CROP PROTECTION PROGRAMME

Characterisation and epidemiology of root rot diseases caused by *Fusarium* and *Pythium* spp. in beans in Uganda

R7568 (ZA0373)

FINAL TECHNICAL REPORT

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Executive summary:500 words

This project has examined the problem of bean root rot using a combination of scientific and socio-economic research. The study has advanced our knowledge of the biology of the disease, the causal agents, their epidemiology and interactions with other bean pests and pathogens. It has also investigated farmers' indigenous knowledge, perceptions of the causes of root rots and potential control measures. The study has focussed on the disease in Uganda but research has been undertaken by international teams. Work on root rots integrates well with other bean research in several national and international programmes. Investment in equipment and staff training has enhanced research capability in Uganda and attracted other donors.

Important progress has been made:

- Studies were made of indigenous technical knowledge of root rots, farmers' crop management practices and their perception of root rots. Farmer groups were established and training, knowledge transfer and resource supply was undertaken. The analysis of survey data from Kabale and Kisoro districts covering farmers' ITK, factors influencing disease, resource distribution, and communication systems, was completed. Dissemination methodologies suitable for effective technology transfer to resource-poor farmers were identified from several PRAs and surveys of farmers' ITK and information flow within communities. Based on the surveys and insights gained on farmer understanding of root rots, and success with the modified farmer field school approach, dissemination materials are under development.
- Surveys of farmers' fields and large collections of root rot pathogens were made.
- Novel rapid and reliable molecular diagnostic tools for the identification, differentiation and quantification of *Fusarium* and *Pythium* were developed, tested and applied to the pathogens collected.
- The distribution of *Fusarium* and *Pythium* spp. associated with root rots in Uganda has been mapped.
- Interactions between root rot pathogens and other biotic (e.g. nematodes and bean stem maggot) factors influencing disease were investigated. In glasshouse tests *Fusarium solani* was a more damaging pathogen than either of two *Pythium* spp. A nematode survey revealed slight galling due to root knot nematodes (RKN) present in many fields but severe galling was rare and there was no association between root rots and RKN.
- Management strategies for control of root rot, appropriate to resource-poor farmers, have been evaluated in terms of their effect on pathogen populations as well as their impact on disease. Several farmer-managed trials were established in community plots involving six farmer groups (with a total of over 100 members). These included participatory variety selection of root rot resistant varieties and fertility improvement using different types of manure. Materials and technology of interest were then selected for use in farmers' individual plots.

- Root rot resistance of nearly 500 bean accessions has been quantified in screen house trials and in farmers' fields. Over 300 germplasm entries were screened for resistance to *Pythium* root rot under artificial inoculation in a screenhouse. Accessions in a root rot nursery (68 entries) and a segregating population (110 entries) were screened at the highland NARO station of Kachiwekano. Several potentially valuable accessions have been identified and will be subjected to further trials.
- Acceptance criteria of root rot management technologies evaluated with farmer groups are better understood and form the basis of scaling up efforts.

Background:

The common bean *Phaseolus vulgaris* is the second most important source of human dietary protein and the third most important source of calories of all agricultural commodities produced in eastern and southern Africa (Pachico, 1993). Production is concentrated in the cool highlands of these areas and as the most important pulse crop in Uganda, beans are grown throughout the country but especially in the south-west. An important food to people of all income categories, beans are especially important to the poor as a source of dietary protein because animal protein is often rare or completely absent from their diets.

In east Africa beans are grown primarily by smallholder farmers, especially women, for home consumption and any excess production would be sold at market. Thus beans play an essential role in the sustainable livelihoods of smallholder farmers and their families providing both food security and income generation. In many areas there are several growing seasons per year, thus crops are grown with minimal rotation and limited or no fallow period. This has led to a decline in soil fertility together with an increase in pest and disease pressure.

Root rot is a major constraint to bean production (CIAT, 1986, 1992). In South Western Uganda in 1994, bean production dropped to 25% of its previous level, dropping further to 20% in 1995. This drop in yield has been attributed to the effect of insect pests and diseases, especially root rot (Opio, 1999).

Bean Root Rots

Root rots of beans have become increasingly important in several areas of eastern and central Africa where intensity of bean production is high. Occurrence and severity are associated with high intensity of bean production and where intensification of land use has resulted in reduced crop rotation and fallow periods, leading to a decline in soil fertility and a likely build up of soil pathogen inoculum. Root rots are currently a major problem in Uganda causing crop failures in some seasons. The increase in human population, land use and decline in soil fertility is expected to be associated with the rise in incidence and severity of root rots over time unless efforts are made to develop sustainable management technologies.

Root rots are believed to be caused by one or more soil-borne pathogens that act either alone or as a complex of two or more pathogens depending on environmental conditions (Rusuku *et al*., 1997). Pathogens that have been isolated from plants displaying root rot symptoms include: *Fusarium oxysporum*, *Fusarium solani*, *Rhizoctonia solani* and *Pythium* spp. The increasing importance and widespread distribution of root rots illustrates the need to understand disease aetiology and to accurately diagnose the components of the pathogen complex responsible for root rots in different production areas.

Fusarium oxysporum is usually associated with bean wilt or ‘bean yellows’, a disease that caused serious crop losses of one of the most popular climbing bean varieties in the Great Lakes Region (G 2333, also known as Umubano in Rwanda). Some five years after the variety had been introduced in SW Rwanda farmers were forced to abandon growing it. Several races of this pathogen are known to exist worldwide and it is important that African isolates of *Fusarium oxysporum* f. sp. *phaseoli* are compared to known races so that appropriate isolates can be used in future screening of bean genotypes. The Pan-Africa Bean Pathology Working Group sees the characterisation of pathogenic diversity of this pathogen as a priority. Fusarium wilt has not yet been reported in Uganda or Kenya, but the variety G 2333 has been released in both countries and the disease may become prevalent in the future particularly if fungal inoculum is seed-borne (Buruchara *et al*., 1999). This vascular pathogen invades the plant via the roots and is likely to be influenced by root rot pathogens.

