PROMOTING POTATO SEED-TUBER MANAGEMENT FOR INCREASED WARE YIELDS IN KENYA, UGANDA AND THE REPUBLIC OF SOUTH AFRICA

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ABBREVIATIONS

ADC	Agricultural Development Corporation
ARC VOPI	Agricultural Research Council, Roodeplaat Vegetable and Ornamental Plant Institute
BCA	Biological control agent
BCA Ω5.1	BCA Omega [Ω] 5.1 developed by CABI Bioscience for KARI
CIP	International Potato Centre
DFID	Department for International Development
INR	Institute of Natural Resources [RSA]
JAGED-SHG	Jitegemee Agricultural and General Development Self-Help Group
KARI	Kenya Agricultural Research Institute
KARI NARL	KARI National Agricultural Research Laboratories
KARI NPRC	KARI National Potato Research Centre
KEPHIS	Kenya Plant Health Inspectorate Service
NARO	National Agricultural Research Organisation [Uganda]
NCST	National Council of Science and Technology
PSA	Potato South Africa
RSA	Republic of South Africa
SSPS	Small-scale [on-farm] Seed Production System
UNSPPA	Uganda National Seed Producers Association
WT	Wild type pathogenic *R. solanacearum*

1. SUMMARY

This research looked to evaluate further two technologies initiated under DFID CPP R6629. Namely, the bicontrol agent [BCA] against bacterial wilt and the on-farm small-scale seed-tuber production systems [SSPS]. In these earlier studies, it was initially envisaged that the SSPS would provide the window for the application of the BCA. However, initial SSPS trial data suggested that the SSPS had significant value in its own right in improving the dynamics of seed flow.

This project sort to position these technologies for wider evaluation and, where appropriate, adoption through a promotional phase. Accordingly:

Biocontrol Agent against Bacterial Wilt
- The BCA was in principle approved for in-country testing in Kenya
- Additional consideration was given to the research approaches necessary in testing the BCA, particularly with regards to BCA persistence and impact on other microbial communities

The Small Scale seed-tuber Production System
- The SSPS was trialed further over an additional 3 seasons [8 seasons in total], providing further validation of earlier trends in optimising of seed production and maintenance of seed health as viewed by yield quantity and quality
- Scope for further improvement of seed dynamics was shown by planting the SSPS-seed cultivation at the less dense spacing of 30 x 30cm
- Monitoring of pests under the seed systems trialed realised the higher than expected significance of soil-borne inoculum of bacterial wilt in causing crop losses
- Scope for using mini-tubers in the SSPS-seed cultivation was successfully ventured by Ugandan farmer; enhancing further the seed utilisation of the SSPS
- In Uganda the adoption of the SSPS-seed cultivation was seen to be driving demand for seed of defined size ranges, with a premium price realised for seed that was suitably sized for use in the SSPS-seed cultivation
- Research approaches to ascertain scientifically based advice on crop rotations that reduce soil populations of bacterial wilt [*Ralstonia solanacearum*] were progressed successfully

Review of the salient features of the potato seed systems in Kenya, Uganda and RSA
- In Kenya and Uganda a good nuclear to basic seed system operates, but with limited capacity thereafter to ensure effective 1st and 2nd phase on-farm multiplication
- In Kenya and Uganda no robust certification / or seed health monitoring is in place. This is a particular weakness given the presence of bacterial wilt
- In RSA, despite a good certification scheme, seed does not reaching the rural smallholders because distribution and packaging of seed is orientated towards largescale practices
- In RSA the varieties available are more suited to high input, largescale production systems and for the preferences of the main urban markets
- In all countries value was seen in forming farmer association as a mechanism to give a critical mass. The Kenyan farmers that were engaged in the SSPS trial work at Njabini formed such an association as a result of this project, named JAGED-SHG.

From this platform the positioning of the BCA and the SSPS was considered in the context of a community based farming system. In discussion with stakeholder groups various way forward scenarios were ventured that have to varying degrees been taken forward. Critically no funding has been secured to progress the BCA and none of the SSPS promotional projects include the resources to ensure robust testing of seed health.

2. BACKGROUND

Preamble: The potato is one of the major food and cash crops in East Africa and the Republic of South Africa [RSA]. Kenya and Uganda for example have a total area of 93,000 and 73,000 ha under potato per year with a per capita consumption of 23 and 19 kg per year. In these countries the potato producing regions are characteristically the populous regions of the highlands, dominated by smallholder farms that operate intensive low input agricultural practices. Emerging local markets for chips and crisps are making potato an increasingly attractive crop for smallholders, although home consumption remains important for securing local food security. By contrast potato production in the RSA, which is the largest potato producing country in Africa, is characterised by large-scale commercial practices that are highly mechanised. However, the dominance of these large-scale enterprises detracts from a significant number of smallholder practices that operate in a similar way to that described as typical to Kenya and Uganda. Here again potato is a valued crop for both cash and home consumption, and the stimulation of smallholder enterprises is a priority of the government of the RSA.

On-farm yields achieved by smallholders have been shown to be very variable and much lower than achieved under optimal conditions. An indication of the level of under-achievement can be gained by comparison of the current average on-farm potato yield in Kenya of less than 10 t / ha to research station yield figures of over 40 t / ha [Lung'aho et al., 1997]. Such low yields have been attributed to near-continuous potato cultivation and the concomitant build-up of diseases and pests, declining soil fertility and a shortage of disease-free seed-tubers. Diseases such as potato blight [*Phytophthora infestans*], bacterial wilt [*Ralstonia solanacearum*] and viruses are recognised as primary constraints to production [Lemaga et al., 1997; Mienie, 1997; Barton et al., 1997].

Seed production: In Kenya and Uganda certified seed production is poorly structured and insufficient to meet national demand. In these countries certified seed production is currently being promoted under respective NARIs in collaboration with the International Potato Centre [CIP]. Existing varieties have been cleaned of viruses and new varieties developed and bulked to basic seed levels, prior to multiplication through regional smallholders in possession of good quality disease free land. In Uganda under an initiative led by AFRICARE [Alacho, 2000] this approach has been enhanced further through the setting-up of potato grower associations that centrally manage the production and distribution of seed. This mechanism of multiplication has been piloted in a number of countries over recent years, and has proven its potential as a strategy to diffuse new varieties. The potential as a pilot structure for a certification scheme has also been established, however, feedback from researchers and farmers suggests greater consideration is required on disease and pest threshold values, the technologies applied to monitor specific priority diseases and pests, and the financial incentives for farmers to become certified seed producers. For example: a] bacterial wilt is notoriously hard to certify against through visual inspections alone and b] The multiplication of basic seed and acquisition of certification has added costs associated that when linked to an insecure market for certified seed represent an unattractive risk to the farmer.

By contrast the RSA has an effective national certification seed production system. The system has validated threshold levels on key diseases and pests determined through research and field inspections over a number of years and embodies a sustaining levy-based financial structure. In the RSA, bacterial wilt has a zero threshold value, and latent infections of seed are monitored for using ELISA technology. Routine batch testing of seed lots under certification for bacterial wilt has markedly reduced the incidence of this disease over the past 5 years. Such bacterial wilt technologies have been developed previously under DFID funding and more recently by CIP, however, the technology has been viewed primarily as a research tools. The success achieved in the RSA suggests that this technology can have a role in the reduction of bacterial wilt in seed-lines in Kenya and Uganda through its application at specific interception points and when allied to improved seed management / IPM strategies.

These factors highlight the inherent problems of on-farm seed selection from ware product, and emphasise the need to improve seed-tuber management. Curiously, seed production practised in Africa shows few differences to ware production, both operating at a planting density of 44,500 tubers / ha. This contrasts to seed production practised in Europe where planting densities of over 60,000 tubers / ha are recommended. The objective of the higher planting density is to maximise seed production [25-55mm sized tubers] per unit area of land through suppressing the production of oversized tubers. This disparity in farming practice may reflect a reticence by farmers to commit solely to seed production as the farmer then lacks the flexibility to take advantage of differences in market prices between ware and seed-tubers [N. Mienie pers comm.]. This is an important consideration in extending seed-tuber production systems to the regional farmers as the approach developed has to be accepted by farmers and seen as beneficial to them individually.

Seed borne disease: Bacterial wilt is the primary seed borne disease of potato in Kenya and numerous other countries and represents a significant threat to livelihoods of many rural families. The limited availability of certified seed to smallholders of old and new varieties is recognised as a compounding factor in the spread and perpetuation of the disease, as farmers have little option but to source seed from unreliable supplies such as their previous harvest, local market or 'neighbour' [Barton et al., 1997]. Accordingly, seed is often planted without any knowledge of its disease status. This situation is further exacerbated by the common practice of commercial middlemen to select only the marketable product from a harvest, leaving mainly the diseased and undersized [<25mm] tubers from which to select seed. Whereas visibly diseased tubers can be selected against, latent infections go unseen and undersized tubers have been shown to give reduced yields due to poor tolerance to drought and / or frost [Steyn, 1997]. It has also been suggested that undersized tubers have a higher risk of latent disease since the small size is likely to reflect the unhealthy status of the parent plant.

IPM strategies for bacterial wilt have most successfully focused on crop management practices [Lemaga et al., 1997] and have targeted the reduction of latent seed-tuber infections and soil populations of the causative bacterium, *Ralstonia solanacearum* [French 1994]. Many of these studies have not resulted in robust scientific data due to an inability to detect the causal organism at low concentrations and / or from backgrounds where other saprophytes dominate. Accordingly, conflicting information on effective control strategies can be found in the literature.

Project outline: Based on these prevailing circumstances a DFID funded research project [RNRKS R6629] to develop a biocontrol agent [BCA] [Smith et al 1997] against bacterial wilt of potato in Kenya was initiated in 1992. Subsequently, in consideration of where and how to apply the BCA in the cropping system, this project extended in the piloting of an on-farm small-scale seed-tuber production system [SSPS] targeted at the smallhold potato producer [Kinyua et al., 1998]. The progress of these very disparate technologies has been reviewed previously in the FTR of R6629. In summary of these earlier works the:

- The BCA was shown to afford significant protection under CU conditions and an application for in-country testing is under review by the Kenya National Council for Science and Technology[1]
- The agronomic merit of the SSPS was becoming apparent after 6 cycles of on-farm multiplication

[1] The BCA is a non-pathogenic mutant of the wild type organism, derived through genetic engineering.

This project continues to build on this earlier research, notably with the view of establishing a promotional framework for up-scaling the SSPS.

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3. PROJECT PURPOSE

Potato is a staple component of Kenyan, Ugandan and Republic of South African [RSA] diets, yet production by smallholders underachieves potential yields. Disease and pest are primary constraints, and linked to seed health. Capacity and / or linkage constraints of certified seed production prevents smallholders planting good seed. Potential to address these compounding constraints has been demonstrated through the development of a on-farm small scale seed production system [SSPS] that separates seed and ware production and promotes IPM of seed-borne diseases and pests that includes the biological control of bacterial wilt [BW]: outputs of DFID CPP, R6629. This project validates further these technologies, and promotes and synergises new and existing uptake pathways in Kenya, Uganda and the RSA.

4. OUTPUTS OF RESEARCH ACTIVBITIES

The Logframe for project R7585 is presented in the Appendix i].

4.1. OUTPUT 1: VALIDATION AND PROMOTION OF SSPS IN THE NJABINI REGION OF KENYA, AND CO-ORDINATING LINKAGES FOSTERED WITH ANALOGOUS PRAPACE FUNDED RESEARCH IN UGANDA AND KENYA

The culminating experiences of the SSPS trail, supporting research and promotional activities are described

4.1.1. Agronomic merit of the SSPS – evaluation at Njabini

Background: The experimental rational, design, management and data arising are presented in the Appendix ii] and iii and Data Appendix ii].

This research aimed to establish a 'window' for the BCA on-farm through improved / intensified on-farm seed management. The SSPS describes a flatbed cultivation planted at a high density [SSPS-seed cultivation] that provides seed for the traditional ridge / furrow ware cultivation [SSPS-ware cultivation] in the subsequent season. A schematic outline of the SSPS trial is presented Figure 1.

The following advantages to the SSPS were proposed:

1) The SSPS strengthens linkages between formal and informal seed production through reducing the initial requirement by a farmer for certified seed, thus increasing the availability of certified seed amongst farmers and facilitating the diffusion of new potato cultivars.

2) Seed selection under the SSPS is optimal for yield and the maintenance of seed health[2].

3) The SSPS separates ware and seed production, and identifies a 'window' for intensive strategies for the management of disease and pest constraints that are precise and affordable to the farmer: these would include known beneficial practices of chemical applications and crop rotation, and be appropriate for application of the BCA.

4) The smallhold farmer is not asked to commit solely to seed production, thus avoiding financial risks associated with specialisation in a market without price guarantees.

[2] Tubers of 25 – 55mm were considered seed for both varieties. For the SSPS-seed cultivation, seed of 25 – 35 were preferred, reserving the larger sized seed [35- 55mm] for the SSPS-ware. For the Farmer's-ware, seed of 25 – 35mm was preferred as this was the typical size chosen by farmers [Barton et al., 1997]. This framework of seed selection and distribution was implemented to return an optimum sized seed to a particular cultivation. With the Farmer's ware, the seed size selection was considered less than optimum for ware yield, but importantly was aimed to mimic current practice.

