Appendix A-i

No.	Farmer name	Small hold size (acres)	Bacterial wilt.
1	Margaret Gichuhi	1	Present
2	Raphael Wahogo	13	Present
3	Frances Maara	9	Present
4	James Muiruri	5	Absent
5	Samuel Kabugi	26	Absent
6	Watson Wachira	Not known (>25)	Absent

Appendix a-i: Background information on small hold farms involved in field trials.

Appendix A-ii

Summary on the management of SSPS field trial

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Planting dates	6-7th Nov. 1997	15-16th April 1998	22-23rd Sept. 1998	18-19th March 1999	14-15th Sept 1999	23-24th March 2000
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	28th Dec 1999 SSPS seed cultivation; 6-7th Jan 2000 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	18th-19th Jan 2000 all plots	26-27th July 2000 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	 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	 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

Appendix A-ii

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
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	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	None	None

Appendix A-iii

Socio- economic questionnaire - Potato disease survey

Name of Grower					Address						
Formal farmer training eg. Extension activities											
Land holding in acres	Self-owned Tenant Leaser				Source of household income (order in priority):	1. 2. 3. 4.					
Crops cultivated (order in priority)	1. 2.				3. 4.	5. 6.		7. 8.			
Crop rotation patterns	1. 2. 3.										
Area planted to potato (Ac.)	1997				1998			1999			
Cultivars planted					Main factor in choice of cult.						
Seed source	Home			Neighbour			Market			‘Certified’	
Farmer/gender practice:	M	F	C	Farmer/gender practice				M	F	C	
Land preparation Fertiliser application Hoeing Pest control applications Dehaulming				Harvesting Seed-tuber selection Marketing							
Source of irrigation/freq.	Rain			River			Bore hole			Other	
Chemical input	Type			Dose.	Freq.		Timing			NPRC/MoALD&M input	
Fertiliser											
Fungicide											
Insecticide											
Herbicide											
Usage of potato produce (as percentage)	Home ware			Home seed			Market ware			Market seed	
Marketing	Direct or via trader						Current value/debe			Max/av./min value per debe	
Ware Seed-tuber											
Bank credit available			Dealer credit available					Other credit source			
Change in potato yield (5 yr.)							Change in potato status (5 yr.)				
Reason							Reason				
Major constraints as seen by farmer											
Pest symptoms (order in priority)	Probable identity (indicate if known by farmer)						Losses			NPRC/MoALD&M input	

Use of commercial middlemen for ware selection	
Awareness of new cultivars; source of information	
Constraints to marketing ware (roads/vehicles/outlets etc)	
Constraints to marketing seed (roads/vehicles/outlets etc)	
Farmer estimation on land set to seed under ware cultivation	
Farmer preferred choice of seed-tuber size	
Farmer actual seed-tuber size	
Other remarks:	

Appendix A-iii

SSPS questionnaire.

What do you consider a (bags/ac)	Good yield	Average yield	Bad yield
What was the yield in (bags/ac)	1997 Spring October	1998 Spring October	1999 Spring October
How did you hear of this meeting			
What was your reason for attending			
Had you heard of the field trials. If so, how, and what?			
Do they have options on obtaining good quality seed, and when did they last purchase such seed.			
When did they last purchase seed from			
What do farmers see as the advantages/disadvantages to the SSPS over ware-to-ware cultivation.		Advantage: Disadvantage:	
Do farmers think it takes longer to plant SSPS than ware (given equal tuber numbers). Justify answer			
What do farmers think the most important aspect of the management of the SSPS. Priorities list.		Planting on good land ( ) Planting depth ( ) Increased pest control ( ) Dehaulming early ( ) Seed tuber selection ( ) Post harvest storage of tuber ( ) Management of the SSPS set-aside ( ) Rotation of the SSPS seed plot ( ) other (specify ( )	
What would farmers see as the main reason (if any) for the SSPS not achieving widescale adoption by farmers.			
Would the division of labour between man/wife/child change for the management of the SSPS from that indicated earlier. Explain your answer.			
Other comments:			

Appendix A-iv

Pest and disease status, and observations on abiotic constraints

Phase	Pest and disease report, and abiotic constraints
Phase 1	Farm 1: 10% late blight incidence; 3 (1.4%) BW plants on Tigoni SSPS seed cultivation and 1 (2.1%) BW plant on Tigoni ware plot; tuber moth in some tubers Farm 6: Minor incidence of tuber moth General low incidence of late blight Waterlogging in farms 1, 2 and 4; high frequency of greened tuber in SSPS seed cultivations
Phase 2	Farm 1: 50% incidence of late blight; 15 (6.8%) BW plants on Tigoni SSPS seed cultivation and 1 (1.3%) BW plant on Tigoni SSPS ware cultivation; minor incidence of tuber moth Farm 3: Minor incidence of tuber moth General low incidence of late blight Greening of tubers not observed, attributed to improved planting method
Phase 3	Farm 1: 5 (2.3%) BW plants on Tigoni SSPS seed cultivation; minor cutworm damage Farm 3: 60% incidence of late blight; millipede damage Farm 5: *Rhizoctonia solani* infection on ware plots; 1 plant infected with *Sclerotium rolfsii* Farms 4 & 6: minor cutworm damage Slight frost damage esp. Farm 1 SSPS seed cultivation; poor/late plant emergence on farm 4 (low moisture level; sandy soil); Farm 3 with soil fertility gradient indicated by plant vigour

Appendix A-iv

Phase	Pest and disease report, and abiotic constraints
Phase 4	Farm 1: 5 (2.3%) BW plants on Tigoni SSPS seed cultivation Farms 2, 3, 5 & 6: minor incidence of late blight Farm 3: millipede damage Farm 4: cutworm damage; post harvest Fusarium dry rot Farm 5: *Rhizoctonia solani* infection (2 plants in Tigoni SSPS ware & 1 R. Tana plant in SSPS ware Farm 6: *Rhizoctonia solani* infection (black scurf) esp on Tigoni ware-to-ware cultivations Farm 3: late weeding in SSPS seed cultivations; Farms 2, 3 & 4 poor/late emergence esp. NPRC seed; R. Tana with high incidence of cracking
Phase 5	Farm 1: 3 (1.4%) BW plants on Tigoni SSPS seed cultivation; minor cutworm esp on R. Tana Farm 3: tuber moth in a few stems Farm 5: *Rhizoctonia solani* infection on some plants Farm 5 & 6: *Rhizoctoni solani* (black scurf) on tubers Farms 1, 5 & 6 with slight frost damage 5 weeks after planting; General ware plant vigour NPRC ware>SSPS ware > Ware-to-ware ware; R. Tana with high incidence of cracking
Phase 6	Not available at time of reporting

Socio-economic inputs to 'Biological Control of Bacterial Wilt Disease of Potato in Kenya'.

Project: ODA RNRRS Crop Protection: R6629 (NR International: ZA0085)

January 1997

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CONTENTS

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ABBREVIATIONS

ADC	-	Agricultural Development Corporation
AFC	-	Agricultural Finance Corporation
AHI	-	African Highland Initiative
ASARECA	-	Association for Strengthening Agricultural Research in Eastern and Central Africa
CIP	-	International Potato Centre
FAO	-	Food and Agricultural Organisation of the United Nations
IARCs	-	International Agricultural Research Centres
ICRAF	-	International Centre for Research in Agroforestry
IMI	-	International Mycological Institute
IPM	-	Integrated Pest Management
KARI	-	Kenya Agricultural Research Institute
kg	-	kilogram
KGGCU	-	Kenya Grain Growers Cooperative Union
MALDM	-	Ministry of Agriculture, Livestock Development and Marketing
NARS	-	National Agricultural Research Systems
NGOs	-	Non-Government Organisations
NPRC	-	National Potato Research Centre
NRI	-	Natural Resources Institute
ODA	-	Overseas Development Administration
PLRV	-	Potato Leaf Roll Virus
PRA	-	Participatory Rapid Appraisal
RRCs	-	Regional Research Centres

1. SUMMARY AND RECOMMENDED ACTION

1. Potatoes are an important food and cash crop in Kenya. The area cultivated during 1995 was estimated to be 96,000 hectares, nearly 4 times the area cultivated in 1965 (27,000 ha). Yields are low at between 7-10 tonnes/ha and increases in output are the result of an expansion in area rather than in yields per unit area. Production is confined to the highland areas of Central, Eastern and Rift Valley Provinces.

2. Potatoes are grown by smallholders, both men and women, and often play a dual role as cash and subsistence crops. Subdivision of holdings with each generation is reported to be creating difficulties for farmers as it becomes impossible to rotate potato crops while continuing to meet the subsistence and cash needs of their families.

3. Marketing presents few problems for cultivators, particularly in the major producing areas, although farmers have little market information or control over the price they receive for their produce. Seasonal price variations can be large (KSh400 to KSh1,000 per 120kg bag), although few farmers have access to, or knowledge of, storage technology to take advantage of these differences.

4. Most farmers appear to attempt some form of rotation, although where 75% of the farm is planted to potatoes at each season (e.g. Meru District), a break of sufficient length to manage pests and diseases must be impossible to achieve. As a result yields are low, despite the use of fertilisers and fungicides. One cause of low yields is the presence of bacterial wilt. All farmers questioned during this brief survey reported having wilt on their farms. The extent and economic consequences of the disease are impossible to quantify on a local or national scale. However, farmer cultural practices are certain to contribute to a spread of the disease in the future. For example, volunteer plants are rarely rogued and disposal of infected plants and tubers is inadequate, many are simply thrown on the headland and must be a potential source of future infection.

5. An analysis of available data suggests that potatoes are potentially one of the most profitable annual crops grown by farmers in the highlands of Kenya. Despite the potential profitability credit has not been made available for potato cultivation partly because of the risk of crop failure as a consequence of disease attacks. Late blight can be effectively controlled with fungicides but there is no control available for bacterial wilt.

6. One of the major constraints farmers face is a shortage of certified or clean seed for potato production. Certified seed is available only in small quantities and farmers rely on home saved or neighbours' tubers for planting material. Farmers reported that they only select tubers from disease-free fields, or seek seed from neighbours that they have observed `growing well' in the field. Those farmers forced to sell their entire crop at harvest to meet their cash needs, often have to rely on the market for seed for the next season. They often have no assurance that the seed is not infected, other than by physical examination, and are at risk of introducing bacterial wilt and other diseases to their farms.

7. The size of the tuber used for seed is also of concern. These tubers are often very small and farmers may be selecting for disease or for poor genetic characteristics.

8. Having established that a shortage of clean seed is a major constraint to potato cultivation and that bacterial wilt is a growing problem for farmers, it is safe to conclude that a biological control for bacterial wilt would play an important role in reducing the incidence of the disease, thereby leading to increased yields and assisting in the production of clean seed. Assuming the biocontrol agent were available in the form of a seed dressing it could be used on all seed at planting time. Alternatively, depending upon the price of the biocontrol preparation it could be targeted at:

* those plots being bulked up for seed by commercial seed producers and farmers; and

* those parts of the farm known to have soil borne *Ralstonia solanacearum*.

Much will depend upon the price of the biocontrol, the labour costs associated with its application (likely to be minimal if in the form of a powder) and the incidence of bacterial wilt and its effect on yield.

9. With regard to the potential value of a biocontrol agent for bacterial wilt the project should:

* proceed as rapidly as is practical to testing of the agent on farmers fields;

* seek to coordinate activities with the African Highlands Initiative (AHI), which has an interest in potato cultivation and IPM, and is shortly to begin diagnostic activities in Embu District (see Appendix 3);

* seek to collaborate with KARI and AHI on surveys, over three years to identify the incidence of bacterial wilt and the economic consequences of the disease in the major producing Districts in Kenya (AHI to provide data on the regional implications). The survey should seek to establish:

  - regional and seasonal differences in the occurrence of the disease;

  - the effects of altitude on disease outbreaks; and

  - farmer's strategies for managing bacterial wilt (IPM) and their efficacy.

10. Monitoring of 10 farmer's fields over a three year (6 seasons) period in all the major potato growing districts will provide evidence of the geographical spread of the disease in Kenya, its economic importance and those areas which should be targeted for assistance with information on IPM, biocontrol and seed production strategies.

11. AHI have agreed in principal to the drafting of a formal collaboration between their project and this project as they plan their second phase early in 1997. This provides Project ZA00885 with a opportunity to extend outputs beyond Kenya to the East African Region. The AHI has already undertaken survey and experimental work in Uganda. Ethiopia and Tanzania are also reported to suffer from bacterial wilt in potatoes (Lemaga, 1996) (personal communication Nancy Kaaya, HRTI, Tengeru, Arusha, Tanzania).

12. It proved premature to attempt to investigate the likely future demand for a biocontrol agent as the prevalence and geographical distribution of the disease has not been firmly established. When more data is available and a product is available for field testing it will be appropriate to undertake further work to establish the social and economic constraints to the adoption of the technology, the training needs of extension workers and farmers and the likely impact on the yields and incomes of potato producers.

2. VISIT BACKGROUND

13. Research at the International Mycological Institute has developed biological control agents effective against bacterial wilt disease under contained conditions (Project XO194). The outputs of this project are to be extended under Project ZA0085. `Biological control of bacterial wilt disease of potato in Kenya and Pakistan' to establish the agricultural potential of the biocontrol agents in Kenya.

14. A socio-economic study of the potential for the incorporation of biocontrol agents into IPM systems of smallholder farms in Kenya was included in the project to investigate the likely future adoption of any technology.

15. The earlier project identified that the African Highland Initiative (a collaborative project between national agricultural research systems (NARS) and international agricultural research centres (IARCs) currently managed by the International Centre for Research into Agroforestry (ICRAF) was undertaking research into potato production in the highlands of eastern and central Africa (see Appendix 3). It was therefore important to establish the nature of their programme of research and identify areas of common interest and means of collaboration, to avoid duplication of effort and resources. Collaboration would also provide opportunities to extend the results of this project throughout the highland areas of East and Central Africa.

3. TERMS OF REFERENCE

3.1 Objectives

16. The specific objectives of this study were to:

* assess the constraints to the uptake of biological control agents into integrated pest management (IPM) systems for smallholder potato production in Kenya;

* assemble production data for potatoes in Kenya and production trends over the past 10 years;

* assess the effects of bacterial wilt on yields of potatoes;

* seek information from producers on current management practices regarding potato cultivation, constraints to the expansion and development of potato cultivation and methods of control of bacterial wilt; and

* investigate the need throughout East Africa for control of bacterial wilt.

17. The wider objective was to inform the future progress of Project ZA0085 `Biological control of bacterial wilt disease of potato in Kenya and Pakistan'.

3.2 Terms of reference

18. a) Assemble production data for potatoes in Kenya (area cultivated, market prices, consumer demand, gross value of production) and production trends over the past 10 years.

b) Assess the effects of bacterial wilt on yields and the gross value of losses attributable to the disease.

c) Using PRA techniques, seek information from producers on:

* current management practices regarding potato cultivation;
* socio-economic constraints to the expansion and development of potato cultivation;
* methods of control of bacterial wilt, their cost and their effectiveness.

d) Examine the likely future uptake of the biocontrol agent, to include:

* methods of application and their costs (including labour costs);
* the purchase price of the agent and its likely effect on yields and market prices;
* social constraints to the adoption of the technology, including gender issues;
* the likely beneficiaries of the technology (i.e. smallholder farmers or large commercial producers).

e) Produce tentative budgets for potato production with and without the use of the bio-control agent.

f) Assess the training needs of farmers and extensionists for promotion of the technology.
g) Seek to collaborate with other local, national or international agencies working to promote potato cultivation in Kenya and East Africa.

3.3 Methodology

19. The socio-economic study involved discussion with appropriate parties in Kenya including representatives of:

* The Ministry of Agriculture, Livestock Development and Marketing (MALDM);
* Kenya Agricultural Research Institute (KARI);
* International Potato Centre (CIP) Regional Office;
* The African Highland Initiative (AHI); and
* potato producers in Embu, Meru, Nakuru and Nyandarua Districts.

20. Attempts were made to contact a random sample of farmers. Although extension workers and officers of the National Potato Research Centre were keen to visit contact, progressive or commercial farmers, efforts were made to also contact smaller less commercial producers. In total, semi-structured interviews were conducted with 25 male and female potato producers.

4. INTRODUCTION

21. The potato is one of the major food and cash crops in East and Central Africa. The highland areas of Ethiopia, Kenya and Uganda, for example, have a total area of 124,300 ha under potatoes and a total annual production of 826,000 tonnes which accounts for 68% of total production in the East-Central Africa region. Mean yields are low and are estimated to be in the region of 6-7 tonnes per hectare. Despite low, and in some cases, declining yields the area sown to potatoes is growing faster than any other food crop and is becoming the preferred food of both rural and urban populations. Low yields can be attributed to continuous cultivation and build-up of diseases, declining fertility, a shortage of clean seed and high yielding planting material. One of the most important diseases in the region is bacterial wilt.

22. After late blight, bacterial wilt is the most important disease of potato production in the East African Highlands. In Ethiopia it is reported to have spread to altitudes higher than 3000 metres. In Uganda it is said to account for a reduction in total yield of 30%. Potato production in East Africa is concentrated in the mid to high elevation areas which are characterized by high population density, small and often fragmented farms, intensive cultivation and declining soil fertility. These conditions often result in farmers continuously cultivating the same crop which provides an opportunity for the bacterial wilt bacterium to perpetuate. These conditions and a shortage of clean seed are providing the ideal environment for the spread of the disease which may become the most important threat to the sustainability of potato production in the near future. A combination of extension and technology is urgently required to reduce or eliminate bacterial wilt and to raise yields to ensure the food security and incomes of smallholder potato producers in the region.

23. The African Highlands Initiative (AHI) has recognised this threat and has begun a programme of research aimed at reducing or eliminating potato bacterial wilt and thereby increasing potato production. Most research to date has been undertaken in Uganda although NARs sub-projects have begun in Ethiopia and Kenya also. The main thrust of their research is an investigation of IPM techniques for controlling the disease. They are not conducting research into biocontrol agents for disease control. The research being undertaken for Project ZA0085 is therefore complementary to the work of the AHI and provides opportunities for research collaboration and dissemination of results and outputs to potato producers in East and Central Africa.

5. POTATO PRODUCTION IN KENYA

24. The potato is an important food and cash crop in Kenya. Production is confined to the highlands where ecological conditions are favourable, although cultivation is spreading to lower altitudes as cultivators migrate in search of land in more marginal environments. Production has grown steadily over recent decades as areas cultivated have expanded, although output per unit area may be falling. Yields therefore remain low and are estimated to be in the range of 7-10t/ha. The growth in potato production has been attributed to population increases in the Highlands, the potato's comparative advantage in terms of yield per hectare under highland agro-ecological conditions and its short vegetative cycle (Scott, 1993).

25. Potato cultivation is attractive to smallholders as it is a favoured food but also serves as a cash crop due to increasing demand throughout the country, particularly by the urban population. Increased production from potato cultivation is of crucial importance in a country with a population of 25.7 million (mid-1992 estimate) growing at a rate of 3.6% per annum (ODA, 1994). High population growth is compounded by the fact that only a small proportion of the country is highland and of high agricultural potential for arable production (18%).