In Rwanda, western Kenya and SW Uganda *Pythium* spp. are the fungal pathogens most frequently associated with severe root rot outbreaks. Consequently, identification of resistant germplasm has targeted resistance/tolerance to *Pythium* spp. and a few varieties are now available which grow well in areas where root rots are a serious problem. Other pathogens known to cause root rots such as *Fusarium* spp. and *R*. *solani* may reduce the effectiveness of the available resistance.

At least four *Pythium* spp. have been implicated in bean root rots but their relative importance in the region and possible synergistic effects are unknown. Identification of *Pythium* spp. is both difficult and slow using morphological characters and, when extracted from soil, complicated by the presence of a wide range of other organisms. Identification to species level is critical for identifying host resistance or introducing other disease management practices (e.g. rotation crops, which should be non-hosts to bean pathogens). One reason for the varied performance of certain bean varieties in different areas of E. and C. Africa may be because of differences in the composition of local pathogen populations. This emphasises the need to identify the primary pathogen(s) in different areas and to determine the level of variation within individual pathogen populations.

Figure 1. Beans showing chlorosis due to root rot

Disease control using resistant germplasm

Bean mixtures rather than pure varieties are grown by farmers in many areas of Uganda as well as Malawi, Rwanda and the southern highlands of Tanzania. Bean mixtures are preferred because they offer a risk aversion mechanism as well as providing a range of agronomic and culinary qualities. Collections of bean mixtures were made in Uganda by D M Teverson, during 1991 (Final Report, A0530), as part of a project studying the functional diversity of bean mixtures. Eight mixtures are available as a result of these collections, from altitudes ranging from 475m near Rubare to 1900m on the slopes of Mount Elgon. These mixtures each contain between 2 and 9 morphological types (components), a total of 46 different components. It may be appropriate to screen selected bean mixture components against characterised isolates of the root rot complex, as part of a wider study of host resistance.

Pathogen and pest interactions

CIAT has noted that various combinations of *Pythium* spp. *Fusarium* spp., *S. rolfsii* and bean stem maggot (BSM) can occur in beans displaying different levels of plant damage. However, the way in which these organisms interact is unclear. Some work has shown interactions between BSM and *Fusarium* spp. Bean stem maggots (*Ophiomyia* spp.) are recognised as the most important pest of beans in all the production environments in Africa, causing losses of 20 to 100% annually (Ampofo, pers. comm.). As with root rots, the bean stem maggot (BSM) problem is aggravated by continuous cropping of beans in areas of high human population. The problem is more acute when BSM and some of the root rot organisms occur together. A model has been developed (Wortmann *et al*, 1998) which shows that the occurrence of BSM and root rots, with the potential yield reductions, may have been underestimated and is predicted to increase in severity unless appropriate management strategies are made available and widely disseminated.

Direct links between the effects of soilborne pathogens and other foliar or viral diseases have not been established. However, some of the root rot-resistant material have the I-gene and are therefore affected by bean common mosaic necrosis virus (BCMNV). There is considerable variability in pathotypes of BCMV and BCMNV in the Great Lakes Region (Spence & Walkey, 1995; Sengooba *et al.*, 1997) so the interaction of root rot resistant material with these viruses requires investigation to ensure durable resistance to both fungal and viral pathogens.

Epidemiology

Population levels of soil-borne pathogens influence incidence and severity of root rots and some of the management efforts have been directed at reducing soil inoculum to below economically damaging threshold levels. Although the effects of management practices can be assessed on the basis of disease severity, this measurement alone is not always a good indicator of soil pathogen populations. Environmental factors and stage of plant growth play a critical role in influencing disease development and severity. There are instances when epidemics are observed in one season and not in the next, a feature which is a source of confusion to farmers. There is therefore need to develop tools and procedures that are simple, fast and accurate for the quantification of pathogen populations; particularly *Pythium* and *Fusarium* spp. This will assist in the development of prediction models but more importantly will facilitate a determination of the effects of various root rot management options (cultural, varietal and biological) on pathogen populations. These tools could also be used to study the influence of environmental factors on pathogen populations in field soils.

Disease management strategy

Research on bean root rots has almost invariably been demand driven, being initiated after the development of serious disease outbreaks, starting with GLR (Rwanda, Burundi and DRC), then in Kenya and more recently in Uganda. Under such circumstances, research has largely focussed on identifying crop and soil management approaches that have an immediate impact on managing root rots e.g. identification and use of resistant cultivars. Some IPM components have been developed using local resources. However, the basis of the positive effects of some of the management practices is not clearly understood. Neither has it been possible to address the underlying factors leading to the development and severity of root rots in these countries. There is need for a better understanding of some of these aspects so that development of integrated pest management strategies (IPM) can be made more efficient and effective.

Work in progress under PABRA (includes NARO and CIAT)

- Identification of new sources of resistance (CIAT)
- Evaluation of Regional Root Rot Nursery (RRN) (KARI, NARO ISAR, CIAT)
- Studies on the reaction of varieties tolerant of low soil fertility to root rots and vice versa (DRC - ECABREN sponsored).
- Investigations into the mechanism of inheritance of resistance (CIAT)
- Improvement of the resistance of local cultivars (CIAT).
- Herbaceous legumes as sources of green manures and management of root rots (KE supported by AHI).
- Interactions between nematodes, BSM and Fusarium wilt (DRC-ECABREN sponsored) by Kijana Ruhebuza (INERA/PNL, Mulungu)
- An investigation into the nature and inheritance of resistance in G685 against Fusarium wilt (CIAT / ISAR - in Rwanda)
- Improving resistance of G 2333 against Fusarium wilt (CIAT/ISAR - in Rwanda).
- Technology transfer of some of the tested IPM components (mainly varieties and soil fertility management) - ISAR, KARI, NARO +NGOs)
- Evaluation (on-farm and on-station)some of the IPM components and options (ISAR, KARI, NARO, CIAT)

Within the National Programs in the region, there are now scientists working on root rots who have greater responsibilities in adaptive research (under the ECABREN and AHI). Collaborative research is now required which focuses on priority areas of strategic research that have not been given adequate attention in the past, but are essential to increase understanding of the problem and which will further support development, refinement and application of IPM strategies. DFID support is sought to achieve this new research in collaboration with CIAT, HRI and NRI.