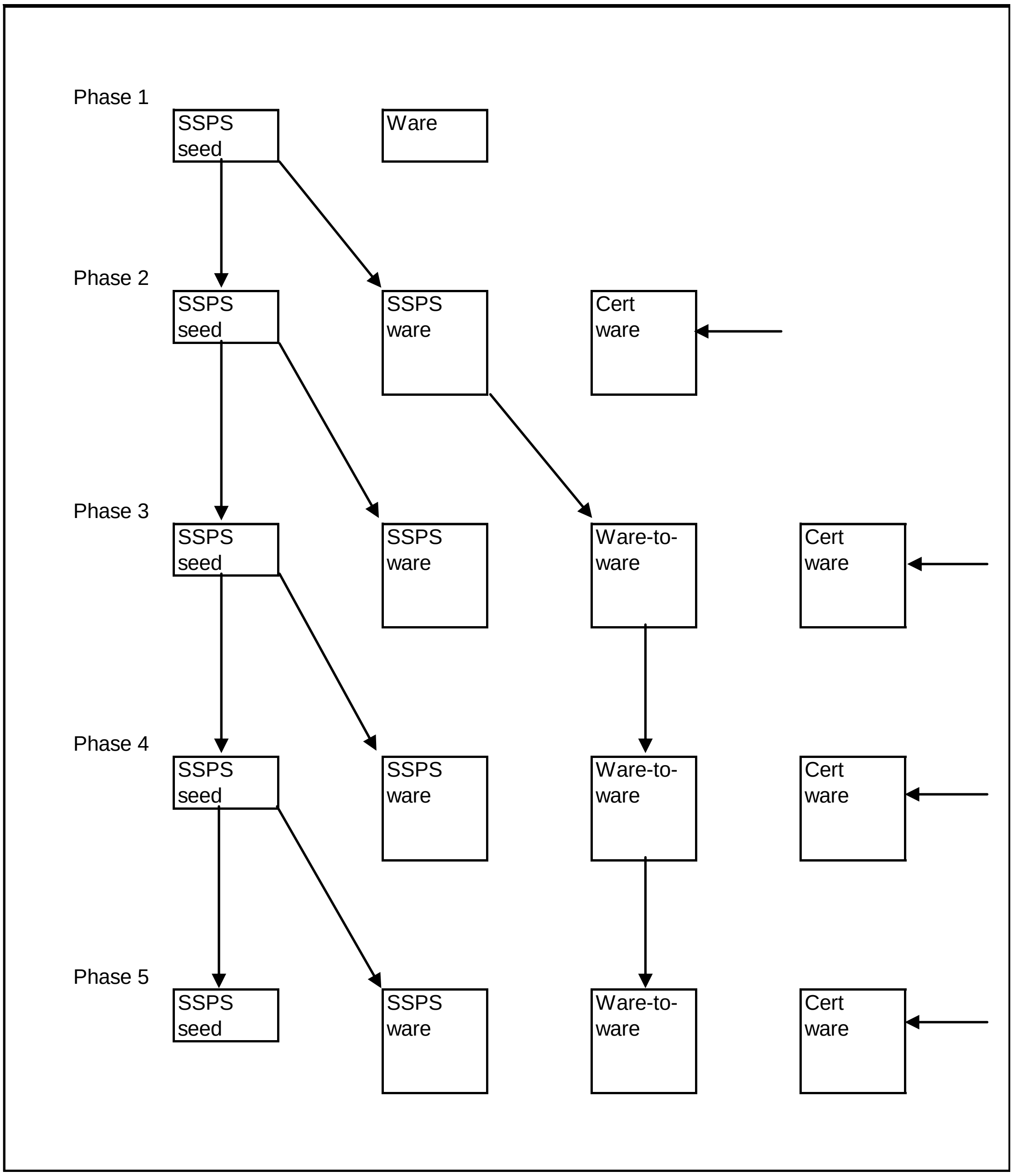

Figure 1: Schematic outline of seed flows under the SSPS trial

Continuing from the trials reported on under R6629, 3 more harvests of the SSPS were undertaken [Phase 6, 7 and 8]. The experiment was terminated at the end of the July harvest 2001, having achieved 8 cycles of production. These data amount to considerable information on the effects of soil type, seasonal factors and pest impacts on potato yield and quality. A summary of the data is presented in the Graphs Section.

The primary findings of this study relate to the productivity of the SSPS-seed cultivations and the resulting yield of SSPS-ware.

***Seed Production*:** The working hypothesis was to maximise production of potato of a seed size per unit area of land. From Graph 1 it is apparent that the closer spacing under the SSPS-seed cultivation skewed production towards smaller tuber sizes of a seed size and in Graph 2 that production per unit area of land increased 3x for both varieties. However, it was also evident that when these data were viewed in terms of production per tuber planted the SSPS-seed cultivation suppressed potential yields [Graph 3]. Thus, from these data both costs and benefits were evident: Seed productivity per unit area of land was increased, but the productivity per seed tuber planted was decreased.

From overview of these data across seasons and by farms [Graph 4 and 5] it was evident that seed production was comparatively consistent between seasons, but more variable between farms, especially under the ware cultivation.

These seed data were used to extrapolate seed requirements in maintaining a 1 ha cultivation. The following equations were used[3].

SSPS-seed cultivation
SSPS-seed cultivation land requirement [Land from 1ha [Y]]

$$Y = A*\rho^1 / \rho^2[SI^1-1]+2\rho^1$$

SSPS-seed cultivation seed input [Seed-tuber input for 1ha]

$$= Y*\rho^2$$

Farmer's-ware cultivation
Farmer's-ware cultivation land requirement [Land from 1ha [Z]]

$$Z = A*\rho^1 / SI^2$$

Farmer's-ware cultivation seed input [Seed-tuber input for 1ha]

$$= Z*\rho^1$$

Where A = Field size to be maintained
ρ^1 = Ware cultivation density
ρ^2 = SSPS-seed cultivation density
SI^1 = Seed index per tuber planted under SSPS-seed cultivation
SI^2 = Seed index per tuber planted under Farmer's-ware cultivation

These comparisons are shown in Table 2, were they are discussed.

***Ware production*:** The working hypothesis was that over cycles of production the health status of the SSPS-seed would be maintained in comparison the Farmer's-ware seed derived from the saving of undersized seed from last seasons ware production. These effects were to be investigated by comparison of the 3 ware cultivations, namely SSPS-ware, Farmer's-ware and Control-ware. From Graphs 6 and 7 it is evident that there is a trend towards maintained productivity of the SSPS-ware in comparison to Farmer's-ware, though this was not substantiated by statistical analysis. However, the extent to which differences might have become evident is questioned by the comparable productivity of the Control-ware yields that acted as the positive control to this trial. The maintained health of the farmer's seed over the time course of this experiment was unexpected and, from a research perspective, disappointing.

From these data the vast majority of variability in the data can be attributed to seasonal and farm effects [Graph 7].

[3] In calculating the SSPS-seed requirement the need for an equal area of set aside land was included.

***Pest control*:** As indicated above, the pest pressure observed over the duration of the trial period was low and thus the relative disease management attributes of the SSPS cannot be claimed strongly. The exception here was with Farm 1 that experienced bacterial wilt. On this farm only, tuber samples of were taken for analysis of latent infections with the CIP bacterial wilt NCM-ELISA kit. These studies and visual observations during the season monitored a persistent and low level of bacterial wilt in Tigoni during Phases 1 – 6[4], and then a high level of bacterial wilt in Phase 7 that carried-on into Phase 8. For this farm comparative data on R. Tana is not strictly available as the original seed was lost at Phase 2. However, R. Tana production was initiated again at Phase 2 with new seed and this was maintained up until Phase 8 in accordance with the SSPS trial remit[5]. Under these R. Tana plots no bacterial wilt was recorded during Phase 2 – 6, but high levels were recorded in Phase 7 amongst tubers from SSPS-ware and Farmer's-ware[6] that was again visible in the subsequent plantings of Phase 8. These observations mirror that observed with Tigoni [See Data Appendix ii] for data on BW occurrence].

Looking at these data from Farm 1 across the treatments there is insufficient evidence to robustly associate, or otherwise, a management practice with the incidence of bacterial wilt. However, it would appear that incidence was largely unrelated to a particular management practice given that under Phase 7 for Tigoni equal incidence of bacterial wilt was recorded between SSPS-seed [min 8.6%] and NPRC certified Control-ware [min 10%]. Accordingly, it seems most probable that the levels of infection observed are primarily explained by soil-borne inoculum that is 'activated' when exposed to favourable conditions: Phase 7 was a notably wetter season especially towards its conclusion[7]. Similar variance in incidence of bacterial wilt was evident amongst the Roslin Tana tubers.

The prominence of soil inoculum as the primary factor affecting production of latently infected tubers that can 'silently' persist until conditions are conducive is a key observation of these studies. This relationship would be worth investigating further, notably in the context of crop rotations. This research represents the most extensive well-controlled study of bacterial wilt in saved seed to date.

***Fiscal and ergonomic considerations*:** The management practices are outlined in Appendix iii]. No additional financial investments were asked of in the management of the SSPS-seed plots beyond the initial outlay of seed purchase. Similarly, data collected under R6629 [See FTR] showed the systems to have equal labour requirement when analysed as tubers planted per unit time.

4.1.2. Optimisation of SSPS-seed spacing

Data arising under R6629 questioned whether the spacing of the SSPS-seed cultivation at 20 x 20 cm was optimal. In address, an additional on-farm assessment was made during Phase 8 on 5[8] of the farmers' sites at a spacing of 30 x 30 cm [plot size 2 x 4.5 m]. Seed used in these assessments was derived from the previous seasons SSPS-seed cultivations and thus was of a common source allowing direct comparisons to be made to production under SSPS-seed and SSPS-ware.

Under this treatment the tuber number planted m^{-2} is altered from 25 under 20 x 20 cm to 11.11 under 30 x 30 cm spacing, a 56% decrease in seed input. Accordingly, this has a marked impact on the dynamics of the seed system as is shown in Table 1. Focusing on

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[4] These ELISA tests were conducted from Phase 4 to 7 only
[5] Yield data arising from these plots has not been included in the main experimental analyses.
[6] No Control R Tana was available during Phase 7
[7] Precise metrological data was not recorded, however, water availability was a major constraint on yield and in Graphs 6 the better rains in Phase 7 are evident.
[8] Farm 1 was not included due to a lack of SSPS-seed and land

Phase 8 and Table 1 it is evident that from a 56% decrease in seed we incurred only a 25 and 32% decrease in seed for Tigoni and Roslin Tana, respectively. More significant perhaps is the seed tuber input required to maintain a 1 ha cultivation, inclusive of the seed production cycling component and setaside component of the SSPS[9] that shows a remarkable effect through the reduced seed requirement of the SPSS-seed cultivation at the 30 x 30 spacing. In Table 1, based on this single seasons data, the seed required to plant a 1 ha cultivation at 30 x 30 was 78% and 68% less than that at the 20 x 20 spacing for Tigoni and Roslin Tana, respectively. Comparison with data from the SSPS-ware also seems to substantiate benefits with similar markedly superior seed flow dynamics. Full management and experimental data is presented in Appendix iv] and Data Appendix iii].

Variety	Spacing	Averaged over Phases			
		Seed index per tuber	Seed index per m2	Land from 1ha [m2]*	Seed-tuber input for 1ha
Tigoni	20 x 20 cm	2.1	53	2067	65172
	30 x 30 cm	3.6	40	1289	14321
	SSPS-ware	5.2	23	2989	13301
Roslin Tana	20 x 20 cm	2.1	53	1900	47497
	30 x 30 cm	3.2	36	1354	15042
	SSPS-ware	4.3	11	6262	27865

Table 1. Effect of seed spacing on seed production of the SSPS-seed cultivation, with comparison to SSPS-ware. * this is the projected area of land that needs to be taken out of ware production to provide seed in maintaining a 1 ha cultivation under a closed system.

Whereas these data are highly impressive and consistent with the results in earlier on-station trials [see FTR R6629], it is worth noting that these data do not take into account seasonal factors. In Table 2, Phase 8 data is normalised to the means of the SSPS-seed data obtained over seasons 3 - 8[10]. These comparisons, whilst still not allowing for any season-specific factors in the Phase 8 data sets, does position these data in line with the overall productivity of the systems. In Table 3 it is evident that these data continue to support the advantages of a 30 x 30 spacing for the SSPS-seed cultivation.

Variety	Spacing	Averaged over Phases			
		Seed index per tuber	Seed index per m2	Land for 1ha [m2]	Seed-tuber input for 1ha
Tigoni	20 x 20 cm	2.6	66	1203	30069
	30 x 30 cm	4.4	49	595	6607
	SSPS-ware	5.5	24	2495	11101
Roslin Tana	20 x 20 cm	2.6	64	1335	33373
	30 x 30 cm	3.9	44	951	10569
	SSPS-ware	4.6	20	5172	23437

Table 2: Projected seed production and needs normalised over season average

4.1.3. Evaluation of potential rotation crops to reduce soil inoculm of bacterial wilt[11]

As indicated earlier a key attribute to the SSPS is the concept of the SSPS setaside; an area of land equal to the SSPS-seed cultivation that is managed for the next seasons planting. This

[9] A key attribute of the SSPS is the setaside of an area of land equal to the SSPS-seed cultivation for next seasons cultivation [See Appendix ii] for more detail].

[10] Data obtained in Phases 1 and 2 was not included as it was only from Phase 3 that full data sets across the 3 treatments were being produced.

[11] This research was linked to DFID CRF 7862 and CPP 7462

land is seen as a key window for management practices for the control of bacterial wilt. However, experiences gained under R6629 demonstrated that it was a difficult concept for farmers to grasp, and frequently the SSPS setaside was not managed effectively, either being planted back to potato or allowed to grow volunteer potato. It was thus evident that clear and useful recommendation were needed to be given to farmers that would see value in the land and also reduce bacterial wilt populations. The need to reduce bacterial wilt populations in soils was made very evident in Phase 7 of Farm 1 [See 4.1.1 Pest control].

Accordingly, building from the methodologies initiated in R6629 a pot experiment was set up at CABI UKC to investigate the relative carrying rhizosphere capacities of maize, cabbage, carrot, faba beans and fallow [soil], with potato acting as the positive control. Accordingly, pathogenic [rif mutants] and BCA [Kan mutants] were enumerated against a soil background onto selective media at various dates over a 2 month period. The details of this experiment and data are presented in the Appendix v] and Data Appendix iv].