26. Future development of the Kenyan Highlands is therefore constrained by population growth, serious shortages of land relative to demand and the inability of farmers to afford the level of inputs necessary for increased production. Arable land per head of the agricultural population declined from 0.18 ha/person in 1965 to 0.11 ha/person in 1988, so the best prospects for future growth are still by increasing physical yields through increased inputs of fertilisers, seeds, herbicides and pesticides.

27. Farmers in the Kenyan Highlands face the challenge of a number of important pests and diseases of potatoes. These include early and late blight, bacterial wilt and several viruses, the most important of which is the leaf roll virus. The incidence of disease may be increasing as production intensifies with the subdivision of agricultural holdings.

5.1 Area cultivated and output

28. The area of potatoes cultivated was estimated to be 96,000 hectares in 1995. The total estimated yield for the same year was 929,000 tonnes (Appendix 1) corresponding to an average yield of 10t/ha. Crissman et al (1993) reported yields varying from 5-20t/ha from surveys undertaken between 1975 and 1985.

29. Potatoes are popular above an altitude of 2,100m as the growth period is faster than maize and the total energy and production per hectare per day is higher. It is estimated that the net revenue per hectare for potatoes at these altitudes is double that for maize (Crissman et al, 1993).

30. There is a general consensus that potato production has expanded in recent decades as a result of an increase in the area planted to the crop rather than to the adoption of new technology (planting material, fertilisers and pesticides).

31. Potatoes are estimated to contribute 2% of the gross value of marketed agricultural production and in recent years the farm revenue from potatoes has been estimated to be around Ksh. 100 million, not accounting for local sales (Kinyae et al, 1996). Consumption of potatoes for subsistence may account for as much as 70% of total production.

5.2 Geographical distribution of potato cultivation

32. Potato production occurs in Central, Eastern and Rift Valley Provinces of Kenya. Most production occurs in the highlands, where, depending upon rainfall availability, two crops can be grown each year. Planting takes place generally at the beginning of the long rains in March/April and the short rains in October/November in the majority of potato cultivating Districts. In Meru District, an important potato producing zone on the northeast side of Mount Kenya, the intensity of the rainfall peaks is reverse that of other Districts. At higher altitudes, such as those found in Kinangop Division of Nyandurua District, frost can be a limiting factor to production.

5.3 Socio-economic characteristics of potato producers

33. The Kenyan Highlands are densely populated and have a high population growth rate which is exerting pressure on the land available for cultivation. Holding sizes are therefore declining as farms are subdivided with each generation. This pressure is keenly felt even in those areas of the former White Highlands where smallholdings were acquired by farmers after independence.

34. Potatoes are found on an estimated half million farms in the Kenyan highlands, most of which are smallholdings. Potatoes vary from being the most important arable cash crop to a minor subsistence crop on these farms. In some Districts, for example Embu, potatoes are primarily a subsistence crop, whereas in parts of Meru and Nyandarua they are the major cash crop for farmers cultivating at the higher altitudes. Crissman et al (1993) reported that in a survey of 60 farms in the range of 1-10 hectares undertaken in 1986, the average area under potato was 0.7 hectares. Of the potatoes produced on these farms 19% were saved for seed, 22% were consumed, 9% stored for future sale and half sold immediately after harvest.

35. As potatoes often play a dual role as cash and food crops both men and women are involved in their production. In Kenya most subsistence potato farmers are women, as they have the responsibility for household food production. Where the crop is grown for commercial reasons men are involved in its cultivation but women also produce for the market.

36. Subdivision of holdings is reported to be one of the reasons why farmers are increasingly suffering the effects of increased pest and disease attacks on their potato crops. As farm size declines so it becomes difficult for farmers to rotate their potato crops to prevent disease outbreaks. Although it is technically feasible to continue to rotate, farmers are then unable to grow sufficient potatoes for their subsistence needs and for sale. They continue therefore to plant the area they need to satisfy their subsistence and cash needs. Careful husbandry and the application of fungicides and insecticides will be essential if yields of potatoes are to be maintained under these conditions. The provision of clean or certified seed may be another prerequisite for future potato production.

5.4 Potato cultivation and marketing

37. Methods of cultivation vary between Districts reflecting local ecological conditions, particularly the quantity and distribution of rainfall. In Kiambu District, for example, potatoes are planted in both April (harvested in August) and October (harvested in February), often on the same plot. On the smaller farms (less than 2 ha) continuous planting of the same area was reported for 3 years or 6 seasons. In Meru District at higher elevations potatoes are the major cash and food crop and large contiguous areas of potatoes can be seen growing. Under these conditions poor management practices on one farm (i.e. non-spraying for late blight) could easily affect the yields of a large number of producers. Farmers, however, recognise the value of spraying and disasters appear to have been averted. Even the smallest and poorest producers were observed spraying their fields during conditions favourable to late blight.

38. Marketing does not present difficulties for farmers in the major potato producing areas although farmers have little market information or control over the price they receive for their produce. Traders play a key role in marketing of the potato harvest. Farmers prefer where possible to sell direct to consumers (e.g. small hotels) where the prices are higher, although most are forced to sell to traders immediately after harvest. Where potatoes are not the predominant annual crop (e.g. Embu District) marketing may be more difficult, although the primary aim of cultivation in these areas is to provide for subsistence.

39. The demand for chipping potatoes in the urban areas is growing for both home consumption and the restaurant trade (tourist and local). Hoteliers prefer large oval shaped tubers with shallow eyes for their chipping machines. Farmers planting dates are influenced by the market, particularly in those Districts with well distributed rainfall. Traders also influence the type of variety planted with farmers reporting that several varieties were grown specifically for the market, these varieties being different to those preferred for home consumption.

40. Seasonal price variations can be large with differences of Ksh600 per 120kg bag being reported for 1996. At harvest in Nyandarua District during March prices fell as low as Ksh400/bag rising to Ksh1,000 during November. Despite the advantages of storage few farmers keep potatoes for long periods. Potatoes were reported to deteriorate quickly and farmers fear that if kept the tubers may begin to display signs of blight or bacterial wilt in the store rendering them unsaleable. The only potatoes stored are those required for seed and subsistence, although some subsistence needs are met from volunteers (and probably some seed needs also).

5.4.1 Yields and rotations

41. Table 1. demonstrates the wide variations in yields experienced by potato producers in Kenya. Yield is very closely correlated with the purchase of inputs such as fertilisers and fungicides and the use of clean seed (if available).

42. Farmers of all sizes do attempt some form of rotation of their crops and the technical understanding of the principle appears to be high. However, most farmers interviewed during the course of this study indicated that they had experienced bacterial wilt and the rotations described in Table 1 are not therefore effective in combatting the problem (although the source of the infection could be either the seed or the soil). It is interesting to note that most farmers grow potatoes at least once a year.

5.5 Returns to smallholder potato production

43. The data in Table 2 demonstrates the potential profitability of potato production in Meru District. When the gross margins for potatoes are compared with those for other crops in the District, it becomes apparent that potatoes are potentially more profitable than any other crop (see Appendix 2).

44. Farmer's actual returns will in most circumstances be much lower than the lowest yield outlined in the Table 2. A farmer in Meru District reported that for each 10 bags of harvested potatoes:

* 2 are consumed by the household;

* 2 are kept for seed for the following crop; and

* 6 are sold as ware.

45. Profitability of potato production can also be severely compromised by disease attacks. Most farmers do appreciate the importance of preventative spraying with fungicides to prevent late blight attacks. Virus infections also reduce yields but the effect of these diseases is generally cumulative over a number of seasons. Bacterial Wilt probably poses the greatest threat to yields at the present time as there are no means of controlling the disease other than by careful management, i.e. rotation, fallowing, resistant cultivars, clean seed etc. Most farmers, particularly the poorest, find it impossible under current circumstances to undertake these management practices.

46. This may help to account for the reluctance of the Agricultural Finance Corporation (AFC) to offer credit for potato production. Despite potentially being the highest earning arable crop for farmers in Meru District the high risk associated with crop failure has prevented credit facilities being made available to farmers. Methods or management strategies to control bacterial wilt will therefore benefit the farmer in terms of increased or more stable yields but will also contribute to the development of potato cultivation generally by reducing risks associated with their cultivation, opening up commercial opportunities for smallholder farmers.

Table 1. Rotations and yields for different farm sizes in five potato producing Districts of Kenya

District	Rotation	Farm size (ha)	Yield (t/ha)
Kiambu	Potato - Maize – Beans – Potato	16.6	32
	Potato - Maize – Potato – Maize	6.5	15
	Potato - Potato – Potato	1.2	14
Embu	Potato - Maize/beans - Potato – Maize/beans	1.2	10
	Potato – Cabbages - Potato – Cabbages	2.7	20
	Potato – Cabbages - Potato – Cabbages	1.2	6
Meru	Potato - Maize – Potato – Maize	2.0	22
	Potato - Potato - Potato - Maize (10 months)	0.4	9
	Potato - Maize/beans (10 months) – Potato	2.0	16
	Potato - Maize (10 months) – Potato	2.8	10
(irrigated)	Potato - French beans - Cabbage – Potato	1.2	20
Nakuru			
	Potato - Potato - Maize (10 months)	4.0	20
	Potato - Cabbage - Potato – Cabbage	0.4	8
	Potato - Beans - Potato - Maize (10 months)	1.2	10
Nyandurua			
	Potato - Potato - Cabbage – Maize	6.0	14
	Potato - Cabbage - Potato – Cabbage	1.6	7
	Potato - Peas - Maize – Cabbage	1.2	4

Source: Socio-economic survey, November 1996

Table 2. One hectare crop budget for potatoes at three levels of production (1995 prices, Meru District)

	Low	Medium	High
OUTPUT			
Yield (kg)	12,500	15,000	25,000
Gross Output (KSh)	187,500	225,000	375,000
INPUTS			
Di-Ammonium Phosphate (KSh)	8,250	11,000	13,750
Manure	10,000	15,000	20,000
Dithane M45 (KSh)	3,750	3,750	3,750
Ridomil (KSh)	-	-	1,500
Gunny sacks (KSh)	5,000	6,000	10,000
Land preparation (days)	20	20	20
Sowing (days)	20	20	20
Spraying (days)	50	50	60
Weeding (days)	50	50	80
Harvesting (days)	30	40	50
Handling (days)	10	12	20
Cost of labour (KSh)	10,800	11,520	15,000
Total variable costs	37,800	47,270	64,000
GROSS MARGIN	**149,700**	**177,730**	**311,000**
RETURN/DAY OF LABOUR	**832**	**926**	**1,244**

Source: District Agricultural Office, Meru

5.6 The extent of bacterial wilt in Kenya

47. Bacterial wilt in potatoes is caused by *Ralstonia solanacearum* (syn. *Pseudomonas solanacearum* race 3). This race has a narrow host range, attacking mostly potatoes, but under high disease inoculum it also attacks tomatoes, eggplants and solanaceous weeds.

48. Bacterial wilt of potatoes is perhaps the most important biotic constraint to potato production in the Kenyan Highlands, after late blight. It was first reported in Kenya in 1940 and since then has spread to most potato growing areas. It is suspected that latently infected tubers may have played a major role in the spread of wilt (Nyangeri et al. 1984). The incidence of wilt is greatest at altitudes between 1500m and 2000m. It is reported to be spreading to higher altitudes, from which it was previously absent. Crop losses attributed to wilt have been reported to be 50% or occasionally as high as 75% on individual fields (Ajanga, 1993). There have been no estimates of its effect upon national yields or the financial or economic consequences of the disease.

49. The disease appears to be location specific as the unpublished data in Table 3 indicates. This suggests that wilt is less of a problem in Meru District than Laikipia, for example.

Table 3. Potato diseases reported by farmers in three Districts of Kenya (%)

District	Blight	PLRV	Bacterial Wilt
Nyandarua	89	2	39
Meru	100	31	2
Laikipia	82	6	71

Source: Kinyae, P. (unpublished data)

50. Continuous cultivation of potatoes provides an opportunity for the bacterium to perpetuate and it is reported that small farmers, wishing to have a crop of potatoes in every season are unable or unwilling to rotate their crops. These conditions coupled with the use of infected seed tubers from previous seasons threatens the viability of potato production, particularly on smallholdings. Larger farmers have more opportunities to rotate potato crops but still encounter the disease if they use home-saved seed or seed from their neighbours.

51. Other farmer cultural practices contribute to the spread of the disease. For example, volunteer plants are rarely rogued (they are used for subsistence purposes) and may be sources of infection, and disposal of infected plants and tubers is inadequate, many are simply thrown on the headland and must therefore be a potential source of future infection.

5.7 Control measures

5.7.1 Integrated Pest Management

52. The use of IPM is considered to be one of the most effective methods of control for the smallholder producer. IPM is reported to control the disease to acceptable levels. It requires a combination of techniques such as the use of:

* disease free seed tubers;
* crop rotation or fallowing; and
* rogueing.

53. A combination of these techniques has been demonstrated to reduce bacterial wilt on experimental plots or on-farm trials in India, Mauritius, Peru, Burundi and Uganda (Lemaga, 1996), in particular the use of crop rotation and disease free seed tubers. Unfortunately in Kenya crop rotation is not well practised by smallholders and there is insufficient clean seed available for cultivators to combat disease problems in this way.

54. Although CIP has played a role in the development and distribution of varieties with improved resistance to bacterial wilt in Central and Eastern Africa, there are no reliable varieties currently available in Kenya. Breeding within the country has concentrated on

breeding for tolerance to late blight, an economically more important disease (until recently). Although efforts are being made to breed tolerance to bacterial wilt elsewhere (CIP, USA), varieties suitable to the environmental conditions found in the Kenyan Highlands are unlikely to be available for some time.

55. Disease free tubers or certified seed have been available in small quantities in the past but may now be in decline as the major producer and supplier, ADC, no longer has sufficient land to produce seed potatoes. The emphasis is changing to the use of outgrowers, with basic disease free seed being made available from the National Potato Research Centre, Tigoni, CIP, and the ADC. However, it will be many years before these schemes will be able to supply the majority of potato growers in the Kenyan Highlands.

5.7.2 Biological control

56. Although a combination of IPM methods may help to control the effects of bacterial wilt, none of these measures can be completely successful (i.e. eradicate the disease). Biological control measures could therefore play an important role in IPM strategies.

57. Given that the provision of clean or certified seed to all potato producers in Kenya is unattainable in the near future and the use of rotation is constrained by holding size, biological control of bacterial wilt, combined with other management measures may be the only realistic strategy to maintain or improve yields.

58. Farmers in the highlands of Kenya are responsive to new technology that they perceive to be beneficial to their farming activities. The use of fungicides and knapsack sprayers is widespread for late blight control. It seems unlikely therefore that a biocontrol product would meet resistance from farmers, although price will be a determining factor as will the degree to which they regard bacterial wilt as a major constraint to potato production.

59. Farmers are unlikely to be able to appreciate fully the issues involved with the use of a genetically modified organisms on their farms, and are likely to be more concerned about the effectiveness of biocontrol agents and their contribution to income and food security. Positive involvement and guidance from Kenyan biosafety legislation will be central to this aspect.

5.8 Choice of potato varieties by smallholders in Kenya

60. Farmers evaluate and choose potato varieties differently to agricultural scientists. They have different priorities and may often have limited access to information or extension to enable them to make informed choices. Potato farmers in Kenya prefer above all varieties for which there is a market demand. Other factors, some of which improve marketability include early maturity, good table qualities (amenable to traditional methods of food production), good storage life, good late blight resistance and low dormancy (for seed). The preferred varieties in the various Districts visited during this survey are outlined in Table 4.

61. Different farm sizes evaluate variety according to different criteria. Small farmers producing mostly for home consumption may prefer blight resistant varieties, not wishing to expend cash on fungicides. Larger farmers producing for the market may judge the best variety to be those with large tuber sizes, higher yields etc. The demands of the market also influence the variety farmers will grow. Kerrs Pink, widely grown in Meru District is renowned for its marketability.

Table 4. Potato varieties grown by farmers in 5 Districts of Kenya

District	Variety reported by farmers
Kiambu	Tigoni (new variety from NPRC distributed to contact farmers) Nyayo Kenya Baraka
Embu	Nyayo Romano Anett Kerrs Pink
Meru	Kerrs Pink Ngure
Nakuru	Amin (introduced from Uganda) Desiree Meru (a CIP clone not officially released) Nyayo Susanna Dutch Robjn Roslin Tana
Nyandarua	Roslin Tana Tana Kamade

Source: Socio-economic survey, November 1996

62. Potato varieties are involuntarily eliminated by disease, seed degeneration and market pressures. Most farmers maintain their own seed or purchase it from neighbours and continue planting this seed until problems develop. Dramatic declines in yield caused by the accumulation of diseases transmitted to future generations by clonal reproduction (viruses, blight and bacterial wilt) can dramatically reduce productivity over a short period of time. Farmers with little available cash or access to credit are unwilling to purchase seed potatoes when they can produce their own at minimal cost. For the majority there is no alternative but to save their own seed.

5.9 Sources of seed potato

63. The National Potato Research Centre (NPRC) produces basic seed which is provided to the Agricultural Development Centre (ADC) for multiplying into certified seed. CIP also assists

the programme through the contribution of germplasm with superior traits. Germplasm evaluation takes place at Regional Research Centres (RRCs).

64. At present the only source of certified potato seed is ADC, a parastatal based at Molo. Although the NPRC (at Tigoni), also distributes disease free seed to farmers for testing, this is in very small quantities and has little impact on the availability of certified seed in

Kenya[11]. The role of NPRC in the production of certified seed is therefore limited to the identification and breeding of new planting material which may be bulked to a certain extent on sub-stations before it is handed over to ADC for multiplication.

65. During 1995 ADC Molo produced 22,000 50kg bags of certified seed for sale to farmers via the Kenya Cooperative Grain Growers Union (KGCCU) stores. At a seed rate of 2 tonnes per hectare this is sufficient to plant only 550 hectares or less than 1% of the total area planted to potatoes in Kenya.

66. ADC has until recently multiplied seed on its own farms. Several of these have been subdivided and it is now seeking outgrowers to maintain output. This centralised seed production scheme was recently criticised by Kinyae et al (1996) for the following shortcomings:

* insufficient production of high quality seed of the desired (by farmers and consumers) varieties; and

* a shortage of outgrowers with the required characteristics and training to maintain quality.

67. The demand for certified seed far outstrips the supply and commercially oriented farmers who understand the benefits of planting certified seed will often find that it is unavailable.

68. The Government of Kenya plans to liberalise the production of certified potato seed in the near future as part of its programme of privatisation. It is not as yet clear whether large scale commercial producers will come forward to improve the supply of seed potatoes throughout the major growing areas. Another development is the interest of two NGOs, World Vision and Plan International in the production of seed potatoes in Meru District.

69. These initiatives should improve the supply of seed potatoes. ADC will continue to play an important role in the multiplication of basic seed provided by NPRC and the provision of material for bulking by other producers.

