late July] despite being well into the dry season. The farmers had planted the crop in 1m wide rows with 0.5m between plants; a neighbouring sweet potato crop was planted in similar width rows.

Vi Agroforestry has 7 major projects in East Africa: 2 in Kenya [Kitale & Kisumu]: 1 in Uganda [Masaka]; 3 in Tanzania [Kagera, Mara & Mwanza] and one starting in Rwanda. They are planning to start two more big projects in southern Africa, one in Mozambique and one in Malawi. In Mwanza, they are working in Ukerewe, Maju and Sengerema and have a total of 180 extensionists each working with 250 – 300 farming families. They are using pigeonpea obtained from Babati called Babati white, getting the seed from an NGO, LAMP Babati [Land Management Programme Babati]. Soil improvement is a high priority for them: the presence of the crop over the dry season also helps protect the soil. I explained my concept of the potential advantages of pigeonpea and it was suggested that I designed a field trial involving sweet potato [Orange-fleshed] and pigeonpea. At the village of Kisessa [near Mwanza] a pigeonpea crop [planted in December 2004] was well-established but had not yet flowered (unlike the CRS trial). The main aim was to improve the soil fertility. The idea of intercropping pigeonpea with sweet potato was also discussed with farmers: they thought it was a good idea. I got mixed messages about Babati white – there may also be medium duration lines which might be more farmer-acceptable and still yield immediately after the sweet potato harvest - rather than delay yielding until the next rains when they occupy land other crops could utilise.

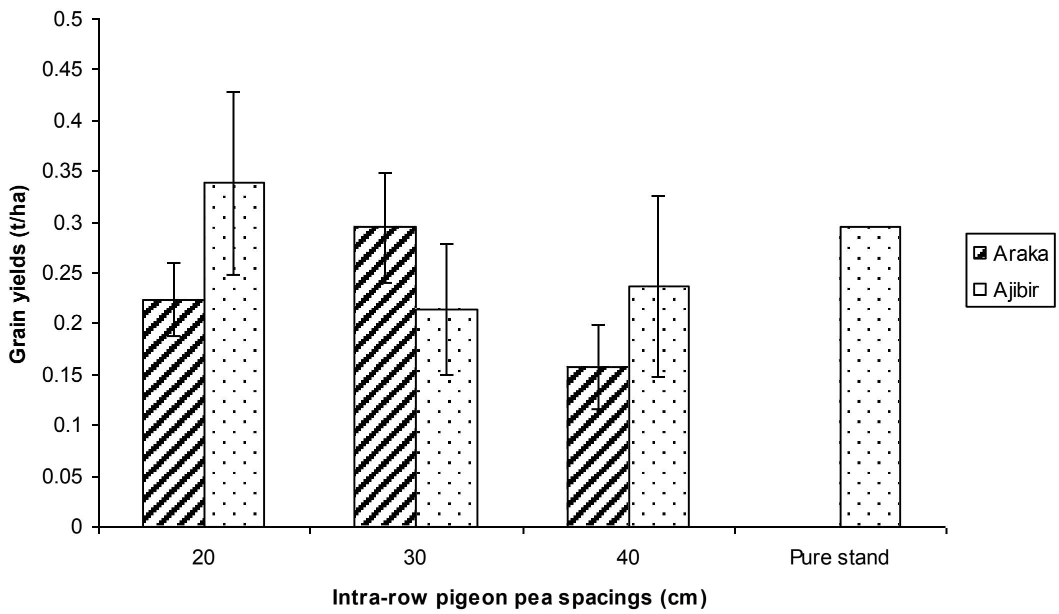
In November 2005, I brought seed of pigeonpea ICEAP 00557 and ICEAP 00554 from ARI-Ilonga (Dr Joseph Mligo). Both varieties had pale-brown seeds that were smaller than Babati white; those of ICEAP seemed slightly larger and I provided Vi Agroforestry (Mrs Dominick) with enough of this to plant 3 trials [2 in Magu District, one in Ukerewe district]. I supplied ARI-Ukiriguru (Mr Chirimi) with ICEAP 00554 for a further trial. We identified the need for soil analyses to examine beneficial effects of pigeonpea on soil fertility [These can be done by either ARI-Ukiriguru (10,000/- per sample for N, P & K) and by SGS [www.sgs.com; edson.msangula@sgs.com], a private company in Mwanza]. As an aside, I was told that Heifer Project International ['Send a cow; HPI] have someone called Mr Zengo based in Shinyanga who is promoting pigeonpea there – but I couldn't find anything on their website.

Ruth Kaggwa's trial at Serere, near Soroti Uganda, planted in March 2005, involved two varieties of sweet potato planted in ridges at the normal distance of 1m between rows and 30 cm between plants and the pigeonpea variety SEPI 1 planted in the furrows at two planting densities with 4 reps. Where pigeonpea had not established, Ruth had gap-filled, with the useful discovery that the seedlings established well even when planted later than the sweet potato. The pigeonpea looked similarly vigorous in sole and intercropped plots as did the sweet potato. Weeds were much less in pigeonpea intercropped with sweet potato due to smothering by the sweet potato and there seemed to be less SPVD in these plots. These trials were harvested in August/September. The yield of intercropped sweet potato and pigeonpea was in both cases quite similar to that of the equivalent monocrop, resulting in far greater productivity (Land equivalent values) for the intercrop. One disappointing result was the overall yields of the pigeonpea. The initial flowering had been badly damaged by insects before the need for insecticide was appreciated [and applied to the second flowering].