A summary of these data is presented in Graphs 8[12]. From these data it is apparent that in comparison to Fallow [soil], maize was able to support notably high populations of BW [2.23 x the Fallow population]; whereas carrot appeared to suppress BW populations [0.58 x the Fallow population; 0.26 x of the maize population]. In these graphs the similarity between the pathogenic and BCA populations provides a useful insight to the nature of the plant interaction. In setting up the experiment it was speculated that a pathogenic interaction would see an increase in the pathogen population with the BCA population appearing static; whereas in a non-pathogen interaction, where BW populations responded only to the nutrient status of their environment any interaction with the plant would be equally received by pathogen and BCA populations. This hypothesis was borne-out in these data.

These data present some of the most robust observations on the BW carrying capacity of crops to data, and provide a clear pathway by which recommendation to farmers on appropriate rotations that reduce soil BW populations can be based on good scientific fact. The obvious next step would be to transfer this approach to the field situation so as to encompass various soil types and effects of farming practice.

Further to these studies on the soil samples taken, preliminary investigations were initiated that looked at the dynamics of the microbial communities associated with the crops. It was speculated that shifts in microbial communities that could be associated with a decline in the BW population could be identified, potentially leading to the isolation of microbial species, possessing high rhizosphere competence and antagonism to BW. The approach taken was based on the use of GC clamped PCR primers to the 16s region, with the amplified product being resolved by Density Gradient Gel Electrophoresis [GC-clamped PCR 16s DNA DGGE].

Through this project the potential of this approach to monitor complex microbial communities over time on a root surface has been demonstrated [See Plate 4], but more investment would be needed to bring to fruition the functional biological understanding of these communities identified. This research would have value in understanding the impact of crop rotations as suggested here, and also in investigating the impact of soil amendments.

4.1.4. Regional testing and promotion of the SSPS

Under this project it was envisaged that synergy with the PRAPACE funded project 'Enhancing the management of bacterial wilt and other diseases through micro-farm seed system in Kenya' [commenced Oct 1999 – Finish Oct 2002] could be achieved.

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[12] Potato populations are not included amongst these data as the WT populations were of several orders of magnitude higher than that on the non-host plants.

Unfortunately, this project was withdrawn due to a restructuring of PRAPACE after only a few seasons. Nevertheless, from the activities that were initiated a number of disseminations were produced for the 3rd International Bacterial Wilt Symposium held in the Republic of South Africa [see Publications].

However, as this opportunity closed, an option to link with the NARO / AFRICARE / IFAD supported farmer fields schools [FFS] in Kabale was made through additional financial support through CIP. Under these funds the SSPS was to be

- Demonstrated in Kabale to farmers through on-farm trial sites operating out of the FFS
- To exchange Ugandan experiences in the setting up of community based potato grower groups with farmers in Njabini

Mr Charles Musoke of AFRICARE co-ordianted the activities of the SSPS in Uganda and undertook the exchange visit to Njabini, Kenya. The report on his experiences can be found in the Appendix vi]. In summary and with some personal observations:

- 2 SSPS-seed cultivations were established on the FFS sites using Victoria during 2001 [1st season May – July]. The harvests obtained by the 2 FFS sites were analysed and these data were consistent with the SSPS findings of Kenya with Seed Index values in the order of 2.5x greater under the SSPS-seed cultivation than the equivalent ware.

  Earlier experiences by farmers of cultivating the SSPS were reported. This had come about through exposure of the SSPS as trailed in Kenya through conference proceedings and the efforts of NARO. It was accounted that in 2000 2nd planting 2 SSPS sites were initiated, followed by 6[13] and 31 in 2001 [1 st and 2nd planting, respectively] and a projected 75 in the 1st season of 2002. Some of these field sites were located in Mbale, Eastern Uganda, through the activities of Makerere University with support of PRAPACE.

  From these experiences of the farmers it was apparent that the SSPS-seed cultivation was evolving from its original format in Kenya. It was observed that farmers were earthing-up from the sides to create a much higher cultivation [see Plate 3] and, perhaps more significantly, were making use of mini-tubers less than 25mm, below the lower level as trailed in Njabini[14], with good results. This observation reflected the higher water holding capacity of the flat bed, which buffers against dry periods more than the ridge / furrow and consequently protects the mini-tubers against desiccation. The realisation that mini-tubers can be used effectively in the SSPS would again further the favourable seed dynamics of the system.

- The mechanisms on the setting-up of an association were not extensively reported on, but figured prominently in the discussions held between Mr Musoki and the Njabini farmers during his visit in July 2001. These discussion formed part of a longer exchange of ideas between project staff and the Njabini farmers on how they the farmers could best link together to maximise the limited inputs available to them and gain access to formal seed and seed certification support provided by KEPHIS. These aspects are addressed more specifically under Output 2.

[13] This figure is inclusive of the 2 SSPS-seed cultivations established under R7585.
[14] In Kenya mini-tubers were not returned to the SSPS-seed cultivation

4.1.5. Summary of Output 1

The additional year of the SSPS trial resulted in some key outcomes on the agronomic merit of seed production under SSPS and ware systems, notably in the context of seed input : output dynamics. Perhaps unsurprisingly the situation is not straightforward and a win : win scenarios is not always obvious. The key findings suggest that there are both costs and benefit to the SSPS; benefit in that the SSPS-seed cultivation produces more seed tuber per unit area of land [Seed Land Index], and cost in that for every tuber planted in the SSPS-seed cultivation fewer seed are returned [Seed Index]. Unfortunately, the benefits in terms of yield and quality remained largely unanswered due to the low overall pest pressure, but a slight trend towards improved production was apparent and no disease constraints were apparent over 8 cycles of production suggesting that the SSPS is not overtly open to pest problems.

Thus, the decision by the farmer as to whether to adopt this method or not may well depend on the primary constraining factor pertaining to his / her production. Is it land or seed? It is the recommendation of this project that where land is limiting then the SSPS presents a good approach to manage your land and seed more effectively. However, where land is not so limiting then seed production under a ridge / furrow system may afford optimal use of scarce seed. From this 'swing and roundabouts' scenario it is important to keep in mind the aim of the project to maximise seed potato access for the poor, and this group would normally be associated with smaller land holdings. Unfortunately, it is the case in Kenya, Uganda and many developing countries that both land and seed are scarce.

Against this complex picture it is an attractive option to place emphasis on the seed dynamics afforded by the SSPS-seed cultivation at a 30 x 30 cm spacing that appeared to outperform both the SSPS-seed 20 x 20 and SSPS-ware spacing. The analyses of these data provided some quiet unexpected advantages, as the feeling of the farmers and scientists at harvest was that this spacing had not delivered as effectively as the 20 x 20. In this context, the overlooked factor was the more than 100% saving of seed at planting that was amplified throughout production. However, as impressive as these data at 30 x 30 are it must be taken into account that these results were obtained over 1 season [though other data was supportive of the conclusions reached [R6629]] that was noted by its dry nature. Accepting this, however, as shown in Table 2 where these data are brought inline with trial-norms, more beneficial seed flows should be achieved under better seasons. In addition to this finding, it is also important to value the experiences of the Kabale farmers in Uganda where, through a clear farmer-driven evolution of the SSPS, significant advantages were being realised in using mini-tubes in the SSPS-seed cultivation, a option that had not been considered in Kenya. This again, if substantiated fully, would be a beneficial parameter in extrapolating the seed dynamics of the SSPS. Future promotion of the SSPS should look to substantiate these seed dynamics more fully, allowing for regional, seasonal and varietal factors.

Whereas these data are quiet conclusive, less certain conclusions were possible on the relative pest management qualities of the systems due to a surprising low pest pressure over the 8 seasons. The exception here was with Farm 1 that was affected by bacterial wilt. However, in this example, which was monitored by field and ELISA testing on harvested tubers, no clear pattern in incidence and management practice was evident. This research on bacterial wilt progression over seasons on Farm 1 presented some of the most robust data to date in partitioning the contribution of seed and soil inoculum, and the influence of seasonal factors. In this context, a key observation was the unexpectedly raised level and new outbreaks of bacterial wilt during Phase 7 that strongly suggested soil-borne inoculum as the primary source of infection under favourable conditions, over and above that which may be in the seed. Previously, studies have attributed BW incidence to latent infections and soil, but not shown the relative significance of these potential sources. These data strongly suggest that, whereas 1 – 5 % latent infection levels are of obvious importance in the spread of the disease, soil inoculum, with favourable weather, presents a more serious risk for substantial field losses.

Accordingly, the main variations in the data were attributable to seasonal and farm level factors. In example, it was very apparent that on Farms 2 and 3 dry seasons markedly reduced production, to the point of complete crop failure in some of the ware crops. Conversely, Farms 4 and 5 consistently ranked the highest yields.

Given the relative partitioning of the contribution made by seed and soil inoculum, the research to define science-based recommendations on effective rotation takes on considerable significance. In this context, the methods developed for enumeration of soil BW populations presented some of the most substantive data to date. Moreover, these approaches are easily transferable to countries with limited research infrastructures such as Kenya and Uganda. The significance that maize may not be a good rotation crop is perhaps unsurprising given the close association potato and maize have in cropping systems that would favour an evolutionary drive towards a mutual association. From these data the management of the SSPS setaside takes on new significance, as whereas it would be unreasonable to advocate a rotation crop that was not maize on a large scale it is more acceptable on a small plot of land, such as the setaside, to encourage farmers to diversify their cropping practices to include alternate crops such as carrot or cabbage that were shown to suppress or give no advantage to BW populations. These highly encouraging data need to be substantiated under field condition where effects of cropping practice, soil type and seasonal factors can also be taken into account.

The value of understanding the dynamic of BW populations under various crops has been made clear by these data. This approach can also be extended to validating frequently advocated claims made on various soil amendments as practices that can reduce BW populations in soil. An adage to this acquired knowledge would be an understanding of the dynamics of the other microbial communities and how these populations interfaced. This was investigated preliminarily under this study by PCR 16sDNA DGGE analyses. Potentially, such studies can be combined to identify those cropping practices that promote specific microbial communities that have significance in the promotion of soil health, the benefits of which would extend far beyond the control of BW.

It is also noted that the method above would be appropriate in any testing of the BCA agent, allow for a robust analysis of the persistence of the BCA and its impact on other microbial communities.

4.2. OUTPUT 2. PLATFORM FOR WIDE-SCALE VALIDATION AND PROMOTION OF SSPS AND BCA AGAINST BACTERAIL WILT ESTABLISHED IN KENYA, UGANDA AND REPUBLIC OF SOUTH AFRICA.

4.2.1. Application on the testing of the BCA against BW under contained-use conditions in Kenya

The application and supporting documentation has been presented previously under FTR R6629. Further information was requested by the National Council of Science and Technology and these materials were provided. In April 2001 qualified permission to test the BCA in Kenya under CU conditions was given. This letter is presented in the Appendix vii].

The gaining of approval for testing the BCA in Kenya was only the second such permission granted by the NCST and to our knowledge the first for a microbe in Africa. Consequently, the opportunity to trail the GMO in-country presented a unique opportunity to both advance Kenya's overt advocacy for the adoption of biotechnology solutions for sustainable agriculture and to develop protocols on microbial GMOs. This success represented a substantial and maintained effort dating back to 1995 on the part of KARI and CAB *International*. Any subsequent phase of testing the BCA would however require a significant investment in support from the international scientific community to ensure that the exacting Best Standards of GM testing where achieved and that effective public participation partnered the development of the technology. Many of the methodologies that would be pertinent to these investigations were established previously under R6629, and as advocated in the evolution of the SSPS concept from the development of the BCA, an appropriate window for its application has been identified within the SSPS-seed cultivation.

4.2.2. A review on formal / informal seed sectors within Kenya, Uganda and RSA, and the role of community-based agricultural association

The surveys were lead by Peter Kinyae of KARI NPRC, with support from Kinyua Murimi of KARI NARL, and Julian Smith and Jane Asaba of CAB *International*. The respective national agricultural research institutes facilitated the visits. A summary of the findings is presented below; with additional detail presented in Appendix viii].

Background

Three short [2 week] visits of Kenya, Uganda and RSA were undertaken during 2002 / 2001 to talk with stakeholder of

- National potato seed-tuber production, inclusive of formal and informal systems, and
- Farmer groups that had organised themselves into co-operative-like structure.

The primary objective of these visits was to review the status of improved or certified potato seed production so as to identify any significant gaps in production and flow to small holder farmers, and to gain an appreciation of the potential role community based farmer associations may play in address of any gaps that were evident. Given the timeframe available this was recognised as an ambitious aim, and, whereas some of the findings would have benefited by further investigation, some interesting insights were achieved.

Seed production in Kenya, Uganda and RSA

Comparison between seed production between these countries initially identified 2 contrasting situations in Kenya and Uganda, and the RSA.

***Kenya and Uganda*:** In these countries certified seed production is ostensibly absent, beyond the phase of production that is best described as a reasonably well organised nuclear to basic seed production system. Consequently, the multiplication of basic seed goes forward through on-farm multiplication with limited oversight from NGOs and / or national bodies. In both countries the value of seed certification at the institutional level is fully realised, however, the level of service provided by the national mandated institutions is limited. In the example of Kenya, KEPHIS provides a pay-on-demand service, but it is questionable whether there is the human and physical infrastructure to support a meaningful service. It is unquestioned that the service these national bodies can offer is seriously compromised by the inability to give robust assurances on the bacterial wilt status, amongst other seed-borne infections. Within these countries at no stage of the production is it evident that any quality-assured identity preserved practices are being implemented to a standard expected in Europe. The consequences of these shortcomings are the well reported recycling of seed by farmers within and between farmers based on at best a word-of-mouth self-policing of health. This practice affords limited flush-out of diseased seed and slows the adoption of new improved seed varieties.

This scenario is particularly evident in Kenya where various attempts to advance the on-farm multiplication of basic seed have only met with limited success. Central to this appears to be a poor appreciation amongst farmers of the value of good seed that underpins any price differential between improved seed and farmers' seed. The establishment of a market driven premium value on seed is a critical step towards any sustainable seed industry. This situation in Kenya has been reached against a background where until relatively recently the government supported Agricultural Development Corporation produced sizable quantities of improved seed. Reportedly, underlying this view of farmers is the influence of 'bad examples' of seed from 'reputable' sources that have undermined confidence. In this regard bacteria wilt is undoubtedly amongst the primary factors.