70. Given the current limitations of the potato seed producing system in Kenya the local market or home-saved seed is the only source of planting material for the majority of farmers in the Kenyan Highlands. Only those farmers in close proximity to growers of certified seed seem guaranteed a source of seed every season.

71. Crissman (1989) reported that farmers more often than not, look for new varieties rather than for clean seed for existing varieties grown. She explained that this is because there is a lack of association of disease with seed degeneration and declining yields are associated with a `lack of robustness' of the variety rather than the seed. The data collected during this survey contradicts that of Crissman. Almost all farmers interviewed explained that if they experienced a severe attack of disease (either bacterial wilt or viruses) they would seek to purchase new seed for the following season. Alternatively they would only select seed from that area of the field that was not affected by the disease. Farmers will therefore continue to plant the same variety or varieties from year to year but will seek clean seed as and when required. However, unless that seed is certified there is no guarantee that it will be free from disease.

[11] This practice must be questioned because instead of acting as multipliers of seed, farmers growing these new varieties sell much of their production as ware keeping only sufficient seed for their own use.

72. Farmers also explained how they would often `target' neighbouring farmers who had been fortunate enough to purchase some certified seed that season. If the farmer had sufficient quantity of ware potatoes from this seed it would be in demand from other farmers as it is generally recognised that these potatoes will have a better health status than their own, and will therefore be potentially higher yielding. It also seems that those farmers who purchase certified seed often do so in small quantities with the intention of bulking up seed for future seasons.

73. The advantages of certified seed appear to be widely recognised, although most farmers complain that the seed is too expensive. However, when comparisons were made with the prices paid by farmers to their neighbours for seed they were very similar to the prices charged by ADC (around Ksh1,500/100kg[12]). However, farmers rarely buy sufficient seed for all their needs, either source would be too expensive. They prefer to multiply their own seed if possible from the small quantities purchased either from ADC or neighbours. This may be done haphazardly, within another crop, and rarely on seed multiplication plots specifically set aside for this purpose.

5.9.1 Seed size

74. Farmers met during the course of this survey described their cultivation practices and demonstrated the size and type of potatoes that were saved or purchased for seed. As ware potatoes are valuable (for sale) the very smallest tubers are used for seed. These are generally much smaller than those that are recommended for seed use by NPRC (35-65mm diameter). There is a danger therefore that farmers may be selecting for disease by choosing the smallest tubers and/or selecting for poor genetic characteristics. This may be particularly true for those farmers who must resort to local markets for their seed. Farmers reported, that where possible they saved seed selected from healthy crops. When seed is purchased from neighbours this is generally the result of having seen the crop in the field, (and noted its health and vigour) or advance knowledge that a particular farmer has purchased certified seed in the previous season. Under these circumstances the danger of selecting for disease is reduced.

6. CONCLUSIONS

75. There are several major constraints to the future development of potato production in the highlands of Kenya. These are:

* declining farm size as a result of subdivision of holdings which leads to poor rotational management practices as farmers plant much of their holdings to potatoes to guarantee subsistence and income;

* the unavailability of clean or certified seed for potato producers at affordable prices to enable them to plant material that is not diseased; and

* poor credit supply for potato production which prevents farmers from investing in seed, fertilisers and pesticides. At present their are no AFC loans available for potato cultivation despite the potential profitability of the crop.

76. Having recognised that a shortage of clean seed is a major constraint to potato production two NGOs have become involved in promoting seed production at higher

[12] ADC currently charges Ksh850/50kg bag of certified seed (size 1 >60mm), Ksh615/50kg bag of certified seed (size 2 45-60mm) and Ksh200/50kg bag for undergrades.

altitudes in Meru District. However, for the foreseeable future farmers will continue to select their own seed, as this is the cheapest option and in many cases the only option open to them. This strategy appears to function reasonably well because:

* farmers recognise the disease status of their own crops;

* farmers therefore select from those portions of the crop that are, in their opinion, disease free;

* they grow several varieties in many cases, even where these are volunteers, and have a wide range of potential seed to choose from; and

* fungicides are widely used to control late blight which may prevent disease transmission via the tubers.

77. Many farmers are only interested in purchasing small quantities of certified seed, as this is all they believe they can afford. They do however, purchase larger volumes of seed from friends and neighbours at similar prices charged for certified seed by ADC. Seed is not purchased every season and may last a farmer 4-6 seasons before new planting material is required.

78. Those farmers who are unable to save their own seed as they sell at harvest to meet their cash needs or consume all their ware potatoes (i.e. the poorest) are most likely to have serious outbreaks of bacterial wilt as they purchase their seed at markets during the planting season. The source and disease status of these seed potatoes will be unknown. The potatoes will also often be small, and may therefore have been produced by diseased plants. Buying small seed potatoes from unknown sources is highly risky. One farmer reported during the survey that last season he bought a whole bag of such seed and harvested nothing (the cause of this failure was probably bacterial wilt, as farmers experiencing late blight are usually able to salvage some tubers for consumption or sale).

79. As farmers select their own seed a biocontrol seed dressing could play a valuable role in reducing the incidence of bacterial wilt. It could be used routinely as a seed dressing at planting, on all material (i.e. bought, home saved, certified etc.). Alternatively, depending upon the price of the biocontrol preparation it could be targeted at:

* those plots being bulked up for seed, both by commercial suppliers of seed, and small-scale on-farm multiplication; and

* those soils known not to have had sufficient break from potatoes to be free from soil borne *Ralstonia solanacearum*.

80. The demand for biocontrol is likely to extend beyond Kenya to the East African region as a whole. Socio-economic and environmental conditions in other East African countries are similar to those of Kenya. Bacterial wilt poses a threat to potato production in at least 3 other countries in the region. Collaboration with the AHI will provide opportunities to extend field testing of biocontrol agents and in the long term the outputs of this research project.

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APPENDIX 1 Potato production in Kenya 1961-92

Year	Production (000tons)	Area (000Ha)	Yields (t/ha)
1961	194	27	7
1962	194	27	7
1963	195	28	7
1964	190	27	7
1965	190	27	7
1966	195	27	7
1967	195	28	7
1968	195	28	7
1969	200	27	7
1970	218	31	7
1971	200	28	7
1972	230	32	7
1973	260	37	7
1974	280	40	7
1975	333	46	7
1976	342	47	7
1977	341	47	7
1978	361	48	7
1979	360	49	7
1980	350	48	8
1981	522	63	7
1982	640	76	8
1983	600	78	8
1984	633	72	9
1985	650	80	8
1986	627	69	9
1987	596	65	9
1988	790	79	10
1989	816	87	9
1990	779	88	9
1991	988	87	11
1992	633	68	9
1993[13]	1033	56	18
1994	806	83	10
1995	929	96	10

Source: Ministry of Agriculture and Livestock Development and Marketing-Crop Division

[13] It is unclear why production should increase by a factor of two between 1992 and 1993

APPENDIX 2 Gross margins for various crops in Meru District (1995 prices)

	Potato	Onions	Wheat	Coffee	Millet	Tea	Maize	Bananas	French Beans	Cabbages	Tomatoes
Yield (kg/ha)	15,000	10,000	2,250	5,200	1,500	12,000	2,430	8,000	3,000	10,000 (heads)	12,500
Gross Output (KSh)	225,000	100,000	33,750	52,000	30,000	159,600	24,300	48,000	75,000	50,000	62,500
Variable costs (KSh)	47,270	44,350	17,190	30,100	10,430	68,862	8,905	19,700	38,500	15,905	20,950
Gross Margin (KSh/ha)	**177,730**	**55,650**	**16,560**	**21,900**	**19,570**	**90,738**	**15,395**	**28,300**	**36,500**	**34,095**	**41,550**
Return/day of labour (KSh)	**926**	**213**	**184**	**540**	**210**	**140**	**282**	**392**	**366**	**559**	**344**

Source: District Agricultural Office, Meru.

APPENDIX 3 The African Highlands Initiative (AHI)

The African Highlands Initiative is a response to the concern of NARS and IARCs that decades of agricultural research in the high-potential but densely populated highlands of east and central Africa has not produced commensurate results in terms of improved and sustainable land productivity. The overall goal of AHI is therefore to sustainably improve and enhance land productivity within intensive land-use systems by working with farmers to evolve policy and technologies that increase agricultural production while maintaining the quality of the natural resource base. This goal will be achieved through:

* the development of a regional programme of research on the management of natural resources;

* strengthening the capacity of NARS to deal with problems related to natural resource management; and

* cooperation between NARS in the region and between NARS and IARCs and other regional research and extension programmes dealing with natural resources research.

AHI will support and collaborate with programmes covering various issues of agricultural production in the highlands, but will focus on the problem of enhancing land sustainable productivity in intensive land-use systems through two main research themes:

* maintenance and improvement of soil fertility; and

* natural resource management strategies for effective and sustainable plant protection.

Three supporting themes have been identified as key features of the initiative:

* diagnostic and socioeconomic studies;

* training, and

* information and documentation services.

AHI operates at three levels:

* national teams based at selected zonal stations;

* Regional Coordination by Technical Advisory Panels; and

* the governing body or legal authority for the initiative with overall responsibility, ASARECA.

The AHI has a research programme to investigate the Integrated Pest Management of Bacterial Wilt, which has a regional focus. To date most of the research work has been undertaken in Uganda.

Source: Wang'ati F. 1994 The African Highlands Initiative: a conceptual framework. Nairobi, Kenya: International Centre for Research in Agroforestry

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY
P.O. BOX 30623
NAIROBI

APPLICATION TO INTRODUCE OR RELEASE GENETICALLY MODIFIED ORGANISMS (GMOs)

NAME OF APPLICANT: Dr Gilbert Kibata

ADDRESS: Kenya Agricultural Research Institute, National Agricultural Research Laboratories, PO Box 14733, Nairobi, Kenya.

TELEPHONE NO: 444031/32, 443956 **Fax:** 443956 **E-mail: cpp@arcc.or.ke**

PREAMBLE: *You are required to answer as many questions as possible to facilitate evaluation of the application. Where you fail to given an answer, give an explanation.*

State all the institutions involved in this work their roles, physical addresses and the contact of the principal investigator.

Kenya Agricultural Research Institute, Nairobi, Kenya.

Principal Researcher: Kinyua Z. Murimi, KARI NARL, PO Box 14733, Nairobi, Kenya. Tel: 444031/32, 443956.

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State the source of funds for the entire work.

UK government; Department for International Development

Applicants should be prepared to provide further information as requested by National Biosafety Committee (NBC).

Applicants are informed that assessments of the application will bear some financial cost.

PART I CORE QUESTIONS

A. Intended Purpose of Planned Introduction

1. a) What are the aims and objectives of the proposal?

Bacterial wilt (*Ralstonia solanacearum*)of potato is a serious constraint to potato production in Kenya. No effective control practices have been found to date, however, recent research has indicated that control may be achieved by biological control with non-pathogenic mutants of the wild type pathogen.

Under funding from the UK government (DFID), a biocontrol agent (BCA) has been developed by CABI Bioscience and in collaboration with KARI for use in Kenya to control bacterial wilt (race 3 biovar 2a) on potato. The BCA is a non-pathogenic mutant of the wild type organism that has been induced through genetic engineering. Two gene manipulation approaches have been used: 1) the insertion of foreign DNA (an omega cassette) and 2) the deletion of genomic DNA (through insertion and forced eviction of the *sacB* gene). These approaches are described in detail herein and the BCAs developed form the subject of this application.

Initial assessments on the efficacy of the BCAs have already been undertaken in the UK and South Africa and have shown consistent levels of protection in the order of 30-50%. Additional research is now required to establish the efficacy of the BCAs against bacterial wilt of potato in naturally infested soils of Kenya and to substantiate its benign environmental impact (other than controlling bacterial wilt).

b) What is the intended eventual use(s) of the products?

The BCA will be suitable for use by smallhold farmers cultivating potato in regions where bacterial wilt imposes a constraint on productivity.

c) How do you propose to dispose of the GMOs?

In the initial stages of the research the GMO will be assessed under contained-use specification. No field release is intended until results substantiate the BCAs efficacy and benign nature. During the initial screenhouse based experimental phase, all contaminated plant material will be autoclaved and soil will be heat sterilized. In the event of a field trial then the release area will be designated a quarantine zone and after the assessment will be left fallow for a minimum of 5 years: a period of time that can be expected to see the extinction of the BCA through natural decline. Greater detail is provided in Question 25.

B. Location

2. a) Describe the size of the proposed GMO introduction.

The GMO introduction will be on a small scale: inoculum quantities will not exceed 10 litres at 10^{10}cfu ml^{-1}.

b) Describe the area of land to be used, and its location, where relevant include a map.

It is proposed that the research be located at the National Agricultural Research Laboratories (NARL) of the Kenya Agricultural Research Institute (KARI) within the Plant Pathology Section. Culturing work will be undertaken within the Bacteriology laboratory and plant assessments undertaken in raised soil beds within the screenhouse. If the

research progresses to a field trial then this will be undertaken within a 10 x 10m plot of land within the quarantine bacterial wilt research site at NARL.

3. a) What are the reasons for the choice of locations?

It is recommended that the work be located at NARL Plant Pathology Section as at this location all the necessary facilities are present, thus centralizing the research activities to one site and minimize movement of the biocontrol agent. To the applicants knowledge no other site within Kenya can provide all the required facilities of this work within such close proximity.

b) Describe in detail the relevant features of the physical environment, particularly those which may minimize or exacerbate any undesirable effects.

Plant Pathology - Bacteriology laboratory:

- The laboratory is structurally sound, and away from obvious environmental hazards, such as overhanging branches of trees.
- The laboratory can be clearly marked as having restricted access and containing a biological hazard.
- The laboratory can be locked.

Screenhouse:

- The screenhouse is structurally sound, and away from obvious environmental hazards, such as overhanging branches of trees.
- The screenhouse can be clearly marked as having restricted access and containing a biological hazard.
- The screenhouse can be locked.
- The screenhouse has a sealed floor.
- The screenhouse is insect proof (24 hole/inch mesh).

Field trial site.

- The field trial site will be bordered with a double fence of 1.5m around a ditch of 0.5m.
- The field trial site will be clearly marked as having restricted access and containing a biological hazard.
- Access to the field trial site will be via two lockable doors that form a enclosed vestibule.

c) How close is the site of human population centres, centres of agricultural activity, or the habitat biota that might affect, or be affected by, the planned introduction?

NARL is within 1km of a population centre, and undertakes numerous agricultural research activities. It is approximately 20km from any major potato production region.

C. Species to be introduced

4. What is the species or organisms to be introduced? Give information on the strain, cultivar, population and specify whether clonal or heterogeneous.

The BCAs (non-pathogenic mutants) are derived from *R. solanacearum* race 3 biovar 2a isolates indigenous to Kenya that have been characterised by genomic fingerprinting using high resolution methods. These studies have shown the *R. solanacearum* population of Kenya to be broadly homogenous with a dominant clonal line and a number of closely related variants (10). The biocontrol agents are derived from isolates representative of these clonal lines. Broader studies focusing on race 3 isolates of world-wide origins have shown the race 3 isolates in Kenya to be typical of a sub-set of *R. solanacearum* race 3 isolates of South America, the centre of genetic diversity and assumed centre of origin of race 3 (3,10). This sub-set is prevalent outside of South America to the exclusion of the other populations.

5. What is the origin of the exogenous hereditary material?

Method 1 (Developed by INRA, France):

Non-pathogenicity is induced by the targeted homologous transformation of the wild type *R. solanacearum* isolate by an omega cassette into the *hrp*O gene of the *hrp* gene cluster (hypersensitivity response and pathogenicity genes) (5). The omega cassette comprises an omega interposon flanked by regions of the *hrp* gene cluster necessary to facilitate homologous transformation and is maintained in a derivative of the bluescript vector housed in *E. coli* (5). The omega cassette encodes for kanamycin resistance.

Method 2 (developed by CABI Bioscience).

The BCAs developed by this method contain no exogenous DNA. This method causes a random deletion mutation induced by the sequential introduction and forced eviction of the *sacB* gene of *Bacillus subtilis* (8). The *sacB* gene is part of the *nptI-sacB-sacR* cassette and is housed in *E. coli* strain (S17-1) (8) on the plasmid pMH1701 which is a derivative of the transposon Tn5 carrying the *mob* site (*oriT*) of plasmid RP4 (9).

Does the exogenous hereditary material come from an organism that causes disease or other ill-health in humans, plants or animals? If so, what are the effects?

No

6. Is the Genetically Modified Organism (GMO) capable of causing disease or other ill-health in humans, plants or animals? If so, what are these effects?

No

7. Cite the scientific truths and proofs carried on similar work and safety measures put in place.

Under UK Health and Safety Executive guidelines the BCAs were assessed as requiring contained-use level 1 operational procedures.

The BCAs have also been assessed under South African biosafety legislation (SAGENE) and accepted for experimental use under contained-use conditions.

8. Describe in detail any Environmental Impact Assessment (EIA) studies carried on similar work.

Analogous research has been undertaken by Dr. André Trigalet of the Institute Nationale de la Recherche Agronomique, France on Race 1 of bacterial wilt affecting tomato. This

research has progressed to a field release in Guadeloupe. Environmental assessments over 2 years have not recorded any detrimental environmental.

D. Habitat and ecology

9. a) What is the natural habitat of the parent organism and its range?

Tropical, sub-tropical and warm temperate regions world-wide. *Ralstonia solanacearum* is a pathogen of numerous crops, however, *R. solanacearum* biovar 2a (the biovar considered here) has a host range restricted to potato, and to a lessor extent, tomato.

b) Where was the parent organism originally isolated?

Highland regions of Kenya.

c) What is the distribution of the parent organism in Kenya?

The parent organism is common to highland areas of Kenya, notably those regions that cultivate potato.

d) Is the parent organism already present at or near the site of the planned GMO introduction(s)?

Yes: within a quarantine zone used for research at the NARL.

e) Is the parent organism exotic to Kenya?

No

f) *Are there any wild relatives of the GMO in Kenya? If so provide information on possibilities of cross hybridization?*

The GMO is derived from the wild type pathogen which is indigenous to Kenya. Environmental impact assessments and other research have not shown any cross hybridisation.

10.) Are there any known predators or parasites of the organism in Kenya? If so, describe.

Numerous soil bacteria will be antagonistic to the BCAs. Examples would include Fluorescent Pseudomonads.

11. Could the introduction of the GMO prejudice any beneficial function of the parent organism or related organisms in the environment?

No.

12. Describe any anticipated direct or indirect ecological effects of the introduction.

It is anticipated that the release of the GMO would reduce bacterial wilt within potato stands and thus have the beneficial affect of increasing ware productivity.

E. Genetics of the GMO

13. What genetic modification has been made? Give a detailed description of the steps undertaken.

The non-pathogenic mutants are induced by one of 2 methods:

Method 1 (Developed by INRA):

Induced by the targeted homologous transformation of the wild type *R. solanacearum* isolate by an omega cassette into the *hrp*O gene of the *hrp* gene cluster (hypersensitivity response and pathogenicity genes) (5). The wild and transformed cells differ only by the inclusion of the omega cassette, which prevents the expression of the *hrp* genes. The frequency of transduction was observed at less than 1 in 10^{12}.