DFID funded collaborative research between NRI, CIAT and the National Bean Programme in Uganda has been ongoing in one form or another since 1984. Host-pathogen interactions between resistance genes in *Phaseolus vulgaris* and avirulence genes in *Pseudomonas syringae* pv. *phaseolicola* were successfully elucidated and have become the standard reference for all those dealing with the disease (Teverson, 1991). More recently, research has been conducted in Tanzania studying the functional diversity and *in-situ* conservation of bean mixtures. The work in R7568 builds directly upon the expertise gained during previous projects. It is now important that the disease complex causing root rots in beans is fully characterised if research into amelioration of root rots is to be effective. However, for the results of such work to be translated into disease control and increased bean yields by the farmer, it is vital to understand the epidemiology of the disease and then study host resistance simultaneously with the study of pathogenic variation. Both need to be put into the context of farmer perceptions of the disease; only then can a strategy for the management of bean root rot be fully effective.

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Project purpose

The Purpose of the project is to refine and promote methods for the sustainable control of bean root rots. The project aims to take an innovative approach to the problem by determining the significance of interactions, not only of components of the pathogen complex causing the disease, but farmers' perceptions, practices and the wider crop environment. This will enhance the productive capacity of beans, particularly in Uganda (as a representative east African country), but also in countries where beans are grown under similar conditions, such as Kenya, Rwanda and Tanzania. The project aims to understand farmers' perceptions of the causes and potential control measures for bean root rots. The epidemiology of root rots will be studied and the significance of interactions between the pathogens causing the disease, other soil micro-organisms and associated bean pathogens and pests will be determined. Focussed interviews and surveys of smallholder farmers will be undertaken to determine the socio-economic factors influencing pest management decisions and control strategies. The information generated will be used as a basis for the development of improved crop management methodologies for sustainable production of beans by resource-poor, smallholder farmers.

Research activities

1.1 Workshop involving project stakeholders to finalise the work plan and ensure co-ownership of the project.

A Stakeholders' workshop was held in Uganda in November 1999 to plan project activities.

1.2 PRA to assess indigenous technical knowledge, to evaluate farmer problems, perceptions and practices in relation to root rots and other soil micro-organisms, bean diseases and pests.

In February 2000 an initial PRA on farmer perception of root rots took place at 2 sites (Kisoro and Kabale). Participating in the PRA were Ms E Ampaire, Dr R Buruchara, Dr S David, Mr J Mukalazi, Dr D Teverson and Mr G Tusiime. Two extension staff of the Ministry of Agriculture from Kisoro District and a CARE staff member from Kabale joined the team to facilitate and assist in translation. PRA at two further sites (see 1.3) was done in April 2000. A detailed report of the PRA results and the methodologies used was compiled.

1.3 Selection of field sites, using results from the PRA study (1.2) according to suitably stratified variables, for a detailed study of root rot affected areas.

Desirable field sites in Kabale, Kisoro (and later, Mbale) were selected for the disease survey and pathogen collection prior to the PRA. After the PRA (1.2) two new sites were designated to replace unsuitable originals. The new sites were identified with the assistance of AfriCare (NGO) and extension staff of the Ministry of Agriculture.

1.4 Disease surveys comparing areas affected and unaffected by root rots to determine the extent and variation of root rot incidence and detailed studies on indigenous technical knowledge, to evaluate farmer problems, perceptions and practices in relation to bean root rots

Using the CIAT GIS facility in Uganda maps of the Kisoro and Kabale showing parishes and roads and with options to include other features of interest e.g. population density were developed. Square grid points were overlaid on the map at distances of about 5 km from each other. The map was used to determine in advance possible collection points, in order to make a representative coverage of parishes and districts. The actual collection points were determined by the situation on the ground and were then placed on the map using GPS information.

Edidah Ampaire used a two-staged approach to investigate ITK of diseases and pests. Twenty farmers (increased to 30 in October 2000) were selected from the two districts for detailed study. Throughout the first planting season Edidah Ampaire and Ministry of Agriculture extension workers collected detailed data from farmers on their understanding of bean diseases concentrating on bean root rots, rationale for various management practices and how information on management practices is shared. This qualitative study of ITK was followed by a formal survey on ITK and farmer perception of root rot disease involving a random sample of 100 bean farmers in Kisoro and Kabale districts. An analysis of survey data using SPSS was completed.

A nematode survey was conducted in Kisoro, Kabale, central and eastern districts in Uganda

1.5 Collection of indigenous knowledge of local germplasm

PRAs were carried out in Kisoro and Kabale during March and April 2000. A report was prepared.
More detailed information was obtained from a study of farmers' local knowledge of bean diseases in Kabale and Kisoro. Data from this study were used for a M.Sc. thesis by Edidah Ampaire.

1.6 Evaluation of the farmer acceptability of alternative control strategies.

A PRA was carried out in Kisoro and Kabale during March and April 2000. The survey activities in 1.4 showed options, limitations and preferences of the control methods available to farmers. A report on the survey has been developed. This formed the basis for the development of a questionnaire for a formal survey conducted in 2001 (1.7).