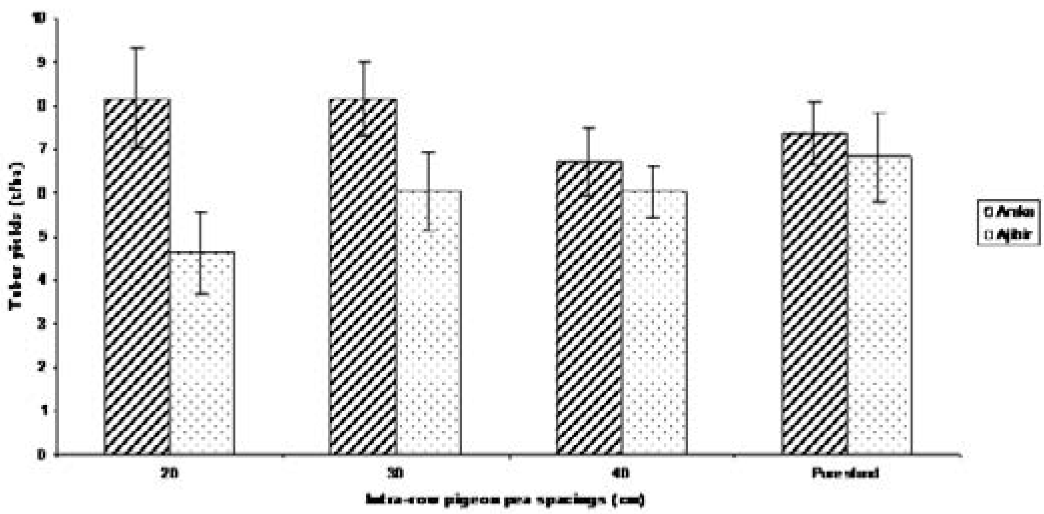
At ICRISAT, I met Dr Eastonce Gwata and Dr Richard Jones. Both ICEAP 00557 and ICEAP 00554 are medium duration and Fusarium resistant – apparently unlike

ICEAP 00068 [see section on CRS]. Babati white landraces were more-or-less wiped out by Fusarium wilt and they have been replaced by ICEAP 00040 and ICEAP 00053, both resistant but both are long duration and therefore unsuitable for the shorter rainy season in Mwanza [perhaps explaining why the Babati white in Mwanza hadn't flowered]. As well as collaborating with CRS in Tanzania, they are working with Mr Joseph Mligo at ARI-Ilonga at Kilosa, and are hoping he will release either ICEAP 00557 and/or ICEAP 00554.

Pigeon pea grain yields across various intercrop spacings



Sweet potato yields across various pigeon pea spacings



Both long and medium duration pigeonpea are indeterminate [whereas the short duration varieties are determinate]. Flowering is promoted by short daylengths and cool temperatures once pigeonpea has passed its juvenile phase. The short daylength stimulus becomes stronger the further away from the Equator: ICRISAT is trying to breed daylength insensitive varieties. In S Hemisphere [e.g., Mwanza], daylength starts shortening and temperature going down in April/May, coinciding with the end of the first rains and the start of the main dry season. Although pigeonpea is a perennial, it is apparently better to pull up the crop after it has cropped [get a build-up of pests and diseases, crop gets too bushy etc]. Both the green pods and the dried mature pods of pigeonpea are picked by hand. It is therefore good at providing employment in what is otherwise a quiet season [except overlapping with cotton harvest?].

I went to the African Crop Science Society (ACSS) meeting in Entebbe in December 2005. Mr Peter Obuo, a pigeonpea researcher at SARI [pobuo@hotmail.com] suggested that wilt-resistant pigeonpea varieties tend to have smaller and coloured seeds. He also suggested that pests tended to be worst during the wet season – so the reason why Ruth's pigeonpea was so badly attacked may be because the first sweet potato planting at SARI is followed by the second rains. This may be less of a problem for the second planting in the second rains – which at SARI is followed by the dry season in November/December. I also met Dr Geoffrey S Mkamilo, Tanzania's National Co-ordinator for Root and Tuber Research Programme [gmkamilo@hotmail.com; utafi@makondenet.com] based at ARI-Naliendele [Mtwara]. Dr Omari Mpoonda also breeds pigeonpea there. Dr Mkamilo told me farmers in Masasi, Nachingwea, Newala and Ruwangwa districts, all in Mtwara Region, often grow sweet potato and pigeonpea together [and never use pesticides!]. In this region, pigeonpea has been grown for many years. In addition, I have been told separately that pigeonpea is now being extensively grown south of Babati, along the road through Kondoa to Dodoma, and sweet potato is also an important crop there.

Overall conclusions: Medium duration pigeonpea varieties are very suitable for intercropping with sweet potato, especially in areas where there is a prolonged dry season. These varieties crop after the sweet potato has been harvested, using residual moisture remaining at lower levels in the soil to produce an additional harvest. Other benefits include improved nutritional security, involvement in the cash economy, improved soil fertility, employment during an otherwise slack period, firewood and weed control. Research evidence + its use in Mtwara region that this crop combination will prove successful elsewhere in dryland areas needs to be confirmed locally but the main need is perhaps to 'fine-tune' how best to include the pigeonpea. Most of the fine-tuning may involve getting the variety right and needs a combination of farmer and scientist research; aspects include:

- Need for insecticide applications to pigeonpea
  - Are there varieties that don't need applications?
- Identifying varieties that suit the end-users but are pest and disease-free
  - both markets and home use may require the large-seeded 'Babati white' type but can wilt-resistance be maintained/ is it necessary?
  - can 'scientists' provide farmers with nearly right varieties from which they can [be trained to] make locally adapted forms?

Some of the answers to these questions may be provided by farmers who already have wide experience of growing pigeonpeas – through surveys in Mtwara region and also in Babati.