Curiously, despite the many similarities between Kenya and Uganda, the situation regarding basic seed multiplication is better in Uganda. Here, the Uganda National Seed Potato Association [UNSSPA] and the NGO AFRICARE have established themselves as reputable producers of improved seed that is valued by farmers and consequently commands a price premium in the market. Within these operations the maintenance of health standards is assisted by regular inspection by NARO, although the production is not certified. Recently, UNSSPA has started to develop additional production management practices that aim to move towards identity preserved practices. The implementation of identity preserved production is seen as critical to govern against the falsification of production through adulteration with non-UNSSPA seed through paper-trail traceability of seed back to the farmer. A further measure to be implemented relates to the selling of seed according to size range, supported by a price structure. Interestingly, this marketing move on seed grading is being driven, in part, by the adoption of the SSPS-seed cultivation that is increasing demand for the lower sized seed classes [25 – 45mm]. However, despite these well-gauged measures no plans are well advanced to undertake robust seed health monitoring, notably with regard to bacterial wilt. As possibly experienced by ADC in Kenya, any loss in confidence by farmers in the quality of improved seed will rapidly undermine the price structure that has been hard won by the farmers of UNSPPA and those supported by AFRICARE. Given the current infrastructures and human capacities, the maintaining of current health standards will become ever harder to achieve as the farmer associations increase in size.

***Republic of South Africa*:** Agricultural production in RSA as a whole is generally characterised by large-scale mechanised practices, and this is also the case with potato where potato production for table and certified seed is overseen through its industry body, Potato South Africa. These production systems are fully quality-assured by identity preserved pathways of monitoring that are of equivalence to European standards. The sampling practices in monitoring for bacterial wilt within seed under certification are more robust than those in the EU. Under these practices the underlying incentive to producers and users of certified seed is the realisation that higher yield and quality will be the outcome of purchasing good seed and this drives a premium on the price of certified seed that offsets the additional costs borne by farmers that endeavour to produce seed of a certified standard.

In addition to the full certification label, a Table potato standard is also overseen by PSA. This affords a lower rigour of health assessment and is not for producing potato for sale as seed, but is offered as an informal service to farmers that wish to recycle their own seed with added certainty. Visibility of the operative certification and table standard in RSA is visible at www.potatoes.co.za , along with other aspects of PSA business.

However, further observations that focused on the seed systems that serve the small-scale practices of rural communities of RSA reveal strong parallels to those prevailing in Kenya and Uganda. Through this project various meetings were undertaken with rural community farmer co-operatives in the KwaZulu-Natal and Eastern Province. Through these discussions it became evident that whilst RSA had an effective certification scheme the distribution of this seed was not orientated towards serving the needs of rural communities. It was also noted that in RSA the varieties of potato promoted through the PSA have been selected under high input systems for the preferences of the main urban markets and consequently may not be those most suitable for production under low inputs systems or as preferred by the rural communities. These compounding factors were evidenced by the preference by rural communities for the variety Astrid. This variety was trailed by the ARC in 1987 and the materials planted today are from that original introduction, perpetuated solely though the on-farm non-certified seed recycling of rural-community farmers. This clearly illustrates the parallel to Kenya and Uganda amongst the smallhold farmers.

These observations illustrate effectively the need for both production and distribution of seed, and the need for that seed to be of the varieties that will perform under the prevailing regional conditions and sought by the local people.

***Estimates on seed demand in Kenya and Uganda*:** Following from these broad characterisations of seed systems an attempt was made for Kenya and Uganda to quantify the national potential to produce certified seed from the optimisation of the nuclear seed production and effective multiplication thereafter. From this starting point these analyses soon became confused through the varying strategies of production within the nuclear seed programmes and estimates of land available to the institutes. During the course of the survey stem-cutting multiplication from mother plants, mini-tuber production in raised bed and field multiplication of pre and basic seed were observed. Accordingly it was thought more reasonable to work backwards from FAO values of land under potato cultivation to estimate certification needs. In Table 3, making use of the data obtained from the seed systems trailed under the SSPS study, 2 scenarios are put forward where farmers replace seed every year or 4^{th} season. The values given demonstrate further the potential advantage of the 30 x 30 cm spacing over other systems, though in this analysis no attempt is made to factor in parameters such as seasonal variability or pest-related rejections. However, as a ballpoint value it may prove useful to have in mind!

Seed source	Item	Land from 1 ha [m2]	Planting density [m2]	Kenya		Uganda	
				Land [ha]	Seed [Mt]	Land [ha]	Seed [Mt]
Estimates on national seed needs							
Current Production	FAO data on production			93,000	74,400	73,000	58,400
Estimated parameter of seed required**	Yearly replacement				156,435		122,793
	Every 4^{th} season				39,109		30,698
Estimates on land put to seed production under various planting densities to meet above requirements							
Farmer's-ware*	Yearly replacement	2345	4.45	21,811	36,689	17,121	28,799
	Every 4^{th} season			5,453	9,172	4,280	7,200
SSPS 20 x 20*	Yearly replacement	1203	25	11,188	105,726	8,782	82,989
	Every 4^{th} season			2,797	2,6431	2,195	20,747
SSPS 30 x 30*	Yearly replacement	595	11.11	5534	23238	4344	18,241
	Every 4^{th} season			1383	5810	1086	4560

Table 3. Estimates made of seed production needs for Kenya and Uganda based on Tigoni SSPS trial data [*] and FAO national statistical data [2002]. ** Weight of seed estimated at 37.8g per tuber* for the purpose of calculations.

Table 3 gives some insight to the scale of the task ahead when measured against reported FAO seed production figures[15]. The data suggests that given a quality assured multiplication of basic seed on farmers' land a significant difference to seed flow could be achieved. The advantages shown by wide-scale adoption of the SSPS would logically assist this position both in terms of multiplication and in distribution.

Value of community based farmers associations

The other aspect of these study tours was aimed primarily at existing co-operatives in RSA and Uganda, and looked at the extent these associations were effective in providing a platform for agricultural production systems inclusive of seed production. It was the intention that these experiences would be transferred to the farmers in Njabini, Kenya, to provoke discussion as they move forward with their ambitions as seed potato producers. In this regard the time available to gather a deep understanding of the issues to hand was not possible, but a few general perception, common ground rules and constraints were evident. Some of these are listed below:

***Characteristics of community based associations*:** In RSA the KwaDindi farmer's association, Indonsa co-operative and Mkangeli Community Development Centre [Umtata] were visited. In Uganda the primary linkage was to UNSPPA and the farmer field schools overseen by AFRICARE. Below is a summary of some of the general themes that were expressed by the farmers in relation to the formation of their farmer group.

Common perceptions:

- Improved food security and diversification
- Improved job creation and security
- Strengthened representation at markets, with micro-creditors etc., and visibility facilitating beneficial linkage to other associations or governmental bodies
- Improved access to inputs, such as seed and agrochemicals
- Improved access to extension / certification services
- Improved linkage to other associations, government bodies and NGOs
- Improved education through improved linkage [see above].
- Woman have a strong role to play in the decision-making

Ground rules:

- Registered through local bye-law, giving legal identity
- Entry membership fee and monthly / yearly subscription fee
- Committee structure
- Ethos of sharing and joint venture

Constraints:

- Lack of money to purchase inputs
- Lack of access to inputs
- Low market opportunities through distribution constraints
- Lack of irrigation
- Low soil fertility
- Poor knowledge of pests and their control and good crop management

[15] A significant discrepancy was evident between FAO data and national data. In example, basic seed production in Uganda was approximated by national scientists at 80 – 150Mt.

- Poor knowledge of commercial enterprise

It was also apparent that a strong linkage to an NGO was important to give specific inputs as backstopping[16]. In RSA, Uganda and Kenya the effectiveness of any national agricultural extension service appears limited.

Njabini farmers group**:** Based on these discussion and those described previously by Mr Musoki [Appendix vi]] a group of Njabini farmers, centred about the core of farmers engaged in the SSPS farmer participatory research, set out to form their own community based potato seed production association. Called Jitegemee Agricultural and General Development Self-help Group [JAGED-SHG] this association is now operational in Njabini and was recently successful in receiving a small project grant through the Kenyan government.

4.2.3. Summary of Output 2

The countries studied under this project provided some interesting contrasts that helped to identify limiting and critical steps in the production of potato seed. Similarly, it was evident that many of these constraints were being felt in the marketing of ware production, notably in respect of how farmers can access and exploit market opportunities. In address it was evident that there were two scales of thinking, one that involved large change and substantial governmental and donor intervention and one that looked to work more closely with farmers to implement local change.

At the higher level for Kenya and Uganda considerable need for strengthening the nuclear – basic seed production was evident and from her for the next 1 or 2 cycles of on-farm production. Critically, current practices were missing quality-assured identity preserved production pathways, and arguably a clear vision on what method of production afforded the best approach. These shortcomings are mainly attributable to a lack of human and infra-structural capacity, notably in certification personnel and laboratory space and equipment to undertake testing for bacterial wilt and virus. However, it was noted in RSA, where these practices were in place and certified seed was available, access to seed by rural communities was still limiting. In the example of RSA it was apparent that the highly sophisticated potato sector industry was orientated towards large scale operations that bypassed smallscale rural practices though inappropriate distribution networks [through main markets only] and marketing [packaging and or bulk sales]. Similarly, in RSA it was noted that the recommended variety list for which seed was available was developed through performance trials under high input conditions and for consumer preference traits of the main urban markets, neither of which gives assurances that these varieties will be appropriate to the rural communities.

It is unfortunate that until the larger picture is re-enforced in regards to monitoring for seed health, then any locally led initiative will run with the risk of unknown levels of bacterial wilt that sporadically appear and undermine farmer-confidence in the seed of that supplier. It is this confidence, which is so easily lost, that has to be nurtured, as it is the farmers that ultimately drive the price differential between improved-seed and farmer's-seed that makes seed production a commercially attractive option. From this study the presence and absence amongst farmers in placing value on seed health was evident in the countries looked: in RSA this is fully realised amongst the large scale farmer, in Uganda with the good work of UNSSPA and AFRICARE this is happening, but in Kenya this situation which was once present through ADC seem now to be less evident. Clearly, any promotion of potato seed that goes forward must include a substantial awareness element on the benefits of new seed and new varieties.

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[16] In RSA the INR provides support to the Indosa and KwaDindi association; in Uganda UNSPPA receives support from ARICARE and NARO

In the context of working with know limitations in monitoring for health the concept of a Table standard of seed as managed in RSA was attractive for the implementation of a locally managed improved seed concept. However, in looking to link such a seed system to nationally mandated seed bodies, maybe with a view to use this as a stepping stone to a higher standard, it should be recognised that it is difficult for these mandated bodies to be associated with 'seed' that, by their working definition, as something that had been certified, is not seed. Nevertheless, given the basket of options available, it was a common view that to develop local capacity to monitor seed health was a useful way forward, especially if this could be embedded into a community based association and a local bye-law.

It remains to be proved, but the primary outputs of this project were encouraging, with scope for improvement possible through modest changes in seed multiplication and distribution [Table 2 & 3]. In this regard the positioning of the SSPS as an optimiser of seed distribution and land utilisation, especially amongst the poorest of the poor, was established. More challenging is the building of a market platform for seed production, driven by the farmers perception that improved seed affords benefit, and in turn that there is opportunity for farmers to exploit higher yields in potato through accessing ware markets supplying the main urban markets or potato industries. It was the view of this study that the role of community based organisations, aligned to appropriate backstopping expertise and some priming funds through a development phase could substantially move towards the commercialisation of potato.

Hand-in-hand with this would be the need to identify good IPM strategies that work together with potato cultivation to present viable cropping system options to farmers. In this context the work on rotation crops reported under Output 1 is significant, presenting opportunity for science-based recommendations on effective rotation patterns. Similarly, the gaining of permission for the progression of the BCA to an in-country testing phase if taken forward may result in an additional control option for farmers.

4.3. OUTPUT 3. TERMS OF REFERENCE FOR AN OPEN CALL ON A LOCALLY-LED SSPS AND BCA TECHNOLOGY PROMOTION / SUPPORT PROJECT, WORKING IN AN INTEGRATED CROP MANAGEMENT SYSTEM [SUSTAINABLE LIVELIHOOD SUPPORT FRAMEWORK]

Collectively, the above laid the foundation for a strong promotional phase of the technologies developed in Kenya, Uganda and RSA, namely the BCA against bacterial wilt and the SSPS. Accordingly, through various discussion groups and meetings various constraints were considered as identified under Output 1 & 2. From these processes the below project concept notes were furthered with donors that looked to address the below salient features:

For the BCA against bacterial wilt:

- To validate further, in-country, the efficacy of the BCA, initially under contained-use conditions and then, results meriting, under deliberate release
- To develop in tandem a dialogue with stakeholders as to the nature of the research, inviting public participation as appropriate

For the SSPS:

- To enhance awareness amongst farmers on the value of investing in improved seed for higher yield and quality
- To promote farmer's associations as focal points for seed production
- To promote the implementation of seed health monitoring operating levels of pest tolerance through the locally managed services, that receive support through national bodies
- To encourage farmer groups and health monitoring bodies to look for legal recognition through local bye-laws

- To promote quality assured identity preserved pathways for production that builds a brand label for the farmer associations' produce
- To provide support for ELISA testing for bacterial wilt at key intervention points along seed pathway [nuclear – basic – on-farm multiplication]
- To package and distribute seed so as to meet local needs of smallholders and with vision to exploit larger markets
- To provide education on approaches to marketing

The projects are summarised below:

4.3.1. Promotional project: Promotion of on-farm small-scale seed potato production in low input farming communities in Kabale district, Uganda

Lead organisation CIP; submitted to DFID CPP; duration 1 yr [April 2002 –March 2003]

Project summary

The project promotes the on-farm small-scale seed potato production system [SSPS] validated under CPP R7858 in Kabale Uganda. The project builds on established Farmer Field Schools [FFS] and recent initiatives to form entrepreneurial seed producers [UNSSPA] with support from National Agricultural Research Organization [NARO], Kachwekano Agricultural Research and Development Center [KARDC], AFRICARE and CIP. The strengthening of linkages between formal and informal seed lines represents a central theme. Project activities will engage the National Agricultural Advisory Services [NAADS] in evaluating the prominence of potato in Kabale and in determining the policy, technical and infra-structural needs for scaling-up the formal and informal small-scale seed systems. Based on these justifications long-term uptake pathways for improved seed health for Uganda will be developed with local and national government, alongside international donors. CIP will apply to IFAD or other donors to support continued promotion and uptake of SSPS within a FFS framework with other partners in Kenya, as an extended 2-3 year phase of work commenced under this project.