1.7 Participatory methods to make a comparative assessment of technology diffusion and farmers' communication channels

A participatory tool, diffusion mapping, was used to understand technology diffusion and farmers' communication channels in Kabale and Kisoro Districts. Thirty-five farmers were involved.
This topic was also explored in a formal survey of 100 farmers in the two districts.

1.8 Acceptance study

Following participatory evaluations of technologies in both group and individual fields over two seasons, assessment of acceptance of technologies was made between November 2002 to February 2003, through group discussions and informal interviews.

2.1 Collection of primary pathogens (from both soil and plant samples) from bean fields in production areas with root rot problems.

Between April 20th and May 4th 2000 collections of root rot pathogens from plants and soils were made from farms in Kisoro and Kabale which were identified in 1.3 and 1.4. One hundred samples were collected from the two districts (40 from Kisoro and 60 from Kabale). Each sample constituted an average of 10 plants and a bulked soil sample from a farmer's field. All areas of both districts were covered except northern Kabale where planting had only just been done and some other inaccessible areas. Only one or two samples were collected from each parish, due to reduced planting of beans, inaccessibility, time constraints and the small size of most parishes. In each bean field sampling followed a W zig-zag pattern over the whole field. The number of plants collected was often determined by the willingness of the farmer to allow plants to be uprooted.

A further 21 bean fields in Mbale District in eastern Uganda were sampled between 15th and 20th May 2000.

A second collection of diseased bean samples from the same areas of Kisoro and Kabale was made during October 2000. The same sampling techniques were used.

A more limited isolate collection was carried out in southwest Uganda in April 2001 followed by a more extensive one in October 2001.

2.2 Isolation of *Pythium* species using standard plating and bait plant techniques.

Initial attempts to isolate *Pythium* spp. from infected plant samples were made with
Corn Meal agar (CMA) and Potato Dextrose agar (PDA). To reduce growth of contaminating organisms a mixture of antimicrobial agents (benomyl, pimaricin, pentachloronitrobenzene, rifamycin, ampicillin and nystatin) was added to PDA. At HRI further isolation of *Pythium* was carried out from infected plant samples collected in May 2000. CMA supplemented with the antibiotics pimaricin (75 $mg.l^{-1}$) and rifamycin (30 $mg.l^{-1}$) was used successfully at HRI for *Pythium* isolation and is now being used routinely in Uganda. A small number of isolates were recovered from soil samples.

2.3 Isolation of *Fusarium* species using selective media and bait plant techniques.

Isolation of *Fusarium* spp. from the May 2000 plant and soil samples was done using Nash and Snyder (1962) agar medium. This medium was modified by adding 2.0 ppm benomyl to improve its selectivity towards *F. solani* f. sp. *phaseoli*.

3.1 Identification and differentiation of *Pythium* species associated with root rots in the region using PCR methods.

Initial tentative identification to species was done at HRI using morphological characters. Structures such as sporangia, oospores, oogonia and antheridia were all examined and compared to descriptions in an identification guide compiled by Plaats-Niterink (1981).

The pathogenicity of 70 isolates was examined by sowing 16 bean seeds of variety K20 into pots of pasteurised topsoil amended with sand/oatmeal inoculum. Four weeks after emergence, plants were carefully uprooted and root damage quantified using a zero to five index (Chellemi *et al*, 2000).

Isolates were grown in V8 liquid culture for seven days at 18-22^{0}C and mycelia harvested by filtration. Fungal DNA was prepared by grinding mycelia in extraction buffer followed by isopropanol precipitation. Solutions of DNA were used in PCR (polymerase chain reaction) together with primers ITS1 and ITS4 (White *et al*., 1990) to amplify the internal transcribed spacer (ITS) region. PCR products were digested with three restriction endonucleases: *Cfo* 1, *Hinf* 1 and *Mbo* 1. The fragments generated were separated by agarose gel electrophoresis, stained with ethidium bromide and visualised by exposure to UV light. Fragment sizes were estimated by comparison with migration distances of 100 bp molecular ladder fragments. Isolates were grouped according to the restriction fragment length polymorphisms (RFLPs) identified with each of the restriction enzymes used.

The ITS1 region of representative isolates from each RFLP group was amplified using primers ITS1 and ITS2 (White *et al*., 1990). The PCR products were sequenced and the resulting sequences compared with each other and with those present in databases.

PCR primers were designed from regions within ITS1 that were found to be unique to each of five groups (RFLP groups) of Ugandan isolates. These primers were used to amplify DNA from a subset of isolates.

Twenty out of 66 isolates of *Pythium* spp were inoculated onto bean plants of variety K20. Isolates of *P. ultimum* and *P. spinosum* displayed similar high levels of virulence whilst several isolates identified as *P. torulosum* and *P. salpingophorum* show different more varied and lower virulence.

3.2 Identification and differentiation of *Fusarium* pathogens associated with root rots.

It is often difficult to distinguish between *Fusarium solani* and *Fusarium oxysporum* on isolation plates.

Species-specific PCR primers were designed for both fungi using the ITS region of *F. solani* and the intergenic region (IGR) of the ribosomal gene repeat of *F. oxysporum*.

These PCR primers were used to amplify DNA extracted from fungal colonies taken directly from isolation plates.

DNA from a collection of *F. solani* isolates recovered from bean plant samples displaying root rot symptoms was amplified using primers ITS1 and ITS4 (White *et al*., 1990). RFLP analysis of the PCR products was carried out using the restriction endonuclease *Rsa* I.

Amplified fragment length polymorphism (AFLP) analysis (Vos *et al*., 1995) of selected *F. solani* isolates was used to quantify variability and identify DNA fragments specific to isolates highly virulent towards beans.

Specific fragments were recovered from gels, sequenced and PCR primers designed. The ability of these primers to amplify DNA only from isolates highly virulent towards beans was tested.