Method 2 (developed by CABI Bioscience).

The method causes a random deletion mutation induced by the sequential introduction and forced eviction of the *sacB* gene of *Bacillus subtilis* (8). The deletion mutant is free of foreign DNA. The method gives rise to an indefinite number of undefined mutants that require screening for non-pathogenicity.

The *sacB* gene encodes for the enzyme levansucrase which catalyses the hydrolysis of sucrose to levan. Levansucrase is toxic to *R. solanacearum*, and many other Gram negative bacteria. Growth on sucrose containing medium therefore indicates loss of the *sacB* gene. Verification of the loss of the *nptI-sacB-sacR* cassette is confirmed by sensitivity to the antibiotic tetracycline. For the purpose of conjugation, active cultures of *R. solanacearum* and *E. coli* are cultured together for 24 hours prior to plating out on selective medium. Tetracycline resistant colonies are then plated out on sucrose containing medium for the identification of deletion mutants. The frequency of these events *in vitro* was observed at less than 1 in 10^{9} and 1 in 10^{11}, respectively.

14. Does the GMO have a potentially unstable genotype?

Method 1: No: In the example of the omega cassette, this has been fully characterised and developed with a view to making it an appropriate vehicle for mutagenesis studies where an environmental release of the mutated organism is intended (4).

Method 2: Not known.

15. a) To what extent is the genetic modification characterised?

Method 1: The omega cassette inserts into the wild type *Ralstonia solanacearum* through a homologous transformation event into the *hrp*O gene of the *hrp* gene cluster (hypersensitivity response and pathogenicity genes) (5). The fidelity of this insertion was proven by RFLP DNA hybridisation analysis using a DNA probe (pVir2) derived from the *hrp* region (unpublished data). The wild and transformed cells differ only by the inclusion of the omega cassette, which prevents the expression of the *hrp* genes. This results in non-pathogenicity. Due to the specificity of the genetic exchange only one class of mutant is obtained.

Method 2: The method gives rise to an indefinite number of undefined mutants that require screening for non-pathogenicity. The deletion mutant is free of foreign DNA.

b) What is the location of the inserted DNA in the final construct, and how many copies are present?

Method 1: A single copy of the omega cassette inserts into the *hrp*O gene of the *hrp* gene cluster (hypersensitivity response and pathogenicity genes) (5).

Method 2: The deletion is a random event and has not been characterised.

c) What markers or sequences will enable the GMO to be identified in the laboratory and under field conditions?

Method 1: the omega cassette is marked by kanamycin resistance and possess unique DNA sequences.

Method 2: By it being free of exotic DNA no marker is present, however, the deletion event gives rise to a unique DNA fingerprint which is diagnostic.

16 a) What type of construct was used in the transformation? Provide a description of the construct, showing the position of the inserted DNA and any other control sequences or markers in the construct.

Method 1: The omega cassette is a 2kb interposon flanked by *R. solanacearum* DNA that is homologous to a specific site within the *hrp* gene. The 2kb DNA fragment contains the kanamycin resistance gene and DNA sequences that encode for trancriptional and translational termination in both reading frame orientations. It houses no DNA sequences that promote transposition events or illegitimate recombination (5).

Method 2: The *sacB* genes is contained within the *nptI-sacB-sacR* cassette on the plasmid pMH1701, a derivative of the transposon Tn5 carrying the *mob* site (*oriT*) of plasmid RP4 (9), and housed in *E. coli* strain (S17-1) (8). The *nptI-sacB-sacR* cassette encodes for tetracycline resistance.

b) Can the construct transfer to other hosts? If so, provide information on its host range.

Method 1: The omega cassette has homology to the *hrp* genes and may have the potential to transfer to other *hrp* containing organisms: the *hrp* genes are conserved amongst many gram negative plant pathogenic bacteria.

Method 2: The plasmid construct containing the *sacB* gene has a wide host range, however, the construct is not present in the BCAs.

c) Is the recombinant construct present in the final construct? If not, how was it removed?

Method 1: Yes

Method 2: No: removed by forced eviction (see Question 13).

17. If no construct involved.

a) If exogenous nucleic acid was introduced, how was this accomplished?

b) How many copies of the gene were inserted?

c) What secondary genetic effects may be anticipated?

18. How does the modification change the phenotype of the organism to be introduced? Present data to demonstrate the effect of the modification, including level of expression and regulation of the genetic insert.

Method 1: The mutation event (insertion of the omega cassette) gives rise to one class of mutants that are characterised as retaining a fluidal colony morphology on CPG agar plates typical of the pathogenic wild type isolates, but are hypersensitive response-negative on infiltrated tobacco leaves and non-pathogenic on potato. The transformed bacterial isolates are also resistant to the antibiotic kanamycin due to a resistance gene encoded on the omega cassette. To current knowledge no other property is affected by the mutation event.

Method 2: Pathogenicity screening selects for mutants that are hypersensitive response negative on infiltrated tobacco leaves and non-pathogenic on potato. They have no acquired antibiotic resistance.

19. a) What intrinsic genetic features, if any, of the GMO regulate its survival and dissemination in the environment? How stable are these features?

None known, however, the lack of pathogenicity significantly diminishes its ability to multiply in the environment through infecting potato.

b) What genetic changes, if any, have been included in the GMO to limit or eliminate its capacity to reproduce or transfer its genes to other organisms?

Method 1: The omega cassette is flanked by DNA sequences that encode for trancriptional and translational termination in both reading frame orientations. It houses no DNA sequences that promote transposition events or illegitimate recombination (5).

Method 2: None

F. GMO stability, survival, dissemination and transfer

20. On the basis of contained experiments or other relevant experiences, provide data on:

a) The survival period of the GMO in habitats relevant to the planned introduction;

Method 1: Studies at CABI Bioscience (UK Centre, Egham) using imported soil from Molo, Nakuru district, Kenya have indicated that the population of the non-pathogenic mutant (omega derived) and the wild type pathogen decline in soil at an equal rate in the absence of potato. The growth of a potato plant has been shown to enhance soil populations of the wild type pathogen, but does not interact with the non-pathogenic mutants which continue to decline in number.

Method 2: The non-pathogenic mutants induced through the *sacB* gene have not been evaluated for their survival properties, however, their similar nature to the omega derived BCAs should indicate a similar response.

b) The growth rate (or generation time) of the parent organism and GMO in the ranges of environmental conditions characteristic for the place and date of the planned introduction.

Not determined - this would be an component of the research.

c) The frequency of reversion or loss of the genetic modification.

Method 1: No reversion or loss of genetic material has been recorded.

Method 2: Not applicable

21. a) What is the capability of the GMO to disperse from the area of the planned introduction? What are the dispersal mechanisms in air, water, soil or vectors?

If the correct working practices are implemented the risk of the BCAs dispersing from the laboratory and screenhouse are minimal. If a field release is undertaken then it is possible that the BCAs can be carried through drainage water.

b) Can the parent organism form long-term survival structures such as seeds or spores?

No

22. Is there any evidence that the novel trait can be transferred to other organisms found at the site of the planned introduction and surrounding environment? If so:

The omega cassette (method 1) may theoretically be transferred, although no experimental evidence has been found to support this.

a) *To what organisms and at what frequencies? List the species that have been tested or otherwise evaluated for receptivity and explain the rationale for this choice.*

The most probable recipient would be the wild type organism or a bacteria housing *hrp* genes.

b) What transfer mechanisms are involved?

Transduction/conjugation can be speculated.

c) What techniques have been used to demonstrate receptivity or transfer?

Rational of transfer based on method of inducing the BCA (method 1). No receptivity or transfer has been recorded from the BCA to another organism.

d) What are any possible adverse effects of the transfer?

None known.

23. Does the modified trait confer a selective advantage on the GMO under certain conditions? If so, what are these conditions? Provide data on growth rates with and without selection pressure.

No

24. Would you expect the GMO to show any competitive advantages over its unmodified parent in mixed populations under the conditions in the test site? If so, what are the advantages?

No

G. Experimental procedures, monitoring and contingency planning

25. Describe in detail the containment facilities and containment levels in place at the experimental stage.

At the time of the commencement of research activities detailed herein, the below contained-use facility (CF) specification and working practices will be established within the Plant Pathology Section of Crop Protection at the National Agricultural Research Laboratories of the Kenya Agricultural Research Institute.

i) Work to be undertaken within the laboratory.

Structural specification:

- The laboratory is structurally sound, and away from obvious environmental hazards, such as overhanging branches of trees.
- The laboratory is clearly marked as having restricted access and containing a biological hazard.
- Access to the laboratory is via a lockable door.

Operational procedures of the laboratory:

- Access to the laboratory is restricted to designate personnel.
- Material containing genetically modified bacteria is handled by registered GMO users only.
- The working environment of the laboratory is organised so that the cultures of the GMO are spatially separate from other bacterial cultures.
- Personnel are clothed with laboratory a coat prior to accessing the laboratory.

Laboratory procedure:

- GMO laboratory procedure always satisfy “good laboratory practice” and the additional restrictions stipulated herein for working with genetically engineered non-pathogenic mutants of *Ralstonia solanacearum*.

Cleaning and Sterilisation.

- Material (petri-dishes, bottles etc.) awaiting sterilisation is clearly marked.

- Any area subject to an accidental spillage of the GMO is immediately surface sterilised by washing with domestic bleach solution (5% Sodium hypochlorite).

Disposal of waste.

- Disposable (petri-dishes etc.) and non-disposable (glassware) consumables is double-bagged in Biological Hazard Bags and autoclaved at 15 p.s.i./121°C for 40mins[14].

[14] The autoclave time specified refers to the minimum period the internal pressure/temperature parameters need to be maintained. Each autoclave should be calibrated independently to ensure these specifications are satisfied. The use of an autoclave indicator strip, such as Steam Sterilisation Integrator (Therma-log S), is strongly recommended to establish correct working practice.

- The autoclave at KARI NARL has been identified as appropriate to undertake this task.

ii) Work to be undertaken within the screenhouse.

Structural specification:

- The CF is structurally sound, and away from obvious environmental hazards, such as overhanging branches of trees.
- The facility is clearly marked as having restricted access and containing a biological hazard.
- Access to the CF is via two lockable doors. The area between inner and outer doors (later termed the vestibule) being of a size to allow the clothing of personnel with laboratory coats and rubber shoes.
- The CF floor is of cement.
- Ventilation of the screenhouse is insect proof (24 hole/inch mesh).

Operational procedures of the CF:

- Access to the CF facility is restricted to designate personnel.
- Material containing genetically modified bacteria is handled by registered GMO users only.
- Personnel be clothed with laboratory coats and rubber shoes dedicated to that facility in the vestibule area, prior to accessing the screenhouse chamber.
- Transport of GMO material to and from the CF and the laboratory is kept to a minimum, and contained within two autoclave bags and a robust container that can withstand accidental damage and contain any resultant material release.

Experimental procedure:

- GMO experimental procedure always satisfy “good laboratory practice” and the additional restrictions stipulated herein for working with genetically engineered non-pathogenic mutants of *Ralstonia solanacearum*.
- Each experiment has an experimental data sheet specifying the date of commencement, nature of the experiment, personnel in charge and deputy, and any additional quarantine aspects not covered by GMO experimental procedure herein.

Cleaning and Sterilisation.

- Material (pots, trays etc.) awaiting sterilisation is clearly marked.
- Disinfectant (domestic bleach: 5% sodium hypochlorite) is used at a concentration of 40ml/l. Allow submersion of material for 24hr for sterilisation before discarding.
- Any area subject to an accidental spillage of the GMO is immediately surface sterilised by washing with domestic bleach solution (5% Sodium hypochlorite).

Disposal of waste.

- Plant material is double-bagged in Biological Hazard Bags to a volume not exceeding 8000cm^3 (20 x 20 x 20cm). The plant material is autoclaved at 15 p.s.i./121°C for 40min.
- The removal of inoculum of soil infected with the genetically modified *R. solanacearum* will require the soil to be left fallow, without water and exposed to sunlight for a period of not less than 1 year. An indication of the absence of viable genetically modified cells can be assessed through plating soil samples onto selective medium. When the soil is assessed free of GMO it is disposed of onto a recognised waste disposal site.

iii) Work to be undertaken on the field trial.

Structural specification of field trial site.

- The field trial site is bordered with a double fence of 1.5m around a ditch of 0.5m.
- The field trial site is clearly marked as having restricted access and containing a biological hazard.
- Access to the field trial site is via two lockable doors that form an enclosed vestibule. The vestibule being of a size to allow the clothing of personnel with laboratory coats and rubber shoes, and for the housing of equipment for cultivation (hoe, spade, fork etc.).

Operational procedures of the field trial site:

- Access to the field trial site is restricted to designate personnel.
- Material containing genetically modified bacteria is handled by registered GMO users only.
- Personnel be clothed with laboratory coats and rubber shoes dedicated to that field site, prior to access.
- Cultivation equipment (hoe, spade, fork etc.) is dedicated for field trial use only.
- Transport of material to and from the field trial site, CF and the laboratory is kept to a minimum, and contained within two autoclave bags and a robust container that can withstand accidental damage and contain any resultant material release.

Experimental procedure:

- GMO experimental procedure satisfy “good laboratory practice” and the additional restrictions stipulated herein for working with genetically engineered non-pathogenic mutants of *Ralstonia solanacearum*.
- Each experiment has an experimental data sheet specifying the date of commencement, nature of the experiment, personnel in charge and deputy, and any additional quarantine aspects not covered by GMO experimental procedure herein.

Cleaning and Sterilisation.

- Material (pots, trays etc.) awaiting sterilisation is clearly marked.
- Disinfectant (domestic bleach: 5% sodium hypochlorite) is used at a concentration of 40ml/l. Allow submersion of material for 24hr for sterilisation before discarding.

Disposal of waste.

- Plant material is incinerated within the boundary of the field trial site.
- Removal of soil inoculum will require the field site to be left fallow for a minimum period of 5 years. An indication of the absence of viable genetically modified cells will be assessed through plating soil samples onto selective medium.

26. a) Describe in detail the overall experimental protocol for the introduction, including the protocol for control, test, and challenge organisms.

Phase 1 Screenhouse evaluation of the efficacy and biosafety of the biocontrol agents.

Experiments will be undertaken within raised beds containing sterile or non-sterile soil. These soil beds will be used for the evaluation of the biocontrol agent through challenge inoculation of wild type and non-pathogenic mutants of *R. solanacearum* on potato. During

the course of these experiments, observations will be made to determine the number of non-pathogenic and wild type *R. solanacearum* cells per unit volume of soil to determine the persistence and impact of the biocontrol agent. This is possible through the use of media that is semi-selective to *R. solanacearum* and supplemented with antibiotics to delineate the non-pathogenic and wild type populations[15], respectively. Events of genetic exchange involving the omega cassette moving to the pathogenic population will also be observed through this study by the isolation of *R. solanacearum* isolates that are resistant to both antibiotics[16] and have a genomic profile that is distinct from the introduced biocontrol agent. Additional tests will verify that the induction of non-pathogenicity is a stable trait with no reversion to a pathogenic form, as detected through pathogenicity screening. These biosafety assessments under natural systems will be complimented by *in vitro* tests targeting the same aspects.

These aspects of the research are expected to take 1 year to conclude.

Phase 2 Field trial evaluation of the biocontrol agent.

This aspect of the research is dependent on successful results being achieved under phase 1 and will be subject to an external review through the National Biosafety Committee or another appropriate scientific body prior to commencement.

Phase 2 will be located on a field trial site of the order of 10m x 10m. Plots within this area will be planted with potato inoculated with the biocontrol agent applied as a powder or liquid formula. The soil will harbour naturalised populations of the wild type bacterial wilt race 3. Soil monitoring of wild and non-pathogenic populations of *R. solanacearum* will be undertaken as outlined in phase 1.

b) How many organisms are to be introduced?

5 BCA strains - 3 developed by method 1 and 2 developed by method 2

c) How many introductions of the GMO are proposed?

One

27. a) What are the arrangements for producing the GMO in quantity, transporting it to the site, and accounting for the transported organisms?

The initial assessments will be on a small scale and the GMO can be multiplied at NARL within the Bacteriology laboratory.

b) How will the GMO be introduced?

The BCAs will be supported in a carrier material and dusted onto potato tubers prior to planting.

28. a) What methods are to be used (if appropriate) to test for batch to batch consistency if large scale production is required to produce GMOs for introduction?

Large scale production is not a requirement at present.

[15] Spontaneous rifampacin resistant mutants of the wild type bacterial wilt will be used under these assessments. Spontaneous mutants are not GMO under the current definitions (annon 92).
[16] The omega cassette encodes for kanamycin resistance (Frey 94).

b) What specific measures have been taken or will be taken in the production process to ensure the quality/purity of the GMO to be introduced?

Not applicable

29. a) How will the survival of the GMO be monitored? Provide a description of techniques for monitoring the presence of GMOs, or transferred genetic material beyond the primary site, including specificity, sensitivity and reliability of detection methods.

Method 1: The fate of the omega cassette will be monitored through isolation of bacteria onto semi-selective medium containing kanamycin. Protocols developed at CABI Bioscience (UK Centre, Egham) have recorded levels of detection at of approximately 100 cells/g of soil. PCR and DNA based techniques can be used to verify the presence of the omega cassette within a bacterium.

Method 2: The lack of a antibiotic marker in these BCAs makes monitoring of these populations very difficult. However, the lack of exogenous DNA also reduces the risk they pose and therefore the need for them to be monitored.

b) If the introduction is likely to affect the characteristics or abundance of other species, how will this be monitored?

The BCAs may reduce the wild type population of bacterial wilt. This can be observed indirectly by observing disease incidence or directly through enumeration of soil populations onto semi-selective media.

c). How will transfer of the introduced gene to other species be monitored?

The fate of the omega cassette can be monitored through the use of selective medium and PCR and DNA based techniques.

30. a) What, if any, potential hazards or deleterious effects can be postulated and how are these to be evaluated during the introduction?

None anticipated.

b) Describe structures or procedures or physical or biological barriers that will be in place to reduce dissemination of the GMO.

See Question 25

c) If transfer of the inserted genetic trait to other organisms with adverse consequences is possible (see A20), what methods will be used to minimise these effects?

None anticipated.

31. a) Will the GMO remain in the environment after the introduction? If so, (i) for what period of time, and (ii) what might be the consequences?

The BCAs will only remain in the environment if a field release is undertaken. Eradication from the field trial zone should be possible by leaving the ground fallow for a minimum of 5 years. No adverse consequences are anticipated.

b) What measures will be taken to reduce populations or disposal of the GMO once the introduction is completed? If so, provide details.

See Question 25: Field trial section.

c) What monitoring is to be undertaken after the introduction is completed?

Using the methods outlined in Questions 26a and 29a GMO populations can be monitored until such time as it is deemed unnecessary.