4.3.2. Promotional project: Promoting Potato Seed-Tuber Management For Increased Ware Yields In Kapchorwa District, Eastern Uganda

Lead organisation, AT Uganda; submitted to DFID CPP; duration 3 yr [Feb 2002 –March 2005]

Project summary

Given the high risk of complete crop failure from bacterial wilt and blight, lack of healthy seed is a major reason why poor households often fail to grow potatoes, even though it is the most lucrative crops to produce in the highlands of Eastern Uganda. Adequate supplies of seed potatoes of good health will significantly increase incomes in a sustainable manner. This project promotes farmer led multiplication and distribution of seed potatoes for poor households under the supervision of local authorities. It will increase potato production and ensure poor people access to new varieties.

4.3.3. Promotional project: Commercialisation of farmer enterprises of the rural communities in the Republic of South Africa

Lead organisation, CAB *International*; submitted to DFID BLCF; duration 3 yrs [project reached 3 rd phase before being declined.]

Project summary

This initiative brings together a consortium of private and civil society entities that aim to bring about social outcomes for agricultural communities of the rural poor in the RSA. The primary objective of this project is to stimulate the economy of rural poor communities through strengthening the capacity of agricultural co-operatives to produce and market potato and maize. This project identifies strongly with enhancing the role of women in rural communities and is inline with a priority of the Government of the RSA to reduce/reverse urban drift in relief of peri-urban related poverty.

4.3.4. Promotional project: Control of Bacterial Wilt in Kenya and Republic of South Africa using a Genetically Modified Biocontrol Agent

Lead organisation, CAB *International*; submitted to ABSP I; duration 3 – 5 yrs [project was not taken forward].

Project summary

This project sets out to validate the efficacy and environmental impact (benign nature) of the BCA against bacterial wilt through contained-use and trail release assessments in Kenya and RSA. The BCA technology will be developed in partnership with the promotion (through separate funding) of potato grower associations adopting the on-farm seed-tuber production system [SSPS] that affords a 'window' for the application of the BCA, improves on-farm seed management and strengthens linkage between formal and informal seed lines. The implementation of the BCA technology will improve yield, quality and food security of ware produce for smallholder in Kenya and RSA.

5. CONTRIBUTION OF OUTPUTS TO PROJECT GOAL

Building on the experimental trials initiated under DFID CPP R6629 a further 3 seasons of potato production was achieved. The results of these field trials continued to underline the appropriateness of the SSPS with significant improved seed flow dynamics realised. Parallel assessments targeting the optimisation of the planting density of the seed production system indicated that further substantial gain would be realised at a 30 x 30 cm spacing of the SSPS-seed cultivation. Supplementary to these production data, pest data did not reveal any management system effects, however the research on bacterial wilt revealed the importance of soil inoculum in crop losses to this disease, over and above seed infections. The primary variance in the trials was attributed to seasonal [rain levels] and farm factors [soil water holding capacity and fertility].

Identified under R6629 as a key component of the seed production system was the management of seed production set aside land: land assigned for the next seasons planting. This land has been identified as a window for rotation practices that when managed correctly would be important to the IPM of BW and other soil borne / seed borne diseases. Research carried out in the UK established a quantitative method for evaluating the impact of rotation crops on soil bacterial wilt populations. Assessments undertaken using UK soil showed maize and bean [*Vicea faba*] to support high populations of BW, whereas carrot supported notably suppressed populations: in relation to a fallow treatment, the magnitude [averaged over a 'season'] of the supported BW populations for potato, bean, maize, carrot and cabbage were 88x, 2.5x, 2.2x, 0.6 and 1x, respectively. In support of these experiments on BW suppression a pilot study was initiated to look for microbial shifts in community structures [community dynamics] associated with the rotation crops to identify a biotic basis for the differences. Through these studies microbial communities that appear enriched in the presence of carrot have been identified. It is speculated that these species may be causative of BW suppression and may have potential as microbial supplements or BCAs against BW.

A wealth of anecdotal information exists as to what is a good or bad rotation crop, and similarly a effective soil amendment [poultry waste, sugar cane residues and green manures] in relation to BW control. Thus, these experimental approaches that give some of the first robust quantitative data on BW dynamics that will lead to science-based recommendation on BW control are very significant. Furthermore the molecular methods are appropriate in substantiating the biological basis of the cropping practice and would have cross-cutting value amongst other CPP DFID projects were BW and other soil diseases are a constraint. There would be significant value in validating these data under field conditions through such ongoing initiatives as R7462, R7462 and AT-Uganda and CIP Uganda promotional projects!

An aim of this project was to co-ordinate outputs with an analogous initiative under PRAPACE funding. It was disappointing that the funding to this project had to be withdrawn with the cancellation of that project: this decision was taken on a basis unrelated to the project . Nevertheless, other activities were successfully built upon with the International Potato Centre. These included a demonstration of the seed plot system in Uganda. The NGO AFRICARE played a central role in the work in Uganda where this project established linkage with community farmer groups catalysed under an CIP led IFAD initiative, Integrated control of late blight and bacterial wilt.

The extent of the demand and the way forward for uptake of the seed system through community driven adoption was studied. This study aimed to reconcile production demand for certified seed with current capacity and distribution and the potential for commercial sustainable linkages between seed producers, seed consumer/ware producers and commercial ware markets. In creating the required linkages between rural farmers, input resources [seed, fertiliser, pesticides etc] and ware markets, significant empowerment was recognised through the formation of co-operatives [farmer association/co-operatives]. Specific studies were undertaken on farmer associations in Kenya, Uganda and RSA. The first-contact nature of these studies did not allow in-depth penetration of the functioning of the associations, but the exposure given did allow a useful exchange of ideas to be achieved. Resulting from these discussions farmers of Njabini were invited to a field day that discussed farmer associations. These discussions led to the formation of a CBO, Jitegemee Agricultural & General Development Self-Help Group [JAGED-SHG].

From this study consideration was also give to seed health and access to certified seed. In this context it was recognised that there was a need for a seed health monitoring system that identified seed of good health, but that may not be certified. A significant problem in progressing this seed standard, whilst linking with national seed inspectorates, is embodied in the definition of the term seed: national inspectorates bodies find it difficult to be associated with a product called seed that is not certified! Nevertheless, if we are to be pragmatic for Kenya, Uganda and the rural communities of RSA a half-way house towards the certified standard that is locally recognised as seed of good health is required to bridge the gap between current farmers seed and certified seed. A recommendation of this report is for development of local seed health monitoring systems for potato that are underpinned by national bodies, but that does not attain the certification standard.

A long-term objective of this project has been the approval of the BCA application for testing in Kenya. This has now been achieved subject to minor clarifications on the nature of the contained-use facility and greater clarity on ownership and utilisation of the technology.

Collectively, the above studies laid the foundation for a strong promotional phase of the technologies developed. Two promotional projects have been agreed in Uganda [1 yr project led by CIP and a 3 yr project led by AT Uganda] and a 3rd project in RSA was submitted to the DFID BLCF that reached the full project proposal stage before being declined [3 yr project led by CABI]. The CIP-led Uganda project has an explicit activity to engage Kenyan farmer groups in 2003 through linkage with IFAD funding under a continuation of the current project. At the current time no opportunity has been identified to work with the BCA in Kenya, or elsewhere, though discussion were initiated with the Agricultural Biotechnology Support Programme.

5.1. Summary of output to purpose

The research activities of this project:

1. validated the SSPS developed under R6629, identifying scope for further improvement through a modified planting density
2. developed methods and produced preliminary results on management recommendation for the SSPS set aside land
3. gained permission to test the BCA in Kenya
4. modelled seed flow mechanisms based on the SSPS
5. engaged farmer association in discussing the value of the SSPS with the objective of basing uptake through such groups; Njabini farmers formed a CBO.
6. developed promotional projects

Implementation of these technologies through the promotional projects will result in:

1. reduced on-farm incidence of bacterial wilt;
2. improved access by farmers to good quality [certified] seed;
3. improved maintenance of on-farm seed health;
4. flush-out of degenerate on-farm seed;
5. increased yield and quality of ware potato yield; and
6. associated benefit to smallholders in terms of improved financial returns and food security, leading to improved livelihoods.

6. FOLLOW-UP INDICATED/PLANNED:

The primary outputs of R7858, namely the BCA and the SSPS, are critically poised for uptake by the target institutes and beneficiaries.

BCA: KARI has expressed a demand for evaluating the BCA in-country. The attaining of permission to test under phased contained-use and deliberate release conditions in Kenya is a major milestone for the project and DFID in presenting the first opportunity for the CPP to move forward with assisting a developing country evaluate a crop-related GM material. A minimum of 3-5 years would be needed to validate fully the BCA and its environmental impact. The research should ideally be conducted by a post-doctorate scientist or through a Ph.D. programme where rigorous monitoring would ensure the highest standards are achieved. In progressing this research a clear and dynamic interface between KARI and CAB *International* is required to ensure research quality standards are achieved.

The need to control bacterial wilt within potato cropping systems of Kenya and many other sub-Sahara African counties is not refuted, however, few authoritative studies has been conducted on the perception by potato farmers and consumers of the BCA and its genetically modified nature. A pre-requisite to the wide-scale adoption of the BCA would be farmer and consumer acceptance of GMO technologies for farming, and thus a social study towards this end in Kenya, in the first instance, and other sub-Sahara African countries is essential. Fulfilment of these activities would need to engage the public and media by nature of the publicity surrounding the use of GMO’s for farming.

Subsequent to the successful evaluation of the BCA and social studies to show farmer/consumer acceptance of GMOs in farming, the establishment of micro-enterprise[s] for the manufacture and marketing of the BCA would be needed. Rhizobial inoculants are produced in RSA by private enterprises and these may represent an expedient option for BCA production.

SSPS: Two and a potential third promotional project for the SSPS has been realised through this one year project. These promotional projects focus in Uganda and RSA, and have ambition to encompass Kenya through linkage to an additional phase of the IFAD funded project in Uganda. Common to all these projects is the involvement of farmer groups [association/co-operatives] and the requirement to link to seed and ware markets.

It is a concern that under the promotional CPP projects no strong linkage has been maintained to the technology developing institute, CAB *International*, and it questionable as to what quality monitoring measures are now in place to ensure the correct adoption of the SSPS. It is also noted with concern that under the promotional projects no provision exists to underpin the implementation of the SSPS with research that substantiates the development of robust recommendations on the management of the SSPS set aside land. The correct management of the SSPS set aside land is seen as critical to the success of the SSPS. These significant gaps in the promotion of the SSPS put at risk the likely success of the SSPS and the investment made by the CPP to date.

7. PUBLICATIONS:

Z.M. Kinyua, L.C. Offord, N. Mienie, R. Gouws, S. Priou, O.M. Olanyo, S. Simons, G.S. Saddler, and J.J. Smith [2002]. Fate of a non-pathogenic mutant of *R. solanacearum* in soil: risk assessment of a putative biocontrol agent. Proceedings of the 3rd International Bacterial Wilt Symposium, South Africa, 4 – 8th February 2002 pp 7. [Oral presentation*]

O. M. Olanya, Z.M. Kinyua, R. E-Bedewy, J.J. Smith, S.N. Kihara, and P.T. Ewell [2002]. Field incidence of potato bacterial wilt in relation to latent infection, seed flow channels and cropping practices in Kenya. Proceedings of the 3rd International Bacterial Wilt Symposium, South Africa, 4 – 8th February 2002 pp 20. [Poster]

Z.M. Kinyua, O. M. Olanya, R. E-Bedewy, J.J. Smith, S.N. Kihara, R.K. Kakuhenzire and C. Crissman [2002]. Seed plot technique: Empowerment of farmers in the production of bacterial wilt-free seed potato in Kenya and Uganda. Proceedings of the 3rd International Bacterial Wilt Symposium, South Africa, 4 – 8th February 2002 pp 26. [Oral presentation*]

O. M. Olanya, Z.M. Kinyua, R. E-Bedewy, J.J. Smith, and S.N. Kihara [2002]. Incidence and spatial variability of bacterial wilt infection on advanced potato clones in central Kenya. Proceedings of the 3rd International Bacterial Wilt Symposium, South Africa, 4 – 8th February 2002 pp 47. [Poster]

*The oral presentations are to be included as papers in a forthcoming book on bacterial wilt originating from the conference.