3.3 Investigation of race specificity of *Fusarium* causing severe wilt on G2333.

Fusarium oxysporum isolates were collected from Ugandan bean plant samples displaying root rots and other samples from Kenya, Rwanda and the Democratic Republic of Congo taken from plants showing 'bean yellows' (wilt) symptoms. Other isolates representing races 1, 2, 3, 4 and 6 (Alves-Santos *et al*., 2002) were received from Spanish researchers.

72 *F. oxysporum* isolates were recovered from bean samples displaying root rots. DNA was extracted from these cultures and this was used in PCR amplification with *F. oxysporum* specific primers. At HRI all 72 isolates were further characterised using the PCR-based molecular technique of simple sequence repeat analysis. ITS and IGR regions of ribosomal RNA genes were also sequenced from selected isolates.

A sub-set from the 72 isolates plus examples of the five races were used in glasshouse inoculation experiments on bean varieties G2333 and some wilt-differential genotypes provided by CIAT. Surface sterilised seeds were planted in sterilised vermiculite and grown for 14 days in a greenhouse at 18^{o}C. Seedlings were then uprooted, washed free of vermiculite and approximately 1cm cut off the ends of all roots. Root systems were immersed in a spore suspension of the test isolate (10^{6}spores.ml^{-1}) for five minutes then the seedlings were replanted in vermiculite in individual pots and grown on in the greenhouse at 18^{o}C with 16h day-length. Symptoms were recorded at five, seven or nine weeks after inoculation and after the final record a section of stem base was removed and examined under a binocular microscope for signs of vascular browning.

Amplified fragment length polymorphism (AFLP) analysis (Vos *et al*., 1995) and sequencing of part of the IGR of selected *F. oxysporum* isolates was used to quantify variability.

3.4 Development of methods to quantify inoculum potential of *Pythium* spp.

Molecular techniques for the detection and discrimination of *Pythium* spp. have been developed and are described in research activity 3.1. Before these technologies can be incorporated in procedures to quantify inoculum, it is necessary to extract from soil samples sufficient pathogen DNA of a quality suitable for use in PCR. Protocols that may be suitable are first being tested with soils containing *Fusarium* propagules (see research activity 3.5) and if successful will be tested on *Pythium*-infested soils.

A dilution plating method for quantification of *Pythium* in soil:

Validation of this technique was done using *Pythium* isolate MS 61, a *P. ultimum* var *ultimum* known to be pathogenic to beans. Inoculum for this species was grown on autoclaved millet incubated for two weeks at 20^{o}C. The infested millet was moistened, thoroughly mixed with pre-sterilised topsoil using a ratio of 1:1, 1:5, 1:10, 1:15 and 1:20 v/v (inoculum:soil) and allowed to

settle for two days. Two grams of each inoculated soil were dissolved in 50 100 and 200mls of sterile water. One ml of the resulting suspension was plated onto a 9cm petri dish containing selective media for *Pythium*. Plates were briefly air-dried in a laminar flow bench. The plates were then incubated at 20^{o}C for two days. Colony numbers were recorded after one day to quantify fast-growing types then again on the second to count slower-growing forms.
Quantification of *Pythium* spp. was undertaken for a number of artificially infested soil samples from screen house experiments and others from field sites in Rubaya and Kicumbi.

3.5 Development of methods to quantify the inoculum potential of *Fusarium* spp.

Molecular techniques for the detection and discrimination of *Fusarium* spp. have been developed and are described in research activity 3.2. Before these technologies can be incorporated in procedures to quantify inoculum, it is necessary to extract from soil samples sufficient pathogen DNA of a quality suitable for use in PCR. A range of concentrations of *Fusarium oxysporum* microconidia and chlamydospores were prepared in sand or soil (peat/loam mixture). Three protocols for extracting fungal DNA from 'soil' samples were tested. These were: a proprietary extraction kit (UltraClean Soil DNA Kit, Mo Bio Laboratories Inc., California, USA), an 'in-house' method based on homogenisation in microfuge tubes containing SDS buffer with 5% w/v milk powder, and a microwave disruption technique (Orsini and Romano-Spica, 2001).
A combination of soil dilution plating on agar media followed by colony filter hybridisation (Arganoza and Atkins, 1995) was also tested as an alternative method for pathogen quantification. Instead of using a radioactively labelled hybridisation probe for detection, the less hazardous method of digoxygenin labelling was used.

A bean hypoctyl 'bait' method for quantification of *Fusarium solani* f. sp. *phaseoli* in soil:

Quantification of *F. solani* f. sp. *phaseoli* inoculum in soils was attempted by using bean hypocotyl sections as 'bait' in infested soils. Laboratory experiments were first conducted to evaluate the method. Soil for the experiment was obtained from an on-station field (Kawanda Agricultural Research Institute) without a history of bean growing. Loam soil (up to 15cm depth) was brought to the lab, spread out to dry for about a week, and clods removed by hand. Macroconodia from a one month-old culture of *F. solani* f. sp. *phaseoli* (isolate P 078) were used for the study. Plates of the isolate were flooded with sterile water before scraping off the mycelia using a clean glass slide. The slurry was filtered through a double layer of muslin to remove mycelium. The concentration of the macroconidia in the filtrate was estimated using a haemocytometer. The appropriate number of conidia was then poured into 3 kg of soil. The infested soil was slightly moistened and then serially diluted with similar but uninfested soil to obtain a range of pathogen concentrations from 200 – 4000 conidia.g^{-1}. Six replicate 9cm petri dishes were half filled with each of the soils and 8 – 10 bean hypocotyl pieces from one-week-old beans of cultivar K20 placed on the soil. Then, more of the same soil was put on top of the bean hypocotyls to fill the petri dishes. The

dishes were then covered and incubated for one week at room temperature (approx. 25°C). The hypocotyls were then recovered from soil and the number of typical stem lesions recorded. The relationship between lesion numbers and pathogen concentration was determined graphically.
The hypocotyl section assay was also tested on soil samples from experiments conducted in the screen house and in the field (see research activity 6.1 below for details).