32. What contingency measures will be in place to remove the GMOs if a hazard becomes evident during the course of the planned introduction? State your institutions emergency response time and capacity.

In the event that a hazard becomes evident research activities under phase 1 (see question 25) can be halted and the BCA removed from the environment (laboratory and screenhouse) within 4 weeks. Under phase 2 the field trial site would need to remain quarantined and left fallow for 5 years.

33. Describe site supervision procedures and any safety procedures undertaken by staff.

See Question 25

34. Who takes liability in case of injury or accident at staff level and testing sites?

Kenya Agricultural Research Institute.

35. a) Have the same or similar introductions been made before, either within or outside Kenya? If so, what were the beneficial or adverse consequences? Provide references or reports of previous assessments.

Analogous research has been undertaken at INRA, France on bacterial wilt race 1, and has progressed to the field trial stage (Guadeloupe). This research has been published in:

Frey, P., Prior, P., Kotoujansky, A., Trigalet-Demery, D., and Trigalet, A. 1994. Hrp^- mutants of *Pseudomonas solanacearum* as potential biocontrol agents of tomato bacterial wilt. Applied and Environmental Microbiology 60:3175-3181.

Ongoing research using the BCAs raised by method 1 described herein are being assessed independently by the African Research Council, South Africa.

b) *Has another country rejected an application for the planned introduction of this organism? If so which country and on what basis?*

No

c) *What factors might suggest greater or less risk for the proposed introduction in Kenya as compared to other countries?*

None

36. State whether the GMO to be introduced has already been imported. If yes, provide importation documentation which could constitute a hazard, not discussed

elsewhere in the proposal. If the GMO is yet to be imported, provide the schedule of intended importation. In the area designated, or (b) elsewhere in Kenya. If so, please explain.

The GMOs are yet to be imported. Dates have not been agreed, pending acceptance of the application to 'Introduce or release genetically modified organisms (GMOs).

Provide any other information you may have that could assist NBC's assessment of this proposal.

See attached summary on previous research with references cited as in the text herein.

PART II PLANTS

Is there familiarity with the parent plant through an extended history of cultivation and of safe use? If not, explain.

What, if any, unintend pleiotropic effects, including undesirable effects on agronomic characteristics of the plant, may result from the expression of the transgene in the GMO e.g. reduced fertility, increased disease prevalence, production losses, grain shedding)? Indicate the likelihood of these events.

Describe the mechanism of pollen spread (by insects or by other means) in the plant.

Provide any available data on pollen viability for the plant.

Indicate any potential pollinators and their range and distribution in Kenya.

Are any members of the genus of unmodified parent plants known to be weeds in the environment? If so, specify?

Are there any literature reports on cross-pollination between the species to which the GMO belongs and wild and needy relatives known to be weeds? If so, provide list.

Provide quantitative data on successful cross-pollination between the plant and any wild and weedy relatives.

If sexually compatible plants exist or grow near the site of the planned introduction, give details and quantify the chances for cross-pollination.

If cross-pollination occurred, would the resulting progeny be likely to enjoy reproductive advantages? If not, explain.

Will the plants in this introduction be allowed to set seeds? If not, is this planned for subsequent introductions?

If plants are allowed to set seed, does the mature seed normally remain contained within an ear, capsule, pod etc. Can all the seeds be readily harvested, or is the seed shed soon after it matures?

Can the seed be dispersed by natural mechanisms? If so, describe.

Are the seeds capable of being dormant for a long time? If so, how long?

Can the plant be dispersed by vegetative propagation? If so, describe the possible mechanisms.

a) What is the likelihood that the imported characteristic could be transferred or integrated into other species, with adverse consequences?

If there is any possibility of such transmission, would it have the potential to affect the distribution and abundance of the other species? If so, specify?

If there is any possibility of such integration, has any attempt been made to minimize the risk (e.g. by importing male sterility or other means of reproductive isolation)? If not, explain.

How might the plant's competitive advantage (reproductive fitness) be changed by the novel trait (i) in the agricultural setting; (ii) in the natural environment? Explain.

Does the novel characteristic change the capacity of the plant to add substances to or subtract substances from the soil (e.g. nitrogen, toxic compounds)? If so, describe the change.

a) Is there any likelihood that the introduced gene could cause an increase in toxicity of the plant for animals and humans? If so, provide available data.

Could any products of the plant concentrate in the natural or human food chain to levels which become toxic? If so, explain.

Is the biodegradability of the plant changed? If so, how?

What secondary ecological effects might result from introduction of the GMO (e.g. effect on endangered native species, resistance of insect populations to an insecticide, reduction or increased in numbers of prey or parasites, etc.)

If the construct involves resistance to a chemical agent (other than selective agents), such as antibiotics, used in strain construction):

Provide data on the degradability, selectivity and toxicity of the chemical concerned.

What is the agronomic significance of the chemical?

What is the biological activity of the chemical?

How is the chemical applied and used?

If the construct involved resistance to a herbicide, explain whether the introduction will:

Result in more effective use of the herbicide;

Result in better weed control in the crop;

Result in more efficient overall farming operation;

Allow a change to a program which involves environmentally friendly chemicals or practices.

If the construct involves resistance to a natural pest, e.g. insects, pathogens such as (fungi, bacteria, viruses, nematodes etc).

Provide information on the likelihood of development or resistance by the target pest/pathogen.

Provide data on selective specificity.

What is the comparative advantage of using the GMO *vis a vis* other conventional methods of insects/pathogen control.

Name ……

Signature ……..

Date ……...

BACKGROUND INFORMATION IN SUPPORT OF THE APPLICATION TO IMPORT INTO KENYA BIOCONTROL AGENTS AGAINST BACTERIAL WILT OF POTATO.

BIOLOGICAL CONTROL OF BACTERIAL WILT DISEASE OF POTATO IN KENYA.

CABI Bioscience (formerly known as the International Mycological Institute) has been involved in developing a biocontrol agent against bacterial wilt of potato over the past 5 years. Funding has been through the Department for International Development (formerly Overseas Development Administration) under two projects each of three year duration. The research has focused on potato cultivation by small-scale farmers in Kenya and has been co-ordinated through the CAB International - Africa Regional Centre and undertaken by the Kenya Agricultural Research Institute (KARI).

Bacterial wilt is caused by *Ralstonia* (Syn. *Pseudomonas*) *solanacearum* (13) and is widely distributed in tropical, subtropical and warm temperate regions. The disease is a major constraint on the production of several important crops aside from potato, particularly other solanaceous crops (tomato, chilli), bananas (Moko disease), groundnuts and ginger (7). However, within what is a very diverse species, a particular sub-set of the pathogen is recognised as causing bacterial wilt disease almost exclusively on potato (3). This is commonly referred to as the potato race, and is synonymous to race 3 or biovar 2a under the current typing schemes (7). This race predominates in cooler climates typical of potato cultivation, and forms the altitudinal and latitudinal limits of *R. solanacearum* distribution.

In Kenya potato cultivation occurs on small-scale farms between 1200 and 2800m over an area of 75,000-100,000 ha per year (2) and is increasing in importance due to rising consumer demand for potato products, especially potato chips. Accordingly, these socio-economic pressures result in insufficient crop rotation which, when coupled with the poor availability of certified seed, encourages the persistence and spread of diseases like bacterial wilt that is ostensibly seed tubers borne (6). Losses in Kenya due to bacterial wilt have been serious in recent years, particularly at mid-altitude growing areas (2). These environments are infected almost exclusively by race 3 isolates (10). To date, no effective control methods exist for bacterial wilt disease, with plant breeding, field sanitation, crop rotation and use of bactericides having met with only limited success. Alternative methods for control, such as biological control, involving appropriate technology and low cost to the farmer are urgently needed.

Various recent studies have indicated that biological control of bacterial wilt could be achieved using antagonistic bacteria such as non-pathogenic mutant of the wild type pathogen (5). However, as a consequence of the heterogeneity within the species *R. solanacearum*, no one biocontrol agent is likely to be universally effective. For this reason, CABI Bioscience has focused its research on race 3, as the relative homogeneity of this race linked to its localised geographic distribution and limited host range affords a simple model in which the efficacy of a biocontrol agent can be readily assessed. Kenya provides an ideal environment for the development of this technology, linking demand for an effective control strategy with the scientific advantages of studying race 3.

The current research in Kenya started in 1992 with the collection of indigenous *R. solanacearum* populations . These populations have been typed by a highly sensitive genomic fingerprinting procedure (rare-cutting restriction analysis by pulsed-field gel electrophoresis) that has identified a clonal population structure (10). This insight has enabled the rational selection of *R. solanacearum* isolates for development as biocontrol agents through mutagenesis to a non-pathogenic form. Two mutagenesis protocols have been adopted for the induction of non-pathogenicity: method 1 (developed by INRA) involved transformation by an exogenous DNA element (omega cassette) that shares homology to the pathogenicity genes; method 2 involves a deletion event induced by the

insertion and deletion of the *sacB* gene of *Bacillus subtilis*. Using these methods non-pathogenic mutants have been produced for the selected race 3 isolates. Under current UK legislation these mutants are defined as genetically modified micro-organisms (GMM) and therefore research activities on these mutants is subject to a GMM risk assessment. These assessments grouped the research activities with the non-pathogenic mutants derived from both methods as GroupII/TypeA, the lowest biohazard value available for a GMM (1).

Initial biocontrol assessments with these mutants under contained-use conditions at CABI Bioscience (UK Centre, Egham) have consistently demonstrated significant levels of protection against the incidence of the disease (11). Current research continues to establish the agricultural value of the biocontrol agents developed and their environmental impact on the indigenous micro-flora of soils. In line with the requirements of the project the research will become increasingly based in Kenya. The next stage of the project is to evaluate the biocontrol agents under Kenyan conditions.

The need for the research continues to gain precedence in Kenya with new and more serious outbreaks of the disease being reported. KARI researchers have likened the disease in the national newspapers to the Aids of potato !

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REPORT ON ATTACHMENT AT THE INTERNATIONAL MYCOLOGICAL INSTITUTE, 21ST APRIL TO 23RD JULY 1997

By

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July, 1997

Summary

Plant bacteriology formed the core of the three-month attachment period at the International Mycological Institute (IMI). I learnt and practised various techniques for the identification and characterisation of bacterial plant pathogens. The techniques can be grouped into two categories: modern and classical methods, emphasis was placed on the latter area.

The modern techniques are generally based on DNA analytical techniques (genomic fingerprinting, species identification), chromatographic procedures (gas, liquid and thin-layer chromatography) and serology. Bacteria identification using classical methods largely considers nutritional, physiological and, to some extent, morphological properties of bacteria. These properties are expressed as observable reactions when appropriate tests are carried out.

I also gained experience in carrying out experiments involving a biological control agent against bacterial wilt of potato. These experiments were complementary to on-going research work at KARI and aspects of the experience gained will be incorporated into this research programme.

Overall, I had a gorgeous attachment period, with an opportunity to work and live with very co-operative people both within and outside IMI.

Attachment Objectives

The attachment was designed for familiarisation in:
i) Culture techniques, isolation and identification of bacterial pathogens of plants.
ii) Working protocols and experimental procedures detailed under DFID RNRRS Project R6629, Biological control of bacterial wilt of potato in Kenya and Pakistan.

Travel and Arrival in Britain

My air-ticket was organised for by the International Mycological Institute (IMI) through CABI-ROAF, Nairobi, from where I collected it. I applied for and obtained a visa through the British Council. Armed with a passport, Visa and the air-ticket, I was able to travel from Jomo Kenyatta International Airport, Nairobi to Heathrow airport, London.

I was delighted to meet Dr. Julian Smith who was waiting for me at Heathrow. Much to his surprise, Julian realised that a British Council duty courier was also expecting me at

the British Council Information desk. The duty officer was equally surprised when he saw Julian leading me away from the arrivals hall. After a brief discussion the officer agreed that Julian could take me to my accommodation in Englefield Green, Egham. This reflected the great assistance that visitors to Britain are accorded.

Accommodation and General Welfare

I was accommodated in 10 South Road, Englefield Green, for the first nine days, following which I moved to 51 Harpesford Avenue, Virginia Water, where I stayed upto 14 June, 1997. From 15 June onwards (six weeks), my accommodation was again at 10 South Road. The moves were due to prior commitments by the house owners.

All the accommodation arrangements were kindly made by Mrs. Stephanie Groundwater. Ms Janet Pryse took care of my accommodation arrangements in the absence of Mrs. Groundwater. The latter was also a source of information regarding travel and places to visit around Egham and in London.

Members of staff at IMI gladly welcomed me in their company on some occasions when they went out for a meal within Egham area. Back at the institute, the smiles on most of them were reassuring and made the working environment very homely. A common question from some of them was how I was getting on, an indication of how mindful they were about my welfare.

The British Council Regional Services Officer, Maureen Kirk, came to see me at IMI during the first week of my attachment period. She provided me with information on several aspects of my stay in Britain. She visited me again after two months to know how I was getting on.

Provision of an IMI bicycle made transport between my home(s), the institute and elsewhere an easy task.

THE COURSE

There were two main parts of my training at the IMI:- Modern methods course and Tropical plant bacteriology.

I: Modern Methods Course

This course was conducted between 21st April and 2nd May, 1997 as *Modern Techniques in the Identification of Bacteria and Filamentous Fungi.* The methods are referred to as *modern* because they differ greatly from the classical or "traditional" methods of microbial identification.

The modern methods generally require a high investment with equipment (Gas chromatograph, high performance liquid chromatograph, thermal cyclers, computer hardware and various software packages, micro pipettes, e.t.c.) and consumables. There are major advantages of these methods among them being the speed and accuracy of microbial identification as long as the correct procedures have been followed.

Several IMI staff members in the Biochemistry and Bacteriology Sections took the course participants through the well-administered lectures and practical procedures that covered the following aspects:

- Protein electrophoresis
- Fatty acid extraction and analysis

- Detection and analysis of secondary metabolites and quinones
- Serology
- DNA extraction from fungi and bacteria
- Polymerase Chain Reaction (PCR) and Restriction DNA digestion
- Random Amplified Polymorphic DNA (RAPDs) and rep-PCR analysis
- Restriction Fragment Length Polymorphisms (RFLP)
- Pulsed-field Gel Electrophoresis (PFGE)
- Taxonomic Computing

The techniques listed above were covered with respect to their application in characterisation and taxonomy of plant pathogenic bacteria and filamentous fungi.

II: Tropical Plant Bacteriology

There were two facets in this area: Identification of phytopathogenic bacteria and Biological control of bacterial wilt of potatoes, caused by *Ralstonia (Pseudomonas) solanacearum*. I worked closely with Dr. Julian Smith in the biological control aspect and with Jacqueline Kolkowski, Lisa Offord and Eithne O'Grady in the bacteria identification methods.

i) Bacteria identification

Activities centred on the use of classical or physiological methods in identifying plant pathogenic bacteria. The methods require relatively low capital investment but are "expensive" in terms of time and consumables. Accurate identification of bacteria is very dependent on the correct and timely examination of tests, some of which can last two to three weeks before they are completed conclusively. Hands-on experience is important in making a correct judgement of a result.

Identification procedures involved the use of a wide range of tests. The tests carried out included:

- Gram staining
- Cell morphology
- Cell motility
- Oxidase reaction
- Levan production
- Production of fluorescent pigments
- Aerobic and anaerobic growth abilities
- Enzyme production tests e.g. Nitrate reductase, arginine dihydrolase, tyrosinase, urease and phosphatase, catalase
- Tolerance tests e.g. TTC, NaCl and erythromycin
- Hydrolysis tests such as Gelatin, Starch, Aesculin hydrolysis
- Carbohydrate utilisation tests, e.g. cellobiose, glucose, lactose, maltose, mannitol, sorbitol, dulcitol, sucrose, trehalose, salicin, e.t.c.
- Potato soft rot
- Pathogenicity tests

By using results from these tests, various bacteria in the groups Xanthomonads, Pseudomonads, Erwinias, Agrobacteria and Coryneforms were identified.

Knowledge of hosts and symptoms was paramount in some instances for proper identification, especially to pathovar levels.

Other aspects covered included preparation of general, selective and determinative bacteriological media

ii) Bacterial wilt work

The aspects covered in this area lay the ground work for biocontrol and integrated pest management (IPM) experiments to be carried out in Kenya. The biocontrol agent was a *Ralstonia solanacearum* strain which had previously been rendered non-pathogenic through genetic engineering. The aspects covered included the following:

- Development of methods for the determination of *Ralstonia solanacearum* populations in soil by plate count on semi-selective media and immuno-capture methods
- Monitoring *Ralstonia solanacearum* (biocontrol and wild type) populations in soil under different cropping systems
- Identification of other natural soil-inhabiting bacteria by fatty acid analysis
- DNA fingerprint characterisation of *Ralstonia solanacearum* by pulsed-field gel electrophoresis
- Efficacy of biocontrol agent in controlling bacterial wilt of potatoes
- *Ralstonia solanacearum* biovar determination tests

Note: Some of these experiments were incomplete by the time I left IMI; Dr. Julian Smith will see to their completion. The experiments are complementary to on-going research at KARI and aspects covered herein will be incorporated into these studies.

Skills Acquired

- Procedures in the culture and identification of plant pathogenic bacteria.
- Handling of a genetically modified micro-organism.
- Experimental protocols for biological control and integrated disease management of bacterial wilt of potatoes.

Departure

With an air ticket, again organised for by IMI, my flight back to Kenya was on 23 July 1997, by British Airways from Gatwick.

Acknowledgements

I gladly acknowledge the British Council and DFID (formerly ODA) for financing my attachment at IMI. I would also like to express my gratitude to the following individuals and institutions for their important roles in facilitating a good start through to a happy ending of my attachment: Dr. Julian Smith (supervisor at IMI), Gilbert Kibata (Crop Protection Co-ordinator, KARI), Graham Farrell (DFID Field Manager), Jacqueline Kolkowski, Lisa Offord, Eithne O'Grady, Stephanie Groundwater, Janet Pryse, KARI and IMI.