8. INTERNAL REPORTS:

Various BTORS

9. PLATES

Plate 1: Typical symptoms of bacterial wilt on potato plant and tuber

Plate 2: Kenyan farmers planting the SSPS-seed cultivation

Plate 3: Ugandan farmers discuss SSPS-seed cultivation. In Uganda farmers are looking to plant mini-tubers in the SSPS-seed cultivation

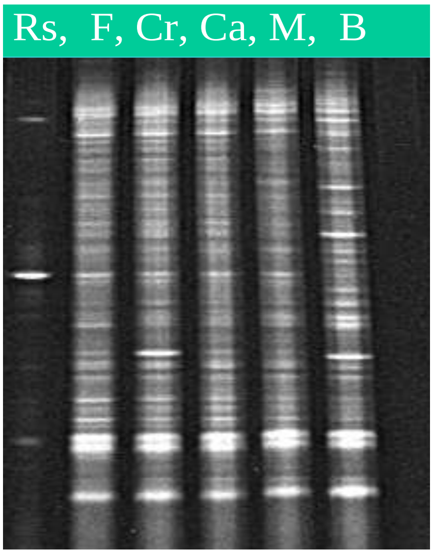
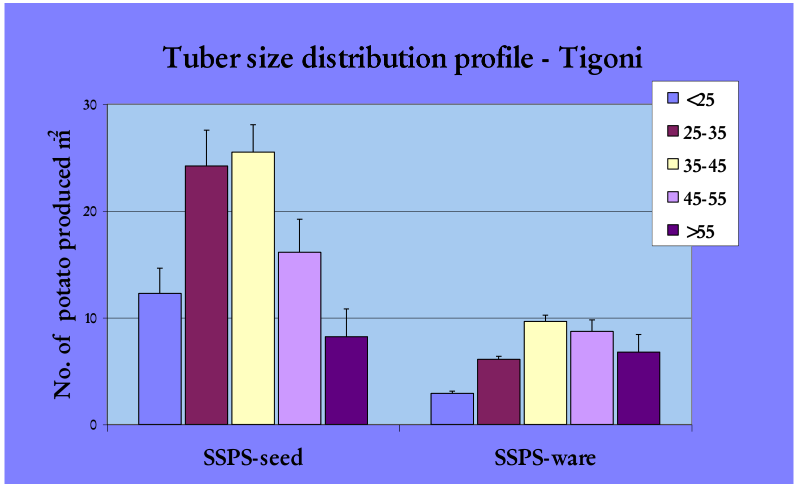


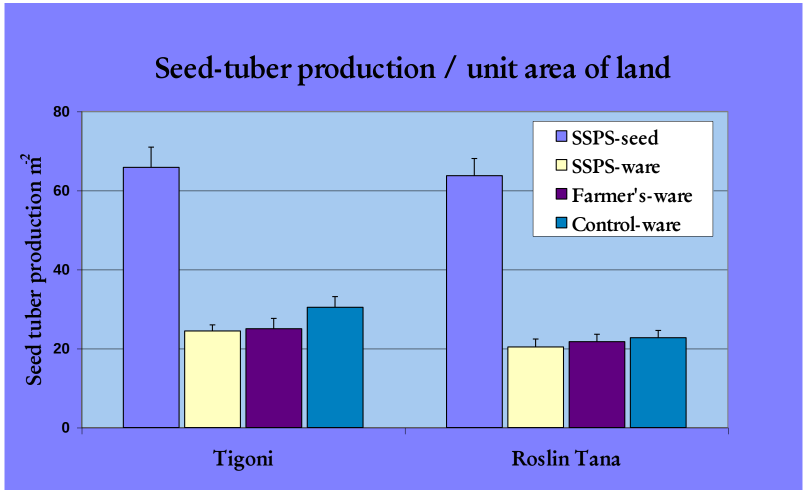
Plate 4: Microbial community profiling of various crop rhizosphere soil by GC clamped 16sDNA primers, fragments resolved by DGGE

Plate 5: Farmers in Kenya discuss the merits of forming an farmers association. They later formed JAGED-SHG

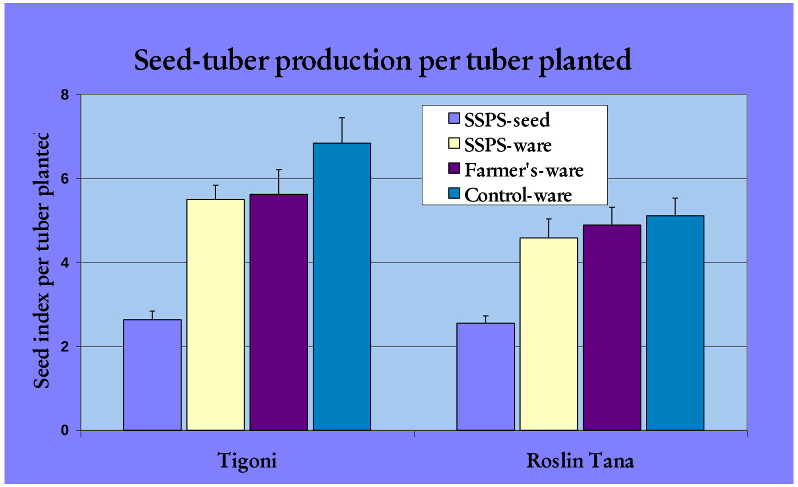
10. GRAPHS



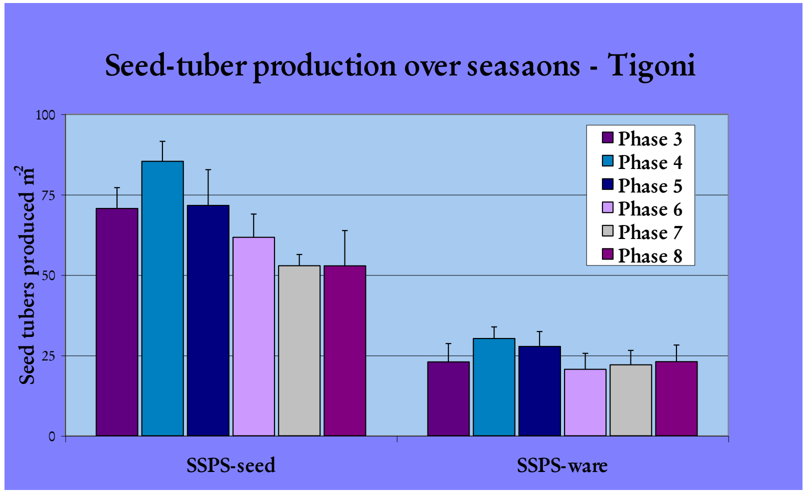
Graph 1: Seed size distribution under SSPS-seed and SSPS-ware management practices



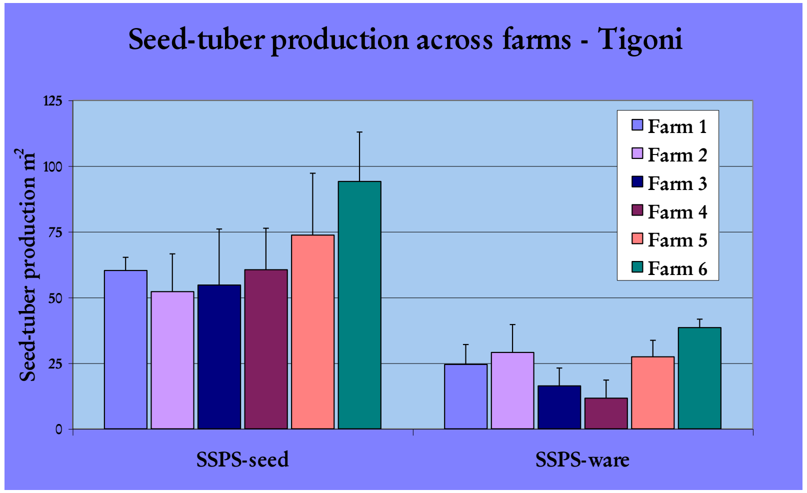
Graph 2: Seed Land Index under the various management practices



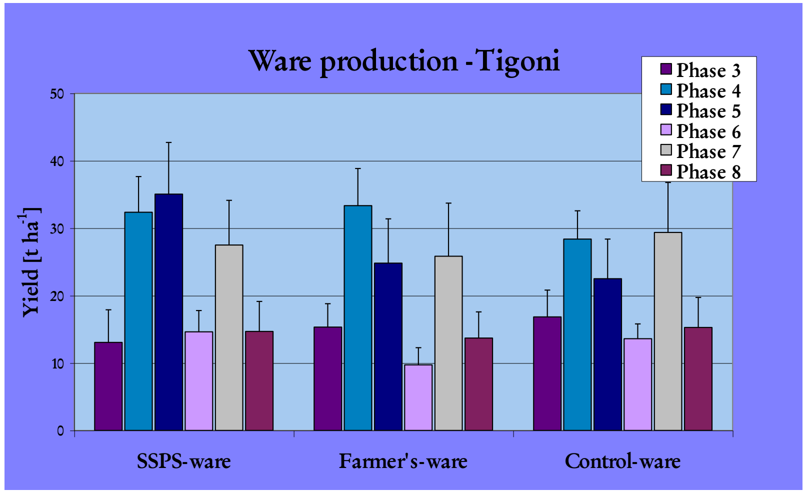
Graph 3: Seed-tuber Index under the various management practices



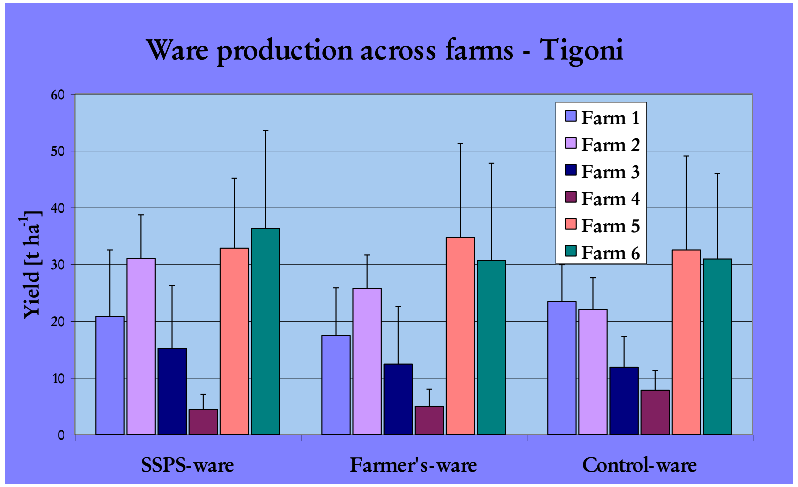
Graph 4: Seed Land Index over the seasons [averaged over farms]



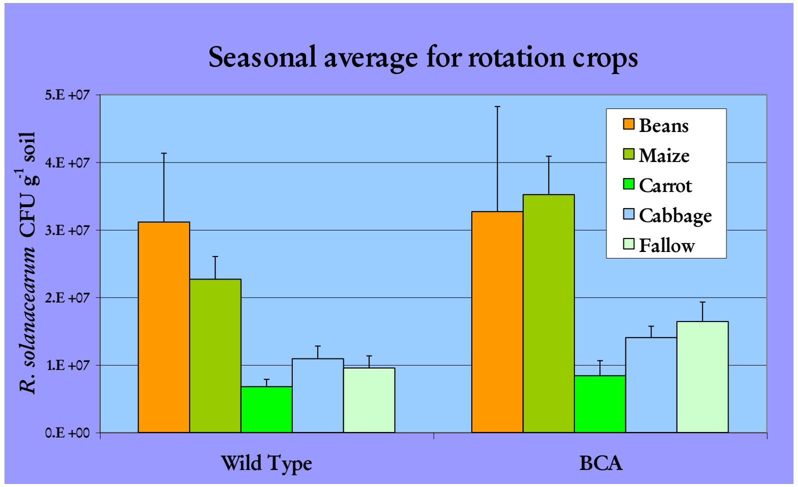
Graph 5: Farm-level seed production [averaged over seasons]



Graph 6: Ware production over seasons [averaged over farms]



Graph 7: Farm-level ware production [averaged over seasons]



Graph 8: *R. solanacearum* supporting capacity of rotation crops

11. APPENDICES

11.1 Appendix i] Logframe R7585

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Goal			
Enter the Programme Purpose that you are addressing	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager
Purpose			
Enter the Programme Output that you are addressing	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager	To be completed by CPP Programme Manager
Outputs			
1. Validation and promotion of SSPS in the Njabini region of Kenya, and co-ordinating linkages fostered with analogous PRAPACE funded research in Uganda and Kenya.	1.1) SSPS field trial at Njabini continued until August 2001; improved knowledge of IPM within SSPS	Technical report; dissemination of results through peer review paper, conference presentation and other publicity material	Analysis of data gives meaningful information within timeframe of project
	1.2) Linkage of PRAPACE and DFID funded SSPS research leading to synergy	Joint dissemination of results through peer review paper, conference presentation and other publicity material	Analysis of data gives meaningful information within timeframe of project
	1.3) Review leading to recommendation on mechanism[s] for community-based promotion of SSPS; pilot study initiated at Njabini	Report submitted; potato growers association operational in Njabini	Openness of farmer groups to co-operate
2. Platform for wide-scale validation and promotion of SSPS and BCA against bacterial wilt established in Kenya, Uganda and RSA.	2.1) Enhanced awareness of SSPS trials in RSA and Uganda	Agreement of field trial designs; management protocols and training aids produced	Openness of farmer groups to co-operate
	2.2) Decisions obtained from applications to Kenyan NCST and RSA National Department of Agriculture requesting permission to assess BCA under CU and field trial conditions of Kenya and RSA, respectively	Official documentation from national quarantine/biosafety bodies	Application processing proceeds within project timeframe
	2.3) Scoping assessment on the potential for smallholders to adopt SSPS in Kenya, Uganda and RSA	Report submitted	Openness of national agricultural systems to divulge information; availability and clarity of required data
3. Terms of reference for an open call on a locally-led SSPS and BCA technology promotion/support project, working in an integrated crop management system [sustainable livelihoods support framework]	3. Consensus of opinion by NARIs, NGOs, other seed potato stakeholders and funding bodies on prioritisation of SSPS and BCA technology promotion/support needs	Call for project proposals as defined by agreed Terms of Reference.	SSPS and BCA prioritised by NARIs, NGOs and other seed potato stakeholders and funding bodies.