4.1 Distribution of *Pythium* species associated with bean root rots mapped.
Distribution maps of Kisoro and Kabale showing the location of *Pythium* spp. identified from bean samples were constructed using GPS data.

4.2 Distribution of *Fusarium* species associated with bean root rots and wilts in the region mapped.
The distribution of *Fusarium* spp. was recorded for the selected sites in Kisoro and Kabale. Maps were not constructed for these fungi because of the uniform and widespread distribution of all the strains encountered.

5.1 Synergistic or antagonistic interaction between *Pythium Fusarium* and *Rhizoctonia* species causing root rot diseases examined.
Laboratory evaluations of antagonistic interactions between *Pythium* spp., between *Fusarium* spp, and between *Pythium* and *Fusarium* spp were made by allowing the organisms to grow together on agar media.
Two greenhouse experiments at HRI looked for synergistic or antagonistic interactions between bean-pathogenic *Fusarium solani* and certain *Pythium* spp. Bean seeds of K20 were sown into pots of pasteurised loam (first experiment) or sterilised vermiculite (second experiment) to which inocula of the pathogens, separately or combined, had been added. Symptoms were allowed to develop then recorded before plants were uprooted and dried to determine yield effects.
Similar greenhouse experiments have also been conducted at Kawanda, which in addition have looked at interactions between pathogenic *Pythium* spp and potentially antagonistic *Mortierella* spp.

5.2 Contribution of seed-borne inoculum of *Pythium* and *Fusarium* to root rot diseases determined.
Twenty-five seed samples were collected from the southwest Ugandan districts of Kisoro and Kabale and analysed for seed borne infection.
A working sample of 200 seeds was tested in replicates of 10 seeds per 9 cm. diameter petri dish of for each sub-sample. Each dish was labelled with a sample number, plating date and the replicate then lined with four filter papers that had previously been well soaked in water. Twenty such dishes were prepared for each sample and incubated at 22°C for seven days in alternating cycles of 12h darkness and 12h light and then examined under a stereoscopic microscope. The organisms present were identified and recorded. For 20 samples, seed was also plated on selective media for *Fusarium oxysporum*, *F. solani* and *Pythium* spp. For *F. solani* seed were plated on Nash media (Nash *et al*., 1962), for *F. oxysporum*, on Komada (Komada, 1975) and for

Pythium spp., on corn meal agar containing antibiotics selective for *Pythium* spp.
In Rwanda an investigation of the infection/contamination of bean seed by *F. oxysporum* was planned. Seed samples were obtained from infected plants but analysis of seed-borne infection was not done because of the sudden departure of the collaborator at the University of Rwanda.

5.3 Interactions between nematodes and bean root rot pathogens studied.

A study was conducted on interactions between *F. oxysporum* and nematodes in different cropping patterns (maize, bean, tomato and combination of the three) with the objective to determine the effect of association of beans with other crops.
In another survey, a total of 29 fields were surveyed in Kabale and 31 in Kisoro. Fields were selected on the basis that they were accessible to the main road and contained a bean crop at a suitable growth stage [4 – 8 weeks after planting]. Ten plants were uprooted in each field and examined for root galls. Root rot severity and the severity of nematode galling were both scored on a 0 – 10 scale and the presence or absence of damage due to BSM was recorded. Information was also recorded on cropping systems and soil types [See BTOR report].

5.4 Interactions between bean stem maggot (BSM) and bean root rot pathogens studied.

The interaction between *F. oxysporum* and BSM was studied with and without application of organic amendments (*Tithonia* and farm yard manure).
Interactions between fusarium wilt, BSM, and nematodes were determined using a variety (G2333) known to be very susceptible to wilt isolates found in the Democratic Republic of Congo (DRC). Assessments were done over two seasons in on-farm and on-station trials at PNL-Mulungu in DRC. Planting was done at weekly intervals over three weeks. Treatments included the control of BSM and nematodes by use endosulphan and furadan respectively and observing the effects on fusarium wilt.

5.5 Interactions between BCMV / BCMNV and bean root rot pathogens studied.

This study was modified to screen resistance of root rot entries to BCMV/BCMNV. Over 160 root rot tolerant or resistant entries were evaluated under field conditions at Kawanda Research Station over two seasons. Susceptible infected spreaders of BCMV/BVMNV were planted around and between the entries. The relatively dry conditions during the trials facilitated spread of the virus by aphids.

6.1 Soil amendments (inorganic and organic) with potential for disease management will be examined and their effectiveness assessed in terms of their effect on pathogen populations.

Soils were amended with farmyard manure or green manure (*Calliandra* spp to evaluate the impact on root rots of improved soil fertility. Experiments were conducted in a screen house using artificially infested soils and in the field (Figure), making use of natural inoculum.

Figure 2. Evaluating the impact of manures on root rots in the field

Fusarium

Screen house: Seed of bean varieties K20 (root rot-susceptible) and RWR 719 (root rot-resistant) were sown in wooden trays containing soil that had been artificially infested with conidia of *F. solani* f. sp. *phaseoli* at the rate of $3000.g^{-1}$ of soil. In addition to the pathogen inoculum, some soils were amended either with 105 g (equivalent to 10 $tons.ha^{-1}$) of farmyard manure or with green manure from *Calliandra* spp. Root rot severity and crop dry matter were recorded every two weeks beginning three weeks after sowing and until crop maturity (six weeks later). At maturity, soils from these three treatments were sampled and pathogen populations determined using the hypocotyl section assay (see research activity 3.1 above).