Approval:

_____

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Jim Waller, IMI

PROGRAMME – END OF PROJECT REVIEW

Tuesday 4th April:

9:00 – 9:30 Opening preambles – Dr. Stanley M. Wokabi, Centre- Director, KARI-NARL, and Jackson Kabira (NPRC)

9:30 – 10:00 Overview of potato in Kenya and Sub-Sahara Africa [Peter Ewell]

10:00 – 10:30 Socio-economic decision making in potato cultivation [Peter Kinyae]

10:30 – 11:00 Coffee

11:00 – 11:30 Main disease and pests affecting potato production in Kenya and Sub Sahara Africa [Modesto Olanya; Kinyua Murimi]

11:30 – 12:00 Foundation Seed Programme – A KARI-NPRC/CIP initiative [Charles Lungaho]

12:00 – 12:30 Novel nursery plot approach to meeting on-farm seed-tuber requirements [Julian Smith]

12:30 – 13:00 Discussion on morning session led by Ramzy El-Bedewy

13:00 – 14:00 Lunch

14:00 – 14:30 Seed-tuber certification in Kenya [Gladys]

14:30 – 15:00 Seed-tuber certification in South Africa [Nico Mienie]

15:00 – 15:30 Coffee

15:30 – 16:00 Research tools underpinning potato research on the control of bacterial wilt [Kinyua Murimi; Sylvie Priou; Modesto Olanya]

16:30 – 17:00 Implementation of new technologies within agricultural communities of Kenya [Martin Kimani]

17:00 – 17:30 Development of rural agriculture in South Africa – the functioning of agricultural co-operative societies by smallholders [David Modise]

17:30 – End Discussion led by Gilbert Kibata

Programme – END OF PROJECT REVIEW

Wednesday 5th April:

9:00 – 9:30	Potato Research undertaken by Africare in Uganda [Francis Alacho]
9:30 - 10:00	Potato research undertaken by PRAPACE and AHI [Berga Lemaga]
10:00 – 10:30	The position of potato in Kenya and the roles of KARI, KEPHIS and the public sector [John Kadera; Gilbert Kibata and Jackson Kabira]. Julian Smith (CABI Bioscience UK Centre [Egham]) to facilitate discussion
10:30 – 11:00	Coffee
11:00 – 11:30	Co-ordination of potato research activities in Kenya and Sub-Sahara Africa – the roles of CIP, PRAPACE, the African Highland Initiative and DFID [Berga Lemaga; Peter Ewell; Anne Stroud; Martin Leach; Jill Lenna]. Sarah Simons (CAB International ARC) to facilitate discussion
11:30 – 12:15	Research Theme 1 – Production of foundation seed-tubers and regional multiplication – a drop in the ocean! [Charles Lungaho; Peter Kinyae]
12:15 – 13:00	Research Theme 2 – SSPS, Good or bad? [Julian Smith; Kinyua Murimi]
13:00 – 14:00	Lunch
14:00 – 14:45	Research Theme 3 – Community structures for regional implementation of certified seed-tuber production and adoption of SSPS, and the roles of extension, NGOs and entrepreneurial initiatives. [Martin Kimani; David Modesi].
14:45 – 15:30	Research Theme 4 – Certification – an achievable goal! [Nico Mienie; Gladys]
15:30 – 1600	Coffee and summing-up

Thursday 6th April

8:00 – 6:00 Visit to Njabini, South Kinangop for Farmer's Open Day

Friday 7th April:

For remaining business

DFID END OF PROJECT REVIEW FOR POTATO RESEARCH ACTIVITIES

Opening remarks by J.N. Kabira: National Potato Research Centre, PO Box 338, Limuru

Potato is one of the most important food crops in Kenya, probably second only to maize as an energy source. The annual production is up to an average of 2.5 million metric tonnes in two seasons. With subdivision of farming areas into even smaller units, production is bound to increase since potato being adopted by an increasing number of growers since the crop has shorter maturity than maize and does well under irrigation, particularly in these days of recurrent droughts in the country.

Although the total area under potato cultivation has been increasing over the years, the yields have not kept pace, declining continuously mainly due to (1) declining soil fertility (2) pests and disease and (3) shortage of clean high – yielding seed material. Production of disease-free seed tubers of the high-yielding varieties such as Tigoni and Asante is recognized as an important aspect in boosting yields and controlling diseases in the farmers fields. Certified seed potatoes have in the past been produced through a centralized scheme with the NPRC-Tigoni providing basic seed for further multipliction by ADC in their high-altitude farms. This system is no longer functioning but I understand the ADC are, however, intending to revive seed potato multipliction initially based at Tall Trees in Molo. Otherwise for the time being, KARI is working with KEPHIS to sort out the seed potato problems of the small growers.

The NPRC-Tigoni produces only limited quantities of clean seeds. These are sold to farmers at the pre-basic seed state due to limitations in resources for further multipliction at both the Centre and sub-centres at Marimba (Meru), Njabini (South Kinangop) and Marindas (Molo). Only Tigoni has irrigation facilities, an adequate storage capacity and working tractors but has land limitations. More basic seed could be produced at the sub-centres if investments in the necessary infrastructure were made. The cost of the seed could then be lowered to a more comfortable level for the small-scale growers to afford. Currently the cost of seed is Kshs, 3,000 per 80 kg. bags, which is too high for most growers.

The current seed production capacity is woefully inadequate to meet the national demand. Various national efforts have been made to meet some of the seed potato demand. A farmer-based seed potato multiplication project was supported by the Technology Transfer Project of ASARECA. CIP, World Vision, Plan International and KARI collaborated to multiply seeds of the varieties Asante and Tigoni that were in high demand in the Mt. Kenya Region. CIP has supported seed multiplication in Molo, Nyandarua, Kitale, Mai Mahiu and Timau. The IDA has been supporting a Foundation Seed Project jon a commercial basis at the Centre. USAID through the MIAC had some input in the seed programme through rehabilitation of the irrigation system, the seed cold store and some support for the Tissure Culture Laboratory which PRAPACE, the Regional Potato and Sweetpotato Network assisted in its further expansion. The USAID is also supporting Mr. Kinyua to do work on management of bacterial wilt in the Meru area.

The seed plot technique is a novel approach for increasing on-farm productivity of seed potatoes. The DFID was kind enough to support Mr. Kinyua and Julian to experiment on the feasibility of this technique in the Kinangops. The two researchers will give us details of their research later, but I think it will suffice to mention here that bacterial wilt is the major constraint facing the future of potato production in Kenya. The practice of growing potato on the same piece of land for years on end (or for that matter without adequate rotation) due to limitation of land definitely is responsible for the proliferation of the

disease. No amount of clean seeds whatsoever will increase yields in such a scenario! As alluded to earlier, potato is now a major food security crop and efforts to improve on-farm productivity should be encouraged. That's why I take this opportunity to thanks the DFID for honouring KARI with the support for the seed plot technique. During the four days of the End of the Project Review you will get an opportunity to visit the project site at Njabini for a Farmer's Open Day. It is my hope that more details will be provided during the Field Day and by the participants in the course of the various presentations and the ensuring discussions.

With this – Ladies and Gentlemen, I have the honour to declare the DFID End of Project Review Workshop for Potato Research Activities officially open.

Thank you very much.

NOVEL NURSERY PLOT APPROACH TO MEETING ON-FARM SEED-TUBER REQUIREMENTS

Kinyua Murimi[1], Nico Mienie[2], Sylvie Priou[3] and Julian Smith[4]

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[3]Agricultural Research Council Roodeplaat, Pretoria, SOUTH AFRICA
[4]CABI Bioscience UK Centre [Egham], Egham, Surrey, TW20 9TY, UK

Potato is a major food and cash crop in Kenya, and is increasing in popularity with the rising consumption of chips. Yet on-farm potato production is known to be highly variable, affected badly by pests and diseases and rarely achieves the productivity known to be possible when planting healthy seed-tuber on well managed, fertile land.

The current challenge being met by researchers at CABI *Bioscience*, Kenya Agriculture Research Institute (KARI), International Potato Centre and the farming community of Njabini is to replenish current farmer seed-tuber material with new disease-free material and to maintain this seed's quality over a number of on-farm generations. The concept being developed centres on the on-farm separation of ware and seed-tuber production through the establishment of seed-tuber nursery beds [a flatbed strip of land planted at high density] that provides the seed-tuber for the next ware planting and perpetuates the seed-tuber nursery bed. This small-scale seed-tuber production system (SSPS) thus breaks away from the traditional ware-to-ware production system, where seed-tuber selection from ware production is an afterthought following selection for market and home consumption needs; a process that biases seed-tuber selection towards undersized, damaged and unhealthy tubers that will be low yielding. Under the SSPS seed-tuber selection is optimal for yield. The system also proposes improved land management, reduced initial seed-tuber inputs per farmer leading to improved distribution of certified seed-tuber and the identification of a 'window' [the nursery bed] for intensive management practices. In this context the SSPS was initially developed as the target for the application of a biocontrol agent against bacterial wilt.

Six farmer-field sites were selected in 1997 for the evaluation of the SSPS against the traditional ware-to-ware system and certified seed-tubers from KARI National Potato Research Centre (NPRC). Two varieties are under assessment, Roslin Tana and Tigoni, a traditional and new variety respectively. Currently the trials have been maintained for 5 seasons (Phases). Under these trials seed-tuber production per unit area of land has been shown to be in the order of 2-3 times greater under the SSPS [Figure 1], with a concomitant reduction in land required to meet on-farm seed-tuber needs. Ware productivity has not been shown to be significantly different during the early phases, however, the latest harvest has shown a strong trend towards greater productivity under the SSPS [See Figure 2]. Incidences of diseases and pests have not been significant under either system.

A facet of working across 6 farms is that the data tends to be very variable. This has highlighted the importance of soil factors and has also revealed an unexpected strength of the SSPS nursery bed, that of a buffering capability against extremes of drought and frost [Figure 1]. The practical significance of this is that farmers, following a poor season, are less likely to need to source seed-tubers from outside their farm (uncertified market material), thus reducing the risk of introducing diseases such as bacterial wilt to the farm. Furthermore, the reduction in land to seed-tuber production makes available a near-equal area of land for a non-solanaceous crop without notable reduction in ware production, thus presenting an option on crop rotation hitherto rarely available.

Accordingly, the initial goals of the SSPS have been realized, although robust conclusions on the benefits to smallholders requires addition trial seasons at Njabini, wider testing under varying environments (as is happening under analogous research in Meru and Uganda) and promotion at the farmer community level.

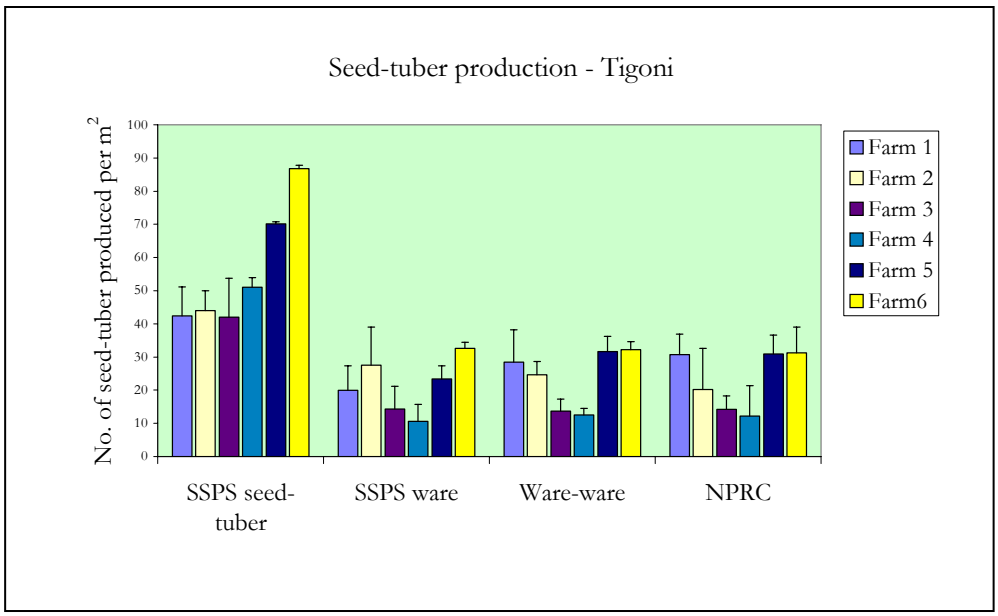

Figure 1.

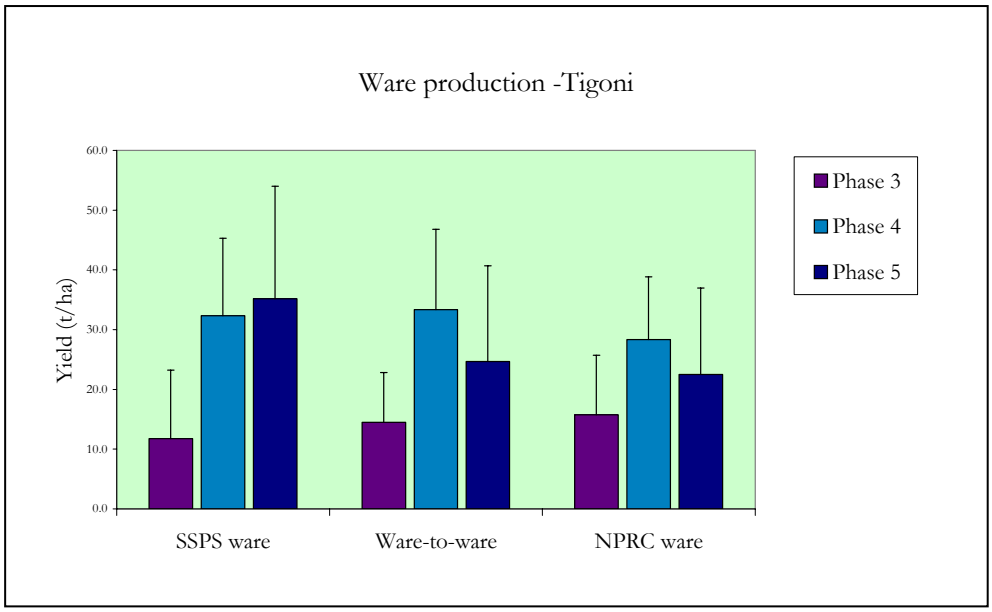

Figure 2.

SEED POTATO CERTIFICATION IN KENYA

Gladys Maina, KEPHIS, P.O Box 49592, Nairobi,Kenya.

Preamble

In order for any country to be self-sufficient in food production there has to be a continuous inflow of high quality varieties that are distinct, stable and uniform. They have to be high yielding and free from seed born diseases. In potatoes these varieties have to be free from most of the, bacterial, fungal and viral diseases. The tolerance should be minimal where necessary.

In Kenya, the KARI - NPRC Tigoni has been given the mandate to breed and maintaining the potato varieties. After breeding, Distinctiveness, Uniformity and Stability (DUS) and National Performance Trials (NPT), are carried out the varieties are released. The varieties are then multiplied in the research station in clones. Mother tubers are maintained in the green house. From the mother tubers potatoes are multiplied into clones A, B and C. They are then sold as stock seed (breeders) seed in clone D. They now leave the Research Station and further multiplication is done into pre-basic, basic, certified 1st and 2nd. The harvested CII is sold to the ware growers who plant for ware purposes.

During the above multiplication, Kenya Plant Health Inspectorate Service (KEPHIS) seed inspectors ensure that the seed potatoes are of high quality, true to type and free from seed born diseases. This is done through a process called seed potato certification. This process involves:-

1) Registration of seed potato growers
2) Field inspection
3) Lot inspection and sampling
4) Labelling and sealing
5) Post control plots

1. REGISTRATION:

For one to be registered he requires land which had not been planted with potatoes and other *solanacious* spp. e.g. tomatoes and egg plant for the last 3 years. The seeds must have been inspected by KEPHIS in the immediate previous season and approved for further multiplication. The farmer should also be familiar with the seed potato regulations, a copy of which can be obtained from KEPHIS. He should also have storage and grading facilities and be a reliable farmer.

2. FIELD INSPECTION:

During field inspection the quality attributes checked are:-

- Previous cropping history of the land
- Separation
- Trueness to variety
- Varietal purity
- Pests and diseases

Some diseases are tolerated upto a certain level, depending on the status of the seed. Others like bacterial wilt are not given any tolerance.

3. LOT INSPECTION:

During the grading of seed potatoes, inspection is done on diseases and pests. Tuber moth eaten tubers, damaged tubers, deformed tubers are all removed. Mixtures are also checked. The seed potato tubers are also checked on proper sizes. Any tuber that is below 28 mm. is regarded as chatt and those above 60 mm, are ware potatoes. Finally a simple is taken for post control plots.

4. LABELLING AND SEALING:

When KEPHIS is satisfied that the quality standards have been met, the bags are sown in such a way that any interference will easily be found out. A label is supplied and sealing is done. The label will show the variety, size of the tubers, status, weight, lot number and date of sealing. The labels given are either white, blue or red depending on class (status) of seed.

5. POST CONTROL:

All the samples collected in all the sealed bags are all planted together to form post control plots for further checking. Emphasis is placed on trueness to variety, impurities and seed-born diseases.

In the case of clones and breeders seed potatoes, field inspection is combined with laboratory tests to ensure that some diseases do not pass un-noticed. Some viruses such as Potato Virus X (PVX) and Potato Virus S (PVS) may not show the symptoms on the plant.

Post control plots also assist in adjusting the seed potato rules, location of weakness in the inspection team and sorting out disputes that may arise in the current season.

6. CONCLUSION:

When certification is completed, the potatoes are then sold for either further multiplication in the case of higher status or commercial growing in the case of lower status. Other factors being alright e.g. fertilization, agronomical factors and good weather the farmer will harvest higher yields.

SEED POTATO CERTIFICATION IN SOUTH AFRICA

Nico Mienie: Agricultural Research Council Roodeplaat, Pretoria, SOUTH AFRICA

BACKGROUND ON SEED CERTIFICATION

The Department of Agriculture used to manage seed potato certification in SA, but since 1989 this function was the responsibility of the Potato Board. With the deregulation of the Potato Board and the inauguration of the Potato Producers Organisation on 1 October 1993, seed certification has been assigned to this organisation who functioned as the certification authority representing the Minister of Agriculture. The South African Seed Potato Certification Service functions as a registered, non-profit orientated Association, under Section 21 and is advised by a democratically elected Board of directors representing each seed producing region in the country.

Management of the certification service took place from Pretoria, whilst potato growers are serviced by five regional offices throughout the country. Viral and bacterial disease testing use to be conducted by three laboratories, each advised by a Board of directors and three privately owned laboratories. Post-control testing (virus and true to type) are conducted at a laboratory called the Coen Bezuidenhout Seed Test Centre and is located north of Pretoria. All the laboratories had to conform to a protocol set by the Laboratory Services and the Department of Agriculture.

As from June 1995, a new certification scheme was implemented in the potato industry. The scheme involves generation (G) identification as from mini tuber production (G0) to G8. After G8, no further seed production is allowed. Tolerances for leaf roll virus and virus Y increases with consecutive generations. Exceeding these tolerances imply downgrading in generations. Within generations, three quality classes exist namely Elite, Class 1 and Standard grade, which cater for tuber borne diseases. The scheme involves a dual phasing-out system.

Three field inspections and tuber inspection are necessary on all registered potato plantings. Normally a statistical tuber sample is drawn for bacterial wilt detection, which in the case of positive results, registration is withdrawn. Certification is only effected when serological results of virus and bacterial tests fall within the norms of the Certification Scheme. Positive serological test results for bacterial wilt have to be confirmed conventionally. These tests are followed by the post control samples, which finally confirm certification. All *in vitro* material is tested for the presence of *Erwinia spp* pathogenic to potatoes, as well as *Ralstonia solanacearum* before planting in greenhouses. Before certification, mini tubers are subjected to the same tests.