Activities	Inputs	Means of Verification	Important Assumptions
1.1) SSPS production evaluated over 2 seasons in terms of yield, quality, disease and pest constraints, social acceptance and financial returns Additional experiments undertaken appropriate to improved IPM of SSPS		Staff costs 8900 Overheads 10680 Capital T&S 16000 Miscellaneous 8500 Total 44080	

Activities	Inputs	Means of Verification	Important Assumptions
1.2) Backstopping advice and research provided to PRAPACE funded SSPS initiatives Research outputs co-ordinated and assimilated giving comparative data on SSPS under 2 additional agricultural systems			
1.3) Survey and report on existing knowledge/experience of community-managed high potential [potato] production systems in Kenya, Uganda and RSA Using existing farmer groups in Njabine, pilot a model community-based potato growers association linking certified seed multipliers to SSPS users			
2.1) Advice/protocols produced on the initiation of SSPS trials in Uganda [AFRICARE/NARO] and RSA [INR/ARC]			
2.2) Follow-up on application to 1] the Kenyan NCST for permission to allow the CU assessment of the BCA in Kenya; and 2] the RSA National Department of Agriculture to allow the field trail assessment of the BCA in RSA			
2.3) Undertake assessment of the national demand for certified seed based on farmers adopting the SSPS Assess current national certification production capacity and the requirements to expand/make available certified seed production inline with projected demand assuming wide-scale adoption of SSPS			
3. Discussions held with NARIs, NGOs and other potato seed stakeholders prioritising SSPS and BCA technology promotion/support needs Terms of Reference agreed on open-call for promotion/support project SSPS and BCA technology promotion/support needs referred to international donors for funding.			

11.2. Appendix ii] Small-scale [on-farm] Seed Production System [SSPS]

On-farm SSPS trials at Njabini

The SSPS was initiated in October 1997 through on-farm trials at Njabini, South Kinangop [Nyandarua district]. Under the trial, SSPS-ware harvests are compared to ware yields under the 'normal' smallhold farmer Farmer's-ware system [Farmer's ware], and with ware yields from certified NPRC Control-seed [Control ware] acting as controls. SSPS and Farmer's-ware systems are initiated from a common source of NPRC Control-seed so direct comparisons can be made [see Figure 1]. Eight cycles of seed production, producing 6 ware harvests across all treatments [see Figure 2] have been recorded.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.
1997										Phase 1		
1998	P1		Phase 2						Phase 3			
1999	P3		Phase 4						Phase 5			
2000	P5		Phase 6						Phase 7 ongoing			
2001	P7		Phase 8						Experiment ended			

Figure 2: Main potato seasons for Njabini and phases of SSPS field trail.

Njabini was selected for the on-farm assessments as this is an important potato-growing region that had been surveyed over the previous 3 years and had a known history of bacterial wilt infested and free farms. Furthermore, this region is served by a NPR sub-Centre that agreed to oversee the day-to-day management of the trials. Six smallholder farmers were invited to participate in the on-farm SSPS field trials. A new and a traditional potato variety were chosen, Tigoni and Roslin Tana, respectively, assessing the relative robustness of a new variety against a land-race adapted variety.

SSPS-seed cultivation management: The salient features of the SSPS are:

- i] The SSPS-seed cultivation is planted each season on soil that was not under potato cultivation the previous season [see point vi].
- ii] Seed spacing on the SSPS-seed cultivation is at 20 x 20 cm under a flatbed cultivation.
- iii] No earthing-up is practised with the SSPS-seed cultivation as the tubers are planted at a depth of 10-15 cm with the use of a dibber.
- iv] Zero disease and pest tolerance is aimed for on SSPS-seed cultivation.
- iv] Dehalming of the SSPS-seed cultivation is undertaken 2 weeks earlier than for the ware cultivations.
- v] Seed selection from the SSPS-seed and SSPS- ware cultivation is targeted at the optimal size for that cultivation [see Seed Selection].
- vi] An area of land equal in size to the SSPS-seed cultivation is managed as a fallow cultivation or planted to a non-solanaceous crop. This land is termed the SSPS setaside and is for the next season's SSPS-seed cultivation.

Ware cultivation management: Ware production was undertaken according to standard practice: planted under a ridge / furrow cultivation at a spacing of 75 x 30 cm, respectively. No rotation was practised with the ware cultivations, mimicking farmer practice.

Seed selection: Tubers of 25 – 55mm were considered seed for both varieties. For the SSPS-seed cultivation, seed of 25 – 35 were preferred, reserving the larger sized seed [35- 55mm] for the SSPS-ware. For the Farmer's-ware, seed of 25 – 35mm was preferred as this was the typical size chosen by farmers [Barton et al., 1997]. This framework of seed selection and distribution was implemented to return an optimum sized seed to a particular cultivation. With the Farmer's ware, the seed size selection was considered less than optimum for ware yield, but importantly was aimed to mimic current practice.

Post-harvest seed treatment: Responsibility for the storage and chitting conditions of seed [SSPS-seed and Farmer's-ware seed] for the next phase planting was left to the farmers. For this purpose each farmer was provided with a wooden crate for the SSPS-seed only; no provision was made for Farmer's-ware seed and this was left to the farmer to manage. In the early phases chitting was promoted for both seed lots by use of Rendite.

Management by phases [see Appendix iii] for additional information]
Phase 1 assessment of the on-farm small-scale seed production system: In phase 1 the potential for seed production under the SSPS-seed cultivation and ware cultivation was compared. This comparison was not integral to the long-term outputs of the main field trial [see Figure 1], but was included to underlined the differences between the systems to the farmers. To allow direct comparisons to be made, it was necessary to impose identical management practice that deviated from the SSPS model.

Treatment combinations for Tigoni and R. Tana:

- i] SSPS-seed cultivations [3 x 3 m] using NPRC Control-seed
- ii] Ware cultivations [3 x 3 m] using NPRC Control-seed

Phase 2 assessment of on-farm small-scale seed production system: Treatment combinations for Tigoni and R. Tana:

i] SSPS-seed cultivations [4.5 x 2 m] using SSPS-seed harvested from Phase 1
ii] Ware cultivations [4 x 4.5 m] using SSPS-seed harvested from Phase 1
iii] Ware cultivations [4 x 4.5 m] using NPRC Control-seed

Phase 3 assessment of on-farm small-scale seed-tuber production system: Treatment combinations for Tigoni and R. Tana:

i] SSPS-seed cultivations [4.5 x 2 m] using SSPS-seed harvested from Phase 2
ii] Ware cultivations [4 x 4.5 m] using SSPS-seed harvested from Phase 2
iii] Ware cultivations [4 x 4.5 m] using Farmer's-ware seed harvested from Phase 2
iv] Ware cultivations [4 x 4.5 m] using NPRC Control-seed

Phase 4, 5, 6, 7 and 8 assessments of on-farm small-scale seed-tuber production system: Phase 3 realises the full experimental outline, with subsequent phases repeating these treatments.

Management aspects of SSPS: Detail on the operation of the field trials is given in Appendix A-ii.

Data collated: Data collated included potato emergence, disease and pest incidence, agronomic factors, chemical inputs, man operator hours and harvest data. Harvest data included total yield and a breakdown of tuber numbers into 5 tuber classes based on tuber diameter [<25, 25-35, 35-45, 45-55, >55 mm]. From Phase 1 data only average tuber weights were recorded for each of the tuber size classes.

Storage pests and diseases were also monitored for both SSPS-seed and Farmer's-ware seed. Latent infection of tubers by bacterial wilt was assessed with the use of a *Ralstonia solanacearum* specific ELISA Kit developed by CIP from Phase 4 onwards. The assessment method for ELISA was based on a sample of 5 x 10 sub-samples [= 50 tubers] per tuber class category under analysis. Thus a positive reaction indicated a minimum of 1 in 5 [20%] tubers infected per sub-sample.

Farmer perception and feedback was continual sought, and a Farmers Open Day was held

Statistical analysis: Hypothesis testing on factors [average seed weight, seed production and ware yields] at each Phase was undertaken by general linear regression [Gensat]; to assess system affects over Phases, Phases were considered as a split factor; hypothesis testing of distribution of harvested tuber size classes between systems at each Phase was tested by split plot analysis where var.system = main plot and harvested tuber size class = split factor [Gensat]; split-split plot analysis was used to assess the distribution of tuber size classes between systems over all Phases where var.system = main factor, var.system.phase = split factor and harvested tuber size class = split-split factor [Genstat].

11.3. Appendix iii] Summary on the management of SSPS field trial

Treatment	Phase 1	Phase 2	Phase 3	Phase 4
Planting dates	6-7th Nov. 1997	15-16th April 1998	22-23rd Sept. 1998	18-19th March 1999
Dehaulming dates	13-14th Feb. 1998	30-31st July 1998	14th Jan 1999 SSPS-seed cultivation; 28-29th Jan 1999 Ware cultivation	24th June 1999 SSPS-seed cultivation; 1st July 1999 Ware cultivation
Harvesting dates	3-4th Mar. 1998	18-20th Aug. 1998	28th-29th Jan SSPS-seed cultivation; 11-12th Feb 1999 Ware cultivation	8-9th July 1999 all plots
Fertiliser Make [trade name] Active ingredient Quantities Dates	Diammonium phosphate $N = 18\%$, $P_2O_5 = 46\%$ 66.6g per m^2 At planting	Diammonium phosphate $N = 18\%$, $P_2O_5 = 46\%$ 66.6g per m^2 SSPS 55.5g per m^2 ware At planting	Diammonium phosphate $N = 18\%$, $P_2O_5 = 46\%$ 66.6g per m^2 SSPS 55.5g per m^2 ware At planting	Diammonium phosphate $N = 18\%$, $P_2O_5 = 46\%$ 66.6g per m^2 SSPS 55.5g per m^2 ware At planting
Fungicide Make [trade name] Active ingredient Quantities Dates	Ridomil Metalaxyl + mancozeb 50g per 20 litres 4 weeks after planting and at 2 week intervals thereafter Total of 5 applications	Acrobat Dimethomorph + mancozeb 50g per 20 litres 4 weeks after planting and week intervals thereafter Total of 4-5 applications.	Ridomil Metalaxyl + mancozeb 50g per 20 litres 4 weeks after planting and at 2 week intervals thereafter Total of 4 applications	Ridomil Metalaxyl + mancozeb 50g per 20 litres 4 weeks after planting and at 2 week intervals thereafter Total of 4 applications
Insecticide Make [trade name] Active ingredient Quantities Dates	Karate Lambdacyhalothrin As by manufacturers instructions Once 6 weeks after planting	Karate Lambdacyhalothrin As by manufacturers instructions Once 7 weeks after planting	Karate Lambdacyhalothrin As by manufacturers instructions Twice at 2 months after planting at 2 week interval	Karate Lambdacyhalothrin As by manufacturers instructions Twice at 2 months after planting at 2 week interval
Tuber sprouting treatment Make [trade name] Active ingredient Quantities Dates	Rindite Ethylene chlorhydrin 0.5ml/kg seed	Rindite Ethylene chlorhydrin 0.5ml/kg seed 18-20th March 1998	Rindite Ethylene chlorhydrin 0.5ml/kg seed 3rd Sept 1998	None

Treatment	Phase 5	Phase 6	Phase 7	Phase 8
Planting dates	14-15th Sept 1999	23-24th March 2000	4-5th Oct 2000	10-12 Aril 2001
Dehaulming dates	28th Dec 1999 SSPS-seed cultivation; 6-7th Jan 2000 Ware cultivation			
Harvesting dates	18th-19th Jan 2000 all plots	26-27th July 2000 all plots	6-8thj Feb 2001 all plots	25-27th July 200l all plots
Fertiliser Make [trade name] Active ingredient Quantities Dates	 Diammonium phosphate N = 18%, P_2O_5 = 46% 66.6g per m^2 SSPS 55.5g per m^2 ware At planting	 Diammonium phosphate N = 18%, P_2O_5 = 46% 66.6g per m^2 SSPS 55.5g per m^2 ware At planting	 Diammonium phosphate N = 18%, P_2O_5 = 46% 66.6g per m^2 SSPS 55.5g per m^2 ware At planting	 Diammonium phosphate N = 18%, P_2O_5 = 46% 66.6g per m^2 SSPS 55.5g per m^2 ware At planting
Fungicide Make [trade name] Active ingredient Quantities Dates	 Ridomil Metalaxyl + mancozeb 50g per 20 litres 4 weeks after planting and at 2 week intervals thereafter Total of 4 applications	 Ridomil Metalaxyl + mancozeb 50g per 20 litres 4 weeks after planting and at 2 week intervals thereafter Total of 4 applications	 Ridomil Metalaxyl + mancozeb 50g per 20 litres 4 weeks after planting and at 2 week intervals thereafter Total of 4 applications	 Ridomil Metalaxyl + mancozeb 50g per 20 litres 4 weeks after planting and at 2 week intervals thereafter Total of 4 applications
Insecticide Make [trade name] Active ingredient Quantities Dates	 Karate Lambdacyhalothrin As by manufacturers instructions Twice at 2 months after planting at 2 week interval	 Karate Lambdacyhalothrin As by manufacturers instructions Twice at 2 months after planting at 2 week interval	 Karate Lambdacyhalothrin As by manufacturers instructions Twice at 2 months after planting at 2 week interval	 Karate Lambdacyhalothrin As by manufacturers instructions Twice at 2 months after planting at 2 week interval
Tuber sprouting treatment Make [trade name] Active ingredient Quantities Dates	 None	 None	 None	 None

11.4 Appendix iv] Optimisation of SSPS-seed cultivation

During Phase 8 a comparison of 2 planting densities was trailed against the normal ridge / furrow spacing. The planting densities were 20 x 20 and 30 x 30 cm, giving a planting density of 25 and 11.11 tubers m^{-2}. The density of ware planting is 4.45 m^{-2}

Using seed derived from the SSPS-seed cultivation the following comparison were performed on 5 of the 6 farmers fields: Farm 1 has insufficient seed and land to accommodate the additional plots. Both varieties Tigoni and Roslin Tana were included in the assessment.

i] SSPS-seed cultivations [4.5 x 2 m] planted at 20 x 20 cm
ii] SSPS-seed cultivations [4.5 x 2 m] planted at 30 x 30 cm
ii] SSPS-ware cultivations [4 x 4.5 m] planted at 30 x 75 cm

The management of the plots was as described for the main SSPS trial. See summary of management below Appendix iii].