Field trial: A field trial similar to the screen house one was set up to further examine the effects of soil amendments. Two sites, (Rubaya and Kicumbi) both in Kabale in the south west of Uganda were selected. These fields had recently produced bean crops and had a history of root rot. The trial was planted as a split plot, fully randomised block design replicated three times. Again, green manure from *Calliandra* spp. or farmyard manure (each at 10 $tons.ha^{-1}$) was incorporated into randomly chosen plots. The 'control' plots received no amendments. Two weeks after the amendments had been incorporated, five rows of beans were sown in each plot with 50cm between rows and 10cm between seeds. Varieties were assigned to main plots and amendments to sub plots. After a further two weeks, plant stand was recorded, and then plots were visited fortnightly to collect data on plant stand and disease severity. Plants and soil were also sampled from each plot at every visit. Plants were carefully dug up using a garden trowel and gently shaken to dislodge soil without losing roots and dried to constant weight. Soil samples enough to fill a 9-cm diameter petri-dish were assayed for *F. solani* f. sp. *phaseoli* propagules using the hypocotyl section assay as earlier described (see research activity 3.1 above).

Pythium

Screen house: Seed of bean varieties CAL96 (root rot-susceptible) and RWR 719 (root rot-resistant) were sown in wooden trays containing soil that had been artificially infested with isolate MS 61 (*P. ultimum* var *ultimum*) to give pathogen concentrations of between 200 and 300 $cfu.g^{-1}$. Farmyard manure and *Calliandra* were incorporated into the soils at rates of 10 $tons.ha^{-1}$ Soil Pythium populations were monitored every two weeks from the date of amendment incorporation through harvesting time using the dilution plating protocol (see activity 3.5). Disease progress in the two varieties was also recorded every two weeks.

Field trial: A field trial similar to the screen house one was set up to examine the effects of soil amendments under more natural conditions. The same two sites that were used in the *Fusarium* field trials were used for *Pythium*. The same experimental design was used. Again, green manure from *Calliandra* spp. or farmyard manure (each at 10 $tons.ha^{-1}$) was incorporated into randomly chosen plots. The 'control' plots received no amendments. Two weeks after the amendments had been incorporated, beans of the same two varieties (CAL 96 and RWR 719) were planted. Soil samples were collected every two weeks and Pythium populations were quantified (see activity 3.5). Disease progress in the two varieties was also recorded every two weeks.

6.2 Bioassay for new germplasm to determine resistance/susceptibility to *Fusarium oxysporum* f. sp. *phaseoli* developed.

Initial experiments in this activity were undertaken at PRI in South Africa. Bean seed was surface sterilised and allowed to germinate in sterile conditions for seven days. Coleoptiles were excised, cut into 2.5cm lengths and placed on glass slides. An incision (1-2mm) was made in the centre of each piece before a block (2-3mm square) of fungal inoculum was taken from a culture plate and placed with the fungal mycelium touching the incision. All inoculated hypocotyls were incubated in humid chambers for five days at 15, 20, 25 and 30^{o}C.

These experiments were repeated at HRI after PRI advised us that they were no longer able to continue with work in this activity.

7.1 Screening of selected germplasm for resistance to specific components of the root rot complex.

Nurseries consisting about 300 diverse germplasm entries were screened for resistance to *Pythium* root rot under artificial inoculation in a screenhouse. Accessions in a root rot nursery (68) and a segregating population (110) were screened at the highland NARO station of Kachiwekano.

7.2 Farmer managed on-farm trials of characterised germplasm and fertility improvement practices.

Several farmer-managed trials were established in community plots involving six farmer groups (with a total of over 100 members). These included participatory variety selection of root rot resistant varieties (including entries of the root rot resistant nursery), segregating populations and fertility improvement (organic & inorganic soil amendments). Materials and technology of interest were then selected for use in farmers' individual plots.

8.1 Dissemination of technologies through demonstrations, field days and dissemination of information.

Technology dissemination is done by evaluation of the technologies using participatory approaches in community fields, which also serve as demonstration, or learning plots for other farmers or other groups. A modified farmer field school approach was used on two farmer groups to address the deficiencies in farmer-knowledge and understanding of the bean root rot disease, as identified in the PRAs and associated surveys and studies. On the basis of the surveys and insights gained on farmer understanding and knowledge of root rots, and in the farmer field school approach dissemination materials are also under development.

Outputs

1 Investigation of indigenous technical knowledge of root rots. Farmers' crop management practices and their perception of root rots determined. Healthy and infected cropping situations compared.

The Stakeholders' workshop held in Uganda in November 1999 enabled project activities to be planned and division of tasks to be agreed (see publications for BTOR).
The final selection of field sites allowed for successful collection of samples and disease information.
The analysis of survey data from Kabale and Kisoro districts covering farmers ITK, factors that influence disease, distribution, and communication systems, was completed, a report has been developed (see publications) and an M.Sc. thesis completed (see publications).
The local names for bean root rot (BRR) in the study areas (Kabale and Kisoro) are *Kiniga* and *Churisuka* respectively. Literally *Kiniga* means, "is angry and commits suicide" while *Churisuka* means "coming home with only a hoe and no harvest". The names depict the effect of the disease on beans and its importance, assessed on the basis of the effects on the crop. Generally, damage to beans (due to diseases) is categorised into "soil and rain diseases". BRR is considered a soil disease because of rotting of roots while foliar diseases are regarded as "rain diseases" because of their association with rain.

***Disease Recognition*:** Most farmers (94 %) recognise and clearly describe above-the-ground symptoms of BRR (yellowing), while a lesser but significant number (64%) associate rotting of roots with BRR. A few think above-the-ground (yellowing) and below-the-ground (rots) symptoms are two distinct and unrelated problems. Development and appearance of symptoms is a well-understood process and 85% of farmers observe symptoms at the 2nd and 3rd leaf stage. However, symptoms and effects of root rots and bean stem maggot (BSM) are largely undifferentiated.