The Certification Scheme is managed on a day to day basis as a management system and not only for record purposes. A complete database has been developed enabling us to trace the route of any seed consignment. Changes in disease frequencies per farm or region can be rapidly identified. All registered plantings are monitored by a satellite navigational system to accurately determine areas and to monitor crop rotation systems. The satellite navigational system can be use by potato growers for farm planning purposes as well.

OBJECTIVES OF THE SCHEME

TO SUPPLY QUALITY SEED POTATOES TO THE INDUSTRY.

The purpose of certification is to certify seed potatoes of which the phyto-sanitary status in respect of diseases and pests, falls within predetermined norms and which is true to type.

BENEFITS OF THE SCHEME

1. **The building up of diseases in seed potatoes and the concomitant building up of diseases in soils will be limited.**

2. The planting of early generation planting material will contribute to greater certainty that the minimum seed-borne diseases are present in seed potatoes.

3. The fact that no uncertified material may be planted on the same land as registered seed potatoes, will combat the infection of plantings with viruses and other diseases.

ACKNOWLEDGEMENT

I would like to thank Dr.Pierre Nortje from Potatoes South Africa for the informative role he played to supply me with suitable information to present this paper.

TOOLS UNDERPINNING POTATO RESEARCH ON THE CONTROL OF BACTERIAL WILT

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INTRODUCTION

A number of tools ('inventions' and technology adoptions) have been utilised in the course of research activities on potato bacterial wilt under the project 'Biological control of potato bacterial wilt in Kenya'. The tools have been developed and/or adopted to address various bottlenecks encountered during various efforts to control potato bacterial wilt using a small-scale seed-potato production system (SSPS) (Kinyua *et al.*, 1998).

THE TOOLS

Some of the tools include the following:

1. A simple grader: This was developed to enhance seed tuber selection. Most farmers in Kenya use home-saved, undersized tubers from a ware cropping system. Such tubers are known to be low yielding and have high risks of harbouring tuber-borne diseases such as bacterial wilt and viruses. Potato tubers for planting should have diameters between 25mm and 55mm. An ideal seed tuber should be around 45mm in diameter (egg size).

The simple grader has two holes, 25mm and 35mm diameter, and helps in avoiding extremely small tubers for planting. The minimum diameter for potato varieties with oblong (oval-shaped) tubers (e.g. 'Roslin Tana', 'Nyayo', etc.) should be 25mm; a tuber that passes through the 25mm hole should not be used for planting. The minimum diameter for potato varieties with rounded tubers (e.g. 'Tigoni', 'Asante', 'Kerr's Pink', etc.) should be 35mm; a tuber that passes through the 35mm hole should not be used for planting.

2. Improvised dibber. This tool helps in making holes for planting seed potato tubers, at a very close spacing of 20cm by 20cm, in seed plots. It's simply a spade handle without the blade and the wooden end is tapered for ease of making holes in well-loosened soil. Its length is about 60cm with a mark at 15cm from the tapered end; the mark shows how deep the dibber should be driven into the ground when making holes. By planting in seed plots, land productivity for seed potato tubers has been increased almost threefold; this has helped in making crop rotation more feasible because less land is committed for seed production compared to a ware planting system. The dibber also enables deep planting which eliminates the need for hilling after plant emergence.

3. NCM-ELISA kit: The kit is used for detection of latent infections in tubers. Enzyme-Linked Immunosorbent Assay on Nitrocellulose Membrane (NCM-ELISA) is an immuno-enzymatic assay which utilises a nitrocellulose membrane instead of a microtitre plate to hold samples and reagents. The assay is quick and easy to perform. Additionally, the nitrocellulose membrane can be stored for several weeks after loading the samples before completing the serological test (International Potato Centre, 1998). Although the NCM-ELISA kit was initially introduced for the purpose of verification under Kenyan conditions, it has been used in detection of latent infections in potato tubers originating

from the small-scale seed-potato production system (SSPS) and has proved a very useful tool. The kit can be used in monitoring populations of *Ralstonia solanacearum* in seed certification schemes, varietal evaluation for resistance/tolerance to bacterial wilt and research on the development of bacterial wilt control components.

4. Semi-selective media: In addition to the utilisation of the NCM-ELISA kit in detection of tuber latent infections, semi-selective media have been adopted for culturing and enumeration of *R. solanacearum* in soils and plant materials. Both Kelman's medium (Kelman, 1954) and SMSA (Englebrecht, 1994) have been utilised.

5. Extension materials: The success of on-farm research activities is partly dependent on the ability of the farmers to participate in the experiments. Therefore, information dissemination and training to farmers has been enhanced through the use of advisory bulletins, calendars with extension messages, and tools such as the dibber and tuber graders described above. These extension materials have greatly improved the understanding and participation of farmers in the SSPS experiments. The use of extension materials has been coupled with seminars/open day meetings for farmers and agricultural extension staff.

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DEVELOPMENT OF RURAL AGRICULTURE IN SOUTH AFRICA – THE FUNCTIONING OF AGRICULTURAL CO-OPERATIVE SOCIETIES BY SMALLHOLDERS

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INTRODUCTION

There are four major factors to be considered when doing Rural Agricultural Development:

1. Participation
2. Communication/ (Top-down)
3. Empowerment/Training
4. Feedbacking/reporting

RURAL DEVELOPMENT HAS BEEN IDENTIFIED AS A KEY STRATEGIC AREA FOR GOVERNMENT INTERVENTION, AS PART OF ITS STRATEGIC AREA FOR GOVERNMENT INTERVENTION, AS PART OF ITS STRATEGY, TO CREATE SUSTAINABLE RURAL LIVELIHOOD AND POVERTY ALLEVIATION.

PARTICIPATION OF ARC IN RURAL AGRICULTURAL DEVELOPMENT IN SOUTH AFRICA

ARC has a formidable research and development capacity, which can play a critical role in rural development in South Africa. ARC has developed a Resource Poor Agriculture Programme to address the diverse needs of the rural development sector. The RPA programme in ARC intends to commit its resources to the national effort on rural development.

Participation of ARC in rural development is done in a co-ordinated manner with other role-players in the communities. The programme of RPA is organized according to ARC Thrusts. The Thrust were done according to the needs identification with clients (farmers and communities) and stakeholders such as National and Provincial government.

SPECIAL COMPONENTS IDENTIFIED AND PRIORITIES BY ARC

i.) Gender
ii.) Indigenous knowledge systems
iii.) Land reform/tenure
iv.) Urban Peri-urban and Rural development
v.) African involvement

The ARC Thrusts are as follows:-

1. Information resources:

This Thrust consists of three sub-Thrusts such as follows:-

- Training
- Transfer of information and technology
- Media options

2. Development of Production and Agri-processing enterpreneurships through new market and product development.

The Thrust is presented in three sub- Thrusts:-

- **Product development**
- **Market surveys, feasibility studies and business plans**
- **Implementation assistance**

3. Improved Plant Protection, animal health, human health and Nutrition in RPA sector.

It is also presented in three sub-Thrusts: -

- Plant Protection
- Animal Health care
- Human nutrition

4. Development of appropriate tools, instruments and equipment for improved production and value adding in RPA and related sectors.

The Thrust is presented in three sub-Thrusts such as:-

- Production
- Processing and storage
- Infrastructure

5. Development of agricultural production systems for the urban, peri-urban and rural Environment.

This Thrust is also presented in three sub-Thrusts:-

- Livestock Production systems
- Crop Production systems
- Mixed farming systems

6. Natural Resource management and Inventories

The Thrust is presented in four sub-Thrusts:-

- Data collection
- Land care
- Small scale collection
- Environmental impacts

FOR THE SUCCESSFUL IMPLEMENTATION OF THE ABOVE THRUSTS IS THROUGH THE AVAILABILITY OF CAPITAL TO ACHIEVE THE GOALS OF RURAL AGRICULTURAL DEVELOPMENT FOR THE COMMUNITIES.

THE ROLE OF AGRICULTURAL CO-OPERATIVES IN SOUTH AFRICA.

The South African political background gave rise to a three pronged character of the South African co-operatives such as:-

i) A well developed co-operative movement amongst developed communities.
ii) Co-operative developed in the former homelands mostly agricultural fields.

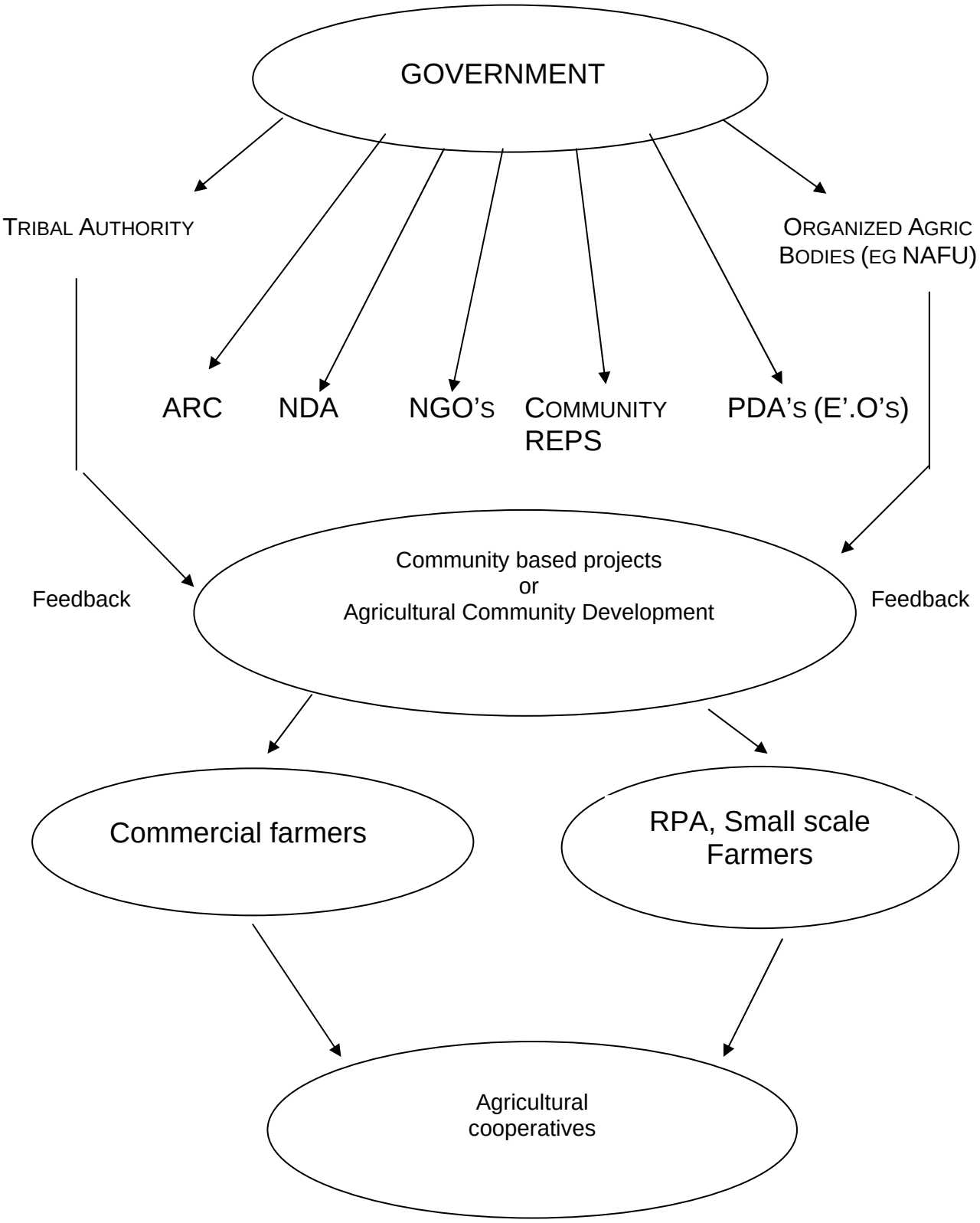
iii) Informal co-operatives i.e. groups functioning like co-operatives but not registered in terms of co-operatives legislation mainly in urban areas.

Co-operatives are seen as private enterprise. The agricultural co-operatives deals with the supply of agricultural inputs like fertilizers, seeds etc and collecting and processing of agricultural products. Co-operatives can sustain the agricultural projects of the RPA farmers in rural areas. The co-operatives in Rural agricultural Community Development have been established on the following objectives.

- Food security
- Job creation
- Rendering of community service
- Economic promotion
- Access to financial services
- Training

Co-operatives in South Africa are formed on the basis of government policy and legislation. Co-operatives are registered and should be known to the government in order to be protected and provided help by the government. The establishment of the co-operatives is to empower people or farmers to help themselves financially not depending from the government and donors in the long run.

RURAL AGRICULTURAL DEVELOPMENT PROTOCOL THROUGH PARTICIPATION IN SOUTH AFRICA



THE CONTRIBUTION OF COMMUNITY SEED POTATO PRODUCTION AND STORAGE TO FOOD SECURITY IN KABALE DISTRICT: A CASE OF AFRICARE/UGANDA.

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Africare's involvement in grassroot development in Africa

Africare is a private non-profit making, charitable and development oriented non governmental organization founded in 1971 in USA with its headquarters based in Washington D.C. It is currently implementing over 150 programs in 28 African countries in the areas of Agriculture, Health, Natural Resource Management, Humanitarian Relief and Local governance. Its assistance is focused on families and communities Africa-wide. It is a member of International Service Agencies (ISA), a part of the Federal Campaign and many corporate as well as state and local government campaigns. It is supported by charitable foundations, the religious community, private organizations, the U.S. government, international agencies, foreign institutions and thousands of individuals.

Current Africare activities in Uganda

Africare is currently implementing a five-year Uganda Food Security Initiative (UFSI) project that started in April 1997 and is scheduled to end by September 2001. The goal of UFSI is to improve household food security in Uganda, particularly Kabale district. It is targeting 71,000 persons in 106 villages. Africare has a project on Integrated management of' Childhood Illnesses (IMCI) for Ntugamo district which started in October 1999.

Objectives of UFSI:

- Increase the quantity of food available for rural household consumption
- Protect soils against erosion and establish means of maintaining and increasing soil fertility
- Provide year around access and egress for commerce, production and marketing
- Enhance household utilization of food, particularly women and children

In order to realize the above objectives, four components are being implemented namely Soil Conservation and Erosion Control, Community Roads Construction, Agricultural Production & Post Harvest Handling and Community Nutrition.

Major constraints and intervention identified during baseline survey and Participatory Rural Appraisals affecting Potato Production in UFS1 target communities in Kabale district:

Food production in Kabale district is critical as the majority (~90 %) of her inhabitants, who are the rural poor, do not have other means of survival without directly depending on the land. However the capacity to meet food production was declining with time. During the baseline survey and interactive participatory rural appraisals (PRAs) the communities identified several factors as being responsible for this scenario. These factors included low soil fertility. Lack of low cost high quality seed of improved crop varieties, High crop losses due to poor storage techniques and structures, poor

agronomic practices, increasing incidences of diseases and insect pests and low farm incomes due to poor marketing and lack of value added products.

The UFSI target communities in partnership with Africare developed strategies to increase crop production and productivity, reduce post harvest losses of seed and food in storage and strengthen the organization and capacity of Kabale farmers, institutions, farmers associations and local NG0s, in organizing, implementing and monitoring food security activities. The priority crops identified by farmers for both cash and food were potato, beans, sweet potato and maize. The potato was clearly the top priority crop for which every farmer thought intervention activities should be implemented to mitigate the problems affecting it. The entry point for the activities was unanimously agreed on as through making available clean seed of improved potato varieties. To do this UFSI target communities developed Village Action Plans (VAP's) which also included rules and regulations, elected Production Committees of 7 members to give leadership, ownership and oversee the activities. Africare then developed a flow chart for an informal community based seed potato production and storage scheme. The thrust of this scheme is to develop the capacity of the communities to produce and multiply high quality seed of improved potato varieties that are generated by the National Agricultural Research Organization (NARO). The philosophy is to enable communities access to varieties with superior attributes and it is hoped that by the end of the project some of the communities either as individuals under Uganda National Seed Potato Producers Association (UNSPPA), small groups or as a whole will be commercial seed producers for the rest of the communities, neighbouring districts and countries. This should have a multiplier effect with benefits of availability of seed to neighbouring communities as well as increased crop yields and increase in food security in the district and wider region.

Rationale for the scheme:

The history of successful potato production in Southwest Uganda has been mixed. It was introduced by colonial administrators in the 1890s and it rapidly spread to the highlands as a garden crop. In the 1940s it was wiped out by late blight and production was sustained by imports from Kenya. In 1968/69, a potato improvement program funded by the Rockefeller Foundation and implemented by was initiated and by 1974, a number of varieties were released namely Uganda 11, Bufumbira, Malirahinda, Muhabura, Nyabwisheny, Kachwekano, Kalengyere, Kabera, Makerere, Lubega and Wurster. However due to all outbreak of political turmoil this program was interrupted and there was decline in production. In 1987 Cruza and Sangema were introduced from Rwanda. Breeding activities were re-initiated in 1989 which resulted in the release of 3 varieties in 1991 i.e. Victoria (381381.20), Kisoro (381379.9) and Kabale (374080.5).

In 1999, 3 other varieties were released viz CIP 382171.4 (NAKPOT 1), CIP 381403.8 (NAKPOT 2) and CIP 575049 (NAKPOT 3). Since the commencement of the program, in the early 1990s, the potato program has developed a strong basic seed program which produces about 100 Metric tonnes (MT) annually. Between 1990 and 1996. the potato program produced basic seed which was then allocated and distributed to districts country-wide as directed by the Ministry of Agriculture Animal Industry and Fisheries (MAAIF). This seed was supposed to be sold and the proceeds banked with the treasury. It was clear that this valuable seed was used to grow ware without realizing any multiplier effect. In the process, there was a perpetual shortage of seed and moreover it was only reaching the relatively well off and the resource poor farmers were being sidelined. This was < 1 % of the national seed requirement. The rest of the farmers were relying on the traditional sources from their own saved seed which was usually the rejects left to sprout, neighbours and open market. In the communities there were recognized farmers specializing in producing seed. The strategy was to improve on this already existing informal farmer based seed potato production system which was based

on business oriented progressive farmers. Those farmers were limited in number and moreover it was still not accessible to the resource poor farmers. When Africare initiated the activities the strategy was to benefit the resource poor small scale farmers for whom food security was critical. This has been achieved by pooling of communal resources to purchase inputs. rent good land, provide materials for store construction and avail labour for field and store construction activities.

Progress and achievements of UFS1 under the community based seed potato production and storage scheme in Kabale district:

Partnership and collaboration:

In order to ensure technical competence of field staff and access to basic seed of improved potato varieties a formal Memorandum of Understanding (MOU) and purchase was signed between Africare and NARO thereby establishing a formal and close partnership with clear expectations from all parties. MOUs were also signed with the target communities (106 villages, 11 women groups. 2 Youth groups and 1 Widows and orphans group) in which the contributions by Africare and communities are clearly spelt out. To complement the farmers training aspects. CIP, NARO and Africare are implementing 8 farmer field schools on IPM of late blight.