11.5. Appendix v] Evaluation of potential rotation crop to reduce soil inoculum of bacterial wilt

This research aimed to establish the interaction of the BCA and WT *R. solanacearum* with rotation crops associated with potato. The assessment was undertaken at CABI Bioscience UK Centre [Egham].

Experimental outline:

Soil microcosms	–	25 cm diam. X 25 cm depth pots [approx 1000cm^{-3}]; Sandy loam soil [Egham]
BCA	–	Omega 5.1
WTs	–	K3, K9, K 41 [spontaneous rifampacin mutants; Biovar 2a; Kenya]
Treatments	–	Soil was inoculated with equal populations of BCA and WT *R. solanacearum* and planted to maize, bean, carrot, cabbage and potato [5 plants per pot]; a no-plant control acted as a fallow treatment
Inoculation of soil	–	Inoculum of WT and BCA grown on CPG plates [48 hr growth at 30ºC]; equal volumes of 10^9 and 10^9cfu ml^{-1} inoculum of WT [equal ratio of isolates] and BCA, respectively, absorbed in vermiculite [1 volume of inoculum to 9 volumes of vermiculite] and brought to saturation with H_2O, prior to dispersal in soil; vermiculite to soil ratio adjusted to 1:10 in all treatments; seeds/tubers planted on day of soil inoculation
Growth conditions	–	14 hr day 10 hr night cycle; min / max temp 20-25ºC
Sampling	–	At each sampling, 1 treatment combination [plant] was assessed; rhizosphere soil and root were weighed independently; soil fractions were serially diluted and plated onto SMSA supplemented with kanamycin or rifamapacin; samples taken at regular intervals over 3 months
Experimental design	–	Randomised complete block design; 5 replicates, planted to 5 plants; 5 sampling dates
Data recorded	–	BCA and WT cfu g^{-1} rhizosphere soil or cfu g^{-1} root
Statistical analysis	–	Hypothesis testing to determine interaction between BCA and WT populations with rotation crops; statistical

analysis by two-way ANOVAR in randomised blocks [Genstat]

11.6. Appendix vi] Linkage with AFRICARE in Uganda - Report on the Small Seed Potato Plot Systems [SSPS] and visit to Kenya

Background:
AFRICARE UFSI has been emphasizing supply of clean planting material to even the most marganalized rural poor village groups. There have been admirable again especially as regards improved potato varieties and these need to be sustained and improved upon. Phasing out in form of purchasing basic seed and supply local communities is now going on. Many have started buying from National agricultural research organisation [NARO] and Uganda National seed potato producer’s Association [UNSPPA] to facilitate the flush through principle after 1 to 2 production cycles.

So far there has been no organized system to enable UFSI farmers to individually multiply the seed derived from their communal gardens and stores. Many have been multiplying it as ware potato and a gain saving it as seed which has compromised quality hence very quick reduction in yield. The farmers have very little land [less than 0.8 ha / person] which can’t allow for rotations. These constraints can be addressed by on-farm production that separates seed and ware production system and promotes Integrated pest and disease management. This system has proved useful in Kenya and hence AFRICARE in collaboration with CABI, CIP, KARI and NARO embarked on pilot project to enhance awareness of seed plot production systems and validate its appropriateness through on farm demonstrations in Kabale District and an exchange visit to Kenya.

Objectives of the activities undertaken:

- To create awareness of the on-farm seed management amongst small holder farmers in Uganda through profiling the small-scale production system in Kenya and through practical demonstrations.

- Training UFSI and NARO staff on SSPS and hence aid in enhancing farmer perception thus improving the relevance of the feed back data obtained on appropriateness and need for the technology specifically within the UFSI community based potato production and storage scheme.

Project activities:

- Establishment of the small seed plots at one AFRICARE village group sites with following participants: AFRICARE staff [6], NARO [3], KARI [2] members, CIP [2] and 30 village members.

- Mini field day at the stage of weeding, with the following participants; 70 farmers, 10 sub county local officials; NARO [3], CIP [1] and 6 AFRICARE staff.

- Harvesting field day: with the following attending;
  Dr. Julian Smith from CABI
  Dr. Modesto Olanyo from CIP
  Dr. Berga Lemaga from PRAPACE
  130 farmers
  6 AFRICARE staff
  12 local council III officials,
  Kabale District Local Government Officials.

- Visit to Kenya by Agricultural Production Officer for 5 days where he participated in field harvesting and interacted with the different players of the seed potato industry in Kenya.

Important aspects of experiences learnt:
Results from the seed plots harvested during the last season clearly indicated results similar to those obtained in the Kenya SSPS as regards yields and quantity of seed size tubers produced [Table 1 and 2]. Yield data showed that the seed plot [20x20] produced more tubers than the conventional planting [ridge follow] at a spacing of 70x30. Tuber yield per square meter in the seed plot was approximately twice than in conventional method.

Farmer’s conclusion during harvesting was that the system required less land than ware potato hence fitting well in their farming systems. The freed land can be managed as next seasons seed plot by leaving it fallow or planting non-solanaceous crop.

From the visit in Njabini village and through interaction with the different stake holders in the Kenya seed potato Industry I gained deep insight in how to clearly interrelate the different players in Uganda, that is the producers of basic seed [NARO], commercial producers and the small scale holders.

Over 60% of the farmers who participate in harvesting have shown interest in trying the new innovation using the seed they will share from the communal gardens this coming season [September-December] according to extension report [UFSI-AFRICARE] July 2001. An improved vision of a sustainable, community based seed management system for small holders seems to be coming into play. The big problem of quick degeneration of seed stocks is well addressed by SSPS. The SSPS approach completes the integrated community based potato production scheme aimed at improving the informal seed potato industry run by farmers. There is however need to strengthen technical backstopping and readily available research capacity to address any complication that may arise as the technology pathways develops. This calls for further net working with other stakeholders if full potential is to be realised. Although this was first hand experience with the small seed plot in Kabale, Uganda, it caused excitement among farmers and its future is yet to be assessed.

Table 1. Summary of the results from Margret

Tuber size	**Seed plot: close [20x 20 cm]**		**Ware potato wide [30 x 70 cm]**	
	$18m^2$	$36m^2$	$18m^2$	$36m^2$
Small	302	604	80	160
Medium	1129	2258	410	820
Large	13	26	94	187
Rejects	112	224	211	422
Total	1444	2862	584	1167

N.B 1] Medium tubers are the ones recommended for seed.
2] NARO and AFRICARE are compiling a technical report on the SSPS

11.7. Appendix vii] Letter of approval for testing the BCA against BW in Kenya under contained-use conditions

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Telegrams: "SCIENCE TECH", Nairobi
Telephone. Nairobi 336173-5, 219420
Fax 330947
When replying please quote

Ref. No.____________________
and Date

P.O. BOX 30623
NAIROBI

............,20............

NCST/13/026

20th June, 2001

The Director
Kenya Agricultural Research Institute
P.O. Box 57811
Nairobi (Attn: **Dr. B. Odhiambo:**
Head of Biotechnology Centre)

Dear Sir,

RE: APPLICATION FOR INTRODUCTION OF GENETICALLY MODIFIED BIOLOGICAL CONTROL AGENT AGAINST BACTERIA WILT OF POTATOES

Further to our discussion on the above application please note the decision of the National Biosafety Committee as discussed on 17th August, 2000 and 21st September, 2000 and our communication to you on 25th September, 2000 ref. NCST/13/026.

1. The application was approved for trials within laboratory and in screen houses.
   Further to this was the condition that the approval of KEPHIS on the facilities for the trials be issued.
2. KARI should clarify the following questions previously expressed in our communication dated 25th September, 2000.
   What are the long term objective and time frame of the project?
   Who owns the technology? What was KARI's role in the development of the technology?

We request that you liase with KEPHIS for the inspection report. Further note that once the above issues are clarified the secretariat will immediately issue approval and details of conditions that will apply to the trials.

Yours faithfully

C. K. Nzau
For : Secretary
NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

c.c. Mr. Gilbert Kibata
Crop Protection Co-Ordinator – NARL

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11.8. Appendix viii] Summary of key findings of trip to South Africa, Kenya and Uganda

Criteria	South Africa	Kenya	Uganda
1. Status of Potato vis-a vis other crops	Potato a very high priority crop, grown in nearly all the provinces [14 production regions]. Currently, 16,000,000 tonnes of ware per year	Potato an important crop in several regions of Kenya [Central, Rift valley, Western – Mt Elgon area, Wundanyi - coastal highlands] [National priority level?]	Potato a priority crop in the South-western region, becoming important in the east, west, central and north-western regions but still not high up on the priority list. [Ware potato approx 400,000 tonnes/yr]
2. Availability of certified/clean seed potato	Certified seed available through PSA for large-scale farmers [mostly]. 72% of potato farmers use certified seed.	Certified seed available through NPRC – Tigoni [and a few seed contract seed growers]. Demand often outstrips supply.	Clean seed available through the National Potato Programme and UNSPPA, currently seed not adequate for all farmers.
3.National seed production [current status]	217, 600 tonnes per year. Approx 10,000 ha annually [13.75 tons/ha]; 400 registered seed growers under the supervision of the Potato Certification Service	Not determined	80-150 tonnes/yr of Basic seed
4. Expertise in seed production	Available through Potato South Africa. Support to farmers from field extension staff, ARC-VOPI and NGOs	Adequate up to basic seed level through NPRC- Tigoni; thereafter weak.	Adequate up to basic seed level; thereafter weak
5. Seed certification [current status and mechanisms]	Sophisticated system under PSA; formal system & less sophisticated informal system [Table potato system] operated. Registered Labs affiliated to PSA. Fee for certification charged	Formal certification system in place through KEPHIS. Fee for certification charged; lacking human and infra-structure capacity	Informal seed certification through NARO and UNSPPA; lacking human and infra-structure capacity
6. Seed quality [incl. disease status]	High. Rigorous disease surveillance / testing undertaken for viruses,	NPRC seed [basic] considered good and free of significant pests.	NARO seed [basic] considered good and free of significant pests.

	BW, Erwinia; True to type testing and diagnostics on request. Few outbreaks of BW [2-3 cases /yr].	Subsequent on-farm multiplication of questionable quality due to lack of rigorous testing for BW	Subsequent on-farm multiplication of questionable quality due to lack of rigorous testing for BW
8. Organizations involved in seed potato production	PSA and NGOs working with for SS farmers [e.g. ACAT]	NGOs supporting CBOs to grow seed. CBO's include Mt. Kenya Seeds of Hope [in Nanyuki, Liakipia district] – supported by World Vision [project ended], Kilema Youth Group [in Wundanyi] – supported by Taita Taveta Agric. Project -TTAP [funded by DANIDA], MEICP [in Mt. Elgon district]	NARO, UNSPPA & AFRICARE through FFS; UNSPPA initially included farmers from 2 districts [Kabale & Kisoro] and is expanding to more districts where potato production is being adopted [will be a truly national organisation]
9. Seed storage facilities	Available for large-scale farmers; Inadequate for SS farmers. NGO such as ACAT promoting DLS.	Available in a few areas or with a few farmers / farmer groups [e.g. Nanyuki, Mt. Elgon Seeds of Hope], but lacking or improvised in many areas. Seed storage a serious problem in Wundanyi.	Seed storage available at NARO stores; UNSPPA farmers building diffused light stores. More needed
10. Availability of markets [for seed]	Organised markets through PSA. Packaging inappropriate [large] for SS farmers. 25kg bag costs US $6.2 [$0.25/kg]	Markets not organized. Individual farmers seek own markets. Seed costs $25/80kg bag [0.31/kg]	Seed market growing fast. Initially distribution done through Dept. of Agriculture district offices; 80kg bag of seed costs $23.5 [$0.3/kg]
11. Knowledge dissemination activities Publicity Farmer training others	PSA provides a daily information service to LS farmers [who pay for it]; SS farmers obtain information through ARC-VOPI or NGOs [mainly through training]. PSA has a database of seed production in all the regions.	Through KARI [Tigoni and NARL & MARD] – farmer training and some publications. More publicity required.	Accessibility to knowledge on seed still limited; Limited publicity [mainly local], & language barriers; Farmer training through NARO and AFRICARE in Kabale
12. Availability of production resources to	Credit for LS farmers though regional banks, inputs through	Largely lacking. NGO's supported farmer groups in Nanyuki and	Limited; UNSPPA providing credit facilities for its members to put up

potato farmers Credit fertilizers pesticides	vendors; SS farmers under ACAT get credit in form of seed & fertilizer packs	Wundanyi with credit [to build stores] and inputs such as fertilizers, but facilities not sustainable after end of projects.	DLS & acquire seed and other inputs; Fertilizers and pesticides available but often fake products on market.
13. Potato Farmers Association Status Benefits Sustainability	PSA – for LS farmers No formal Assoc. for SS farmers but farmer groups under NGOs such as ACAT benefit from support [see 14 above]	Existing groups are loose [temporary] e.g. Wundanyi group was growing potatoes for one season and passing on seed to another group [under TTAP]. Past efforts to establish formal groups were not successful. Nanyuki Group membership was reducing due to land pressure & poor markets	UNSPPA growing in membership [currently 25 members], activity level & geographical scope; Benefits to members include mobilization of credit, technical support and markets. Sustainability envisaged through members good will, membership fees and a revolving fund.
14. Response to introduction of SSPS Farmers Other stakeholders	Concept welcome by SS farmers and ARC VOPI. The latter would try it with SS farmers. PSA too big to get involved but can support certification through its Table Potato Certification Scheme	SSPS concept welcome by SS farmers and stakeholders but sustainability questions raised	SSPS well received by farmers through AFRICARE run FFS. Opportunity for dissemination of SSPS technology to be explored through further CIP / AFRICARE / CABI partnership

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