***Cause of Root Rots*:** Conditions associated with or considered to cause BRR include: poor soils, continuous cropping, use of poor seed, water stagnating in fields, too much rain or drought conditions. The latter further testifies the lack of distinction between the effects of BRR, BSM or even soil fertility. Too much rain implies heavy downpours resulting in high moisture content in the soil.

***Traditional Management Practices*:** The destructive effects of root rots were associated early on with bad omens by some communities, which used certain rituals to "chase it away" without success. Growing new bean varieties is a BRR management practice that has been used by up to 60% of farmers. About 50% and 40% of farmers respectively stopped growing large and medium sized seed due to their susceptibility. Forty-eight percent introduced small sized seed because of their tolerance to root rots and high yields. Sixty percent adjusted components of varietal mixtures by either removing large seeded types (36%), planting only medium and small seeded varieties (17%),

increasing proportions of small seeded types within the mixture (16%) or simply reducing the proportions of large seeded varieties (14%).
A number of cultural practices are carried out routinely for reasons other than managing root rots. These include: manuring (by 63% of farmers) to improve soil fertility; “seasonal rotation ” (by 100%) to meet needs for other crops; fallowing (by 54%) in very poor plots to improve soil fertility; planting on raised beds or ridges (by 90% in Kisoro) to avoid flooding; growing beans as a sole crop particularly climbers (by 91%); intercropping (by 94%) and terracing (by 71%). Whereas some of these practices are useful IPM components (e.g. manuring or planting on raised beds) farmers do not appreciate their benefits against root rots.

***Conclusion and Implications*: **The above clearly show that:

- Farmers have a good knowledge of the above-the-ground symptoms and overall crop damage caused by BRR based on their observations
- Farmers associate the disease with certain soil and environmental factors. However, due to reliance on (“easily visible”) symptoms (e.g. yellowing and wilting) the effects of (“invisible”) BSM and soil fertility are easily confused as being due to root rots. This is a major diagnostic weakness that can result in the use of incorrect management practices or the rejection of appropriate ones.
- Traditional management practices having useful effects have been limited to varietal manipulation leading to reduction or elimination of large seeded components and the introduction of small seeded ones in varietal mixtures.
- Certain practices (e.g. manuring and planting on mounds or ridges) are routinely used for other reasons and are not appreciated as components in the IPM of root rots.

Results obtained clearly show the need for using a learning approach in the introduction and dissemination of IPM technologies against root rots (and BSM) among the communities studied. However, the understanding of the farmer traditional knowledge of BRR gained should enable development of appropriate material information to fill gaps in farmers’ knowledge. Information has been recorded that illustrates the ways in which agricultural technology, particularly seed, is shared and how information flows within communities. Farmer to farmer contact is the most common route whilst farmer communication with other organisations, individuals and networks also occurs but less frequently.
Farmers prefer to learn about new technologies by receiving demonstrations either on farmers’ fields or other selected places that farmers can easily access.
Based on survey results, three dissemination approaches were used involving six farmer groups; an intensive learning approach i.e. a modified Farmer Field School (2 groups), a participatory evaluation of technologies (3 groups), and availing technologies and information (1 group).

Two categories of technologies were evaluated; the first are resistant or tolerant varieties assembled from previous evaluations under both field and greenhouse conditions and comprised different seed types and growth habits.

The second category consisted of fertility improvement options, including use of inorganic and organic fertility sources particularly farmyard and green manures.

Figure 3. Participatory farmer research group

In acceptance evaluations, all farmers appreciated the effects of fertility improvement. However, the majority of farmers preferred the use of farmyard manure to inorganic fertilizers because the former is usually available and affordable. However, high labour requirements are involved in transporting it to distant steeply-sloping fields and this in addition to the quantities needed to cover large field or gardens are the major limitations.

Resistant varieties were the most preferred type of technology by all farmers. However, there was diversity of criteria that influenced acceptance or rejection of varieties. This was based on a number of criteria including tolerance to root rots (reflected as plant stand), marketability, seed types (colour and size), number and size of pods, yield, resistance to rains, early maturity, cooking time and taste although there cases where tradeoffs are considered. For example a variety may be late maturing (undesirable) but accepted because it yields well. Based on this several materials were selected by groups and individual farmers with seed being increased for wide distribution. These include SCAM-80CM/15, MLB-48-89A, Ihumure, and BOA –5-1/16.

There were certain exceptions as illustrated by results obtained from an all-women group. Some tolerant root rot materials evaluated were black seeded. Such beans are usually neither popular nor marketable. However this group observed that the materials were not only the highest yielding but were the best in taste. To get around the colour, the women first “roasted” beans seeds in a saucepan/frying pan (as they do with maize or groundnuts) and then ground them into flour. The flour can be kept longer than cooked beans and is added into cabbages or any green vegetables or just cooked alone as needed. Another advantage is that it takes less time to cook and is comparable to groundnuts. The black colour in the sauce disappears and the sauce is said to be sticky a preferred feature. Preparation of sauce from flour is considered to be time saving particularly for women from the pilot areas who always leave their gardens late in the evenings.

2 A comprehensive collection of primary pathogens causing bean root rots collected and isolated.

Isolation media giving improved recovery of root rot fungi were developed and applied.

Addition of the antibiotics pimaricin and rifamycin to CMA is now used routinely in Uganda for isolation of *Pythium* spp.

The addition of 2 ppm benomyl to Nash and Snyder agar medium has improved its selectivity towards *F. solani* f. sp. *phaseoli*.

Details of *F. solani* isolates collected are given in Table 1.

The locations of the field sites used for collection of samples of soil and plant material (Figure 4)are shown on the following maps (Figures 1, 2 and 3).

Figure 4. Bean