Community capacity building:

The capacity of the communities to identify their problems and design activities to mitigate them has been enhanced. The Village production committees identify a site for seed production. The extensionists inspects the land and gives approval on the basis of history, location. presence/absence of volunteers, soil fertility and proximity of ware crop. The community organizes land preparation and is guided by the rules and regulations. The community purchases inputs, supplies compost and animal manure. and provides all the requisite labour for field activities. It also assures security of the activities.

Farmer training:

There is an efficient extension system with the current coverage of 1 extensionist to 1170 farm families. There has been deliberate effort to change farmers attitudes through farmer to farmer exchange visits, drama shows and study tours. As a result of this there are now over 70 farmers confident and willing to train other non-target farmers as volunteers (farmer extensionists).

Asset creation:

Construction of 63 five-tonne diffused light stores has been accomplished in 63 villages. The stores have reduced post harvest losses from 40- 26 %. The store is communally owned. It is sighted in one of the members homes who signs an agreement with the community to utilize it for the next 10 years. Thereafter it may become the property of the landowner or they may reverse the agreement and extend the ownership. Africare contributes roofing iron sheets. perspex sheets nails, doors, ventilators and timber to hold the tubers in the shelves and pays for skilled labour. The farmers put up the wall and shelves with their own materials and provide all the manual labour.

Seed potato production and diffusion:

Africare has so far supplied 58 MT of basic seed of improved varieties such as Victoria, Uganda 11, Musitamya, 388575.5 and Kisoro over the past 5 seasons. Of these 4 seasons have given 259.4 MT which have benefited 25,000 people in 3571 households.

As a result the yields have increased from 7 MT/ha to 12.2 MT/ha. In the UFSI target villages the number of farmers utilizing improved seed has increased a hundred-fold by 1999. A survey conducted in July 1999 indicated that 59.8 % of the target farmers passed on the seed to other farmers by way of gifts and sale. It was found that on average seed potato informally flowed/diffused to 3.4 other farmers.

Major constraints and challenges:

Inadequate seed health mainly attributable to bacterial wilt infections due to reluctance to rogue out (volunteers and infected), inaccurate land history, latent infections at all levels of seed production.

Late blight due to the favourable weather, adulterated/fake fungicides, improper use of chemicals, continuous cultivation and late seedbed preparation. Inadequate resource mobilization among farmers due to poverty (for fungicides, land and other inputs.)

Prospects and opportunities:

- Well developed informal based seed production, distribution and marketing system based on a farmers association.
- Target farmers to become business oriented seed growers.
- Improved knowledge in control diseases/pests and sustainable crop production.
- Improved knowledge in post harvest handling and marketing skills.
- Empowered confident communities planning and making decisions for their own benefits.

END OF PROJECT REVIEW – 4th – 6th of April 2000

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Appendix B

SUMMARY OF STATISTICAL ANALYSIS

BIOLOGICAL CONTROL AGENT (BCA) EFFICACY, FORMULATION AND INTERACTION WITH POTATO VARIETIES AND *R. SOLANACEARUM* WILD TYPES (WTS) OF WORLD-WIDE ORIGINS

EFFICACY OF BCA

BCA EFFICACY ASSESSMENT UNDERTAKEN AT CABI BIOSCIENCE UK CENTRE [EGHAM]

***** ACCUMULATED ANALYSIS OF DEVIANCE AT DAY 56*****

Change	d.f	deviance	mean deviance	deviance ratio	approx F pr.
+ Rep	7	8.767	1.252	0.60	0.757
+ BCA	1	39.759	39.759	18.94	<.001
Residual	87	182.631	2.099		
Total	95	231.157	2.433		

Dispersion parameter is estimated to be 2.18 from the residual deviance

BCA EFFICACY ASSESSMENT UNDERTAKEN AT ARC VOPI

***** ACCUMULATED ANALYSIS OF DEVIANCE AT DAY 56*****

Change	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
+ Rep	1	1.312	1.312	1.31	0.252
+ BCA	2	44.054	22.027	22.03	<.001
Residual	146	162.151	1.111		
Total	149	207.517	1.393		

* MESSAGE: ratios are based on dispersion parameter with value 1

PATHOGENICITY OF *R. SOLANACEARUM* BIOVAR 2A ISOLATES REPRESENTATIVE OF PERU, COLOMBIA AND OTHER COUNTRIES ON DIVERSE POTATO VARIETIES, AND IMPACT ON BCA EFFICACY

PATHOGENICITY ASSESSMENT ON *R. SOLANACEARUM* BIOVAR 2A ISOLATES REPRESENTATIVE OF PERU, COLOMBIA AND OTHER COUNTRIES ON *S. TUBEROSUM* AND *S. ANDIGENA* VARIETIES

***** ACCUMULATED ANALYSIS OF DEVIANCE AT DAY 19*****

Change	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
+ Replicate	3	2.426	0.809	0.81	0.489
+ Strcom	2	42.367	21.183	21.18	<.001
+ Varcom	1	0.267	0.267	0.27	0.605
+ Strcom.Varcom	2	4.907	2.453	2.45	0.086
Residual	311	353.605	1.137		
Total	319	403.572	1.265		

Ratios are based on dispersion parameter with value 1

***** ACCUMULATED ANALYSIS OF DEVIANCE AT DAY 23*****

Change	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
+ Replicate	3	6.6320	2.2107	2.21	0.085
+ Strcom	2	38.8851	19.4425	19.44	<.001
+ Varcom	1	9.2692	9.2692	9.27	0.002
+ Strcom.Varcom	2	0.4592	0.2296	0.23	0.795
Residual	311	134.6523	0.4330		
Total	319	189.8978	0.5953		

Ratios are based on dispersion parameter with value 1

BCA EFFICACY ASSESSMENT AGAINST *R. SOLANACEARUM* BIOVAR 2A ISOLATES REPRESENTATIVE OF PERU AND OTHER COUNTRIES (EXCEPT COLOMBIA)

***** ACCUMULATED ANALYSIS OF DEVIANCE AT 14 DAYS*****

Change	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
+ Replicate	3	2.5616	0.8539	0.85	0.464
+ BCA	3	181.8699	60.6233	60.62	<.001
+ Isolate	1	0.9357	0.9357	0.94	0.333
+ Variety	1	0.1041	0.1041	0.10	0.747
+ BCA.Iso	3	2.2120	0.7373	0.74	0.530
+ BCA.Var	3	2.3393	0.7798	0.78	0.505
+ Iso.Var	1	0.0808	0.0808	0.08	0.776
+ BCA.Iso.Var	3	13.4367	4.4789	4.48	0.004
Residual	301	232.8469	0.7736		
Total	319	436.3869	1.3680		

Ratios are based on dispersion parameter with value 1

***** ACCUMULATED ANALYSIS OF DEVIANCE AT 18 DAYS*****

Change	d.f.	deviance	mean deviance	deviance ratio	approx chi.pr
+ Rep	3	4.1778	1.3926	1.39	0.243
+ BCA	3	203.5900	67.8633	67.86	<.001
+Isolate	1	4.1888	4.1888	4.19	0.041
+ Variety	1	1.0540	1.0540	1.05	0.305
+ BCA.Iso	3	3.8519	1.2840	1.28	0.278
+ BCA.Var	3	1.0534	0.3511	0.35	0.788
+ Iso.Var	1	1.0446	1.0446	1.04	0.307
+ BCA.Iso.Var	3	15.9111	5.3037	5.30	0.001
Residual	301	207.4918	0.6893		
Total	319	442.3634	1.3867		

Ratios are based on dispersion parameter with value 1

EPIDEMIOLOGY OF BCA AND *R. SOLANACEARUM* WT POPULATIONS IN SOIL, AND INTERACTION WITH POTATO AND ROTATION CROPS

SURVIVAL OF BCA AND *R. SOLANACEARUM* WT IN SOIL AND INTERACTION WITH POTATO

***** ANALYSIS OF VARIANCE ON BCA POPULATIONS AT DAY 56 *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.7550	0.3775	2.99	
Rep.*Units* stratum					
BCA	1	0.5633	0.5633	4.46	0.079
Treatment	1	0.0833	0.0833	0.66	0.448
BCA.Treat	1	0.0300	0.0300	0.24	0.643
Residual	6	0.7583	0.1264		
Total	11	2.1900			

***** ANALYSIS OF VARIANCE ON BCA POPULATIONS AT DAY 113 *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.6017	0.3008	0.76	
Rep.*Units* stratum					
BCA	1	0.1633	0.1633	0.41	0.544
Treatment	1	0.1633	0.1633	0.41	0.544
BCA.Treat	1	0.5633	0.5633	1.43	0.277
Residual	6	2.3650	0.3942		
Total	11	3.8567			

***** ANALYSIS OF VARIANCE ON WT POPULATIONS AT DAY 56 *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.4617	1.2308	1.74	
Rep.*Units* stratum					
WT	1	2.3408	2.3408	3.30	0.119
Treatment	1	6.3075	6.3075	8.90	0.025
WT.Treat	1	1.2675	1.2675	1.79	0.230
Residual	6	4.2517	0.7086		
Total	11	16.6292			

***** ANALYSIS OF VARIANCE ON WT POPULATIONS AT DAY 113 *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.7617	0.3808	1.85	
Rep.*Units* stratum					
WT	1	0.4033	0.4033	1.95	0.212
Treatment	1	2.4300	2.4300	11.77	0.014
WT.Treat	1	0.6533	0.6533	3.17	0.126
Residual	6	1.2383	0.2064		
Total	11	5.4867			

Appendix B

SEED PRODUCTION – IMPROVING SEED MANAGEMENT AND ESTABLISHING A 'WINDOW' FOR THE APPLICATION OF THE BCA

SEED SIZE AND WARE YIELD

ASSESSMENT AT KARI NARL

***** ACCUMULATED ANALYSIS OF VARIANCE ON YIELD*****

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Rep	3	11.588	3.863	1.47	0.233
+ Variety	1	96.980	96.980	36.96	<.001
+ Treatment	1	0.001	0.001	0.00	0.988
+ Seedsize	4	72.687	18.172	6.93	<.001
+ Var.Treat	1	0.037	0.037	0.01	0.906
+ Var.Ssize	3	18.603	6.201	2.36	0.082
+ Treat.Ssize	4	10.597	2.649	1.01	0.411
+ Var.Treat.Ssize	3	0.838	0.279	0.11	0.956
Residual	51	133.807	2.624		
Total	71	345.138	4.861		

***** ANALYSIS OF VARIANCE ON TUBER NUMBER AND SIZE DISTRIBUTION*****

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	917.03	305.68	3.10	
Rep.Var.Ssize.Treat stratum					
Variety	1	6317.19	6317.19	63.98	<.001
Seedsize	4	7053.58	1763.40	17.86	<.001
Treatment	1	198.41	198.41	2.01	0.162
Var.Ssize	3(1)	1367.57	455.86	4.62	0.006
Var.Treat	1	62.19	62.19	0.63	0.431
Ssize.Treat	4	239.08	59.77	0.61	0.661
Var.Ssize.Treat	3(1)	18.32	6.11	0.06	0.980
Residual	51(6)	5035.22	98.73	3.60	
Rep.Var.Ssize.Treat.Cl stratum					
Class	4	5422.81	1355.70	49.41	<.001
Cl.Var	4	970.13	242.53	8.84	<.001
Cl.Ssize	16	1987.58	124.22	4.53	<.001
Cl.Treat	4	97.68	24.42	0.89	0.471
Cl.Var.Ssize	12(4)	684.54	57.04	2.08	0.019
Cl.Var.Treat	4	100.16	25.04	0.91	0.457
Cl.Ssize.Treat	16	948.99	59.31	2.16	0.007
Cl.Var.Ssize.Treat	12(4)	521.33	43.44	1.58	0.098
Residual	216(24)	5926.00	27.44		
Total	359(40)	35624.77			

Appendix B

ASSESSMENT AT NJABINI

***** ANALYSIS OF VARIANCE ON YIELD*****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Farm stratum	3	1048.73	349.58	8.86	
Farm.Var.Ssize stratum					
Variety	1	275.52	275.52	6.98	0.018
Seedsize	2	995.79	497.90	12.61	<.001
Var.Ssize	2	12.79	6.40	0.16	0.852
Residual	15	592.15	39.48	3.08	
Farm.Var.Ssize.Treat stratum					
Treatment	1	67.69	67.69	5.28	0.034
Var.Treat	1	28.52	28.52	2.22	0.153
Ssize.Treat	2	47.38	23.69	1.85	0.186
Var.Ssize.Treat	2	15.04	7.52	0.59	0.567
Residual	18	230.87	12.83		
Total	47	3314.48			

*****ANALYSIS OF VARIANCE ON TUBER NUMBER AND DISTRIBUTION*****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Farm stratum	3	62215.	20738.	13.67	
Farm.Var.Ssize stratum					
Variety	1	36.	36.	0.02	0.880
Seedsize	2	93125.	46563.	30.70	<.001
Var.Ssize	2	3459.	1729.	1.14	0.346
Residual	15	22753.	1517.	1.80	
Farm.Var.Ssize.Treat stratum					
Treatment	1	5199.	5199.	6.18	0.023
Var.Treat	1	3176.	3176.	3.78	0.068
Ssize.Treat	2	3413.	1707.	2.03	0.160
Var.Ssize.Treat	2	3017.	1508.	1.79	0.195
Residual	18	15140.	841.	0.83	
Farm.Var.Ssize.Treat.Cl stratum					
Class	4	200175.	50044.	49.57	<.001
Var.Cl	4	163241.	40810.	40.42	<.001
Ssize.Cl	8	20020.	2502.	2.48	0.015
Treat.Cl	4	6822.	1705.	1.69	0.156
Var.Ssize.Cl	8	16716.	2090.	2.07	0.042
Var.Treat.Cl	4	9488.	2372.	2.35	0.057
Ssize.Treat.Cl	8	7827.	978.	0.97	0.463
Var.Ssize.Treat.Cl	8	13737.	1717.	1.70	0.103
Residual	144	145386.	1010.		
Total	239	794945.			

ii) SMALL-SCALE (ON-FARM) SEED PRODUCTION SYSTEM (SSPS)

*****ANALYSIS OF VARIANCE ON TOTAL TUBER NUMBER AND DISTRIBUTION*****

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Farm stratum	5	3019.31	603.86	7.04	
Farm.Var.Syst stratum					
Variety	1	189.90	189.90	2.21	0.165
System	1	18076.37	18076.37	210.83	<.001
Var.Syst	1	72.61	72.61	0.85	0.377
Residual	11(4)	943.14	85.74	3.42	
Farm.Var.Syst.Ph stratum					
Phase	3	333.02	111.01	4.43	0.008
Var.Ph	3	98.35	32.78	1.31	0.283
Syst.Ph	3	192.57	64.19	2.56	0.066
Var.Syst.Ph	3	19.12	6.37	0.25	0.858
Residual	46(14)	1153.31	25.07	0.39	
Farm.Var.Syst.Ph.*Units* stratum					
Class	4	15342.62	3835.65	59.39	<.001
Var.Cl	4	4539.61	1134.90	17.57	<.001
Syst.Cl	4	9204.72	2301.18	35.63	<.001
Ph.Cl	12	4823.21	401.93	6.22	<.001
Var.Syst.Cl	4	1410.28	352.57	5.46	<.001
Var.Ph.Cl	12	681.78	56.82	0.88	0.568
Syst.Ph.Cl	12	2423.02	201.92	3.13	<.001
Var.Syst.Ph.Cl	12	281.75	23.48	0.36	0.975
Residual	248(72)	16016.19	64.58		
Total	389(90)	65083.78			

***** ANALYSIS OF VARIANCE ON AVERAGE TUBER WIEGHT - PHASE 1 DATA ONLY *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	5	792.33	158.47	6.74	
Rep.*Units* stratum					
System	1	1350.00	1350.00	57.42	<.001
Variety	1	416.67	416.67	17.72	<.001
Sys.Var	1	20.17	20.17	0.86	0.369
Residual	15	352.67	23.51		
Total	23	2931.83			

Appendix B

*****ANALYSIS OF VARIANCE ON LAND INDEX – SEED M^{-2}*****

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Farm stratum	5	11669.41	2333.88	11.51	
Farm.Var.Syst stratum					
Variety	1	910.45	910.45	4.49	0.043
System	3	72952.81	24317.60	119.91	<.001
Var.Syst	3	86.27	28.76	0.14	0.934
Residual	27(8)	5475.43	202.79	2.55	
Farm.Var.Syst.Ph stratum					
Phase	3	3691.61	1230.54	15.49	<.001
Var.Ph	3	1105.65	368.55	4.64	0.005
Syst.Ph	9	1326.23	147.36	1.85	0.069
Var.Syst.Ph	9	469.05	52.12	0.66	0.746
Residual	92(28)	7310.33	79.46		
Total	155(36)	88942.91			

***** ACCUMULATED ANALYSIS OF VARIANCE ON WARE YIELDS *****

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Farm stratum	5	11562.93	2312.59	45.05	
Farm.Var.Sys stratum					
Variety	1	1769.17	1769.17	34.47	<.001
System	2(1)	134.20	67.10	1.31	0.294
Var.Syst	2(1)	52.07	26.03	0.51	0.610
Residual	19(16)	975.30	51.33	1.17	
Farm.Var.Syst.Ph stratum					
Phase	3	8391.29	2797.10	63.80	<.001
Var.Ph	3	677.92	225.97	5.15	0.003
Syst.Ph	6(3)	502.11	83.68	1.91	0.092
Var.Syst.Ph	6(3)	188.28	31.38	0.72	0.638
Residual	69(51)	3025.24	43.84		
Total	116(75)	20177.18			

Appendix B

OPTIMISATION OF SSPS SEED CULTIVATION SPACING AND INTERACTION BETWEEN VARIETIES

SEED PRODUCTION UNDER VARYING PLANT DENSITIES AND PLANTING METHODS

ANALYSIS OF VARIANCE ON TUBER NUMBER AND DISTRIBUTION

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	12.878	6.439	0.25	
Rep.Var.Sp stratum					
Variety	2	3094.144	1547.072	59.30	<.001
Spacing	3	6354.639	2118.213	81.20	<.001
Var.Sp	6	2420.744	403.457	15.47	<.001
Residual	22	573.922	26.087	3.62	
Rep.Var.Sp.Cl stratum					
Class	4	8250.967	2062.742	286.49	<.001
Var.Cl	8	1482.633	185.329	25.74	<.001
Sp.Cl	12	5144.056	428.671	59.54	<.001
Var.Sp.Cl	24	2123.144	88.464	12.29	<.001
Residual	96	691.200	7.200		
Total	179	30148.328			

***** ANALYSIS OF VARIANCE ON LAND INDEX – SEED M^{-2}*****

SOURCE OF VARIATION	D.F.	S.S.	M.S.	V.R.	F PR.
Rep stratum	2	24.50	12.25	0.20	
Rep.*Units* stratum					
Variety	2	7547.17	3773.58	60.83	<.001
Spacing	3	28513.42	9504.47	153.20	<.001
Var.Sp	6	7036.83	1172.81	18.90	<.001
Residual	22	1364.83	62.04		
Total	35	44486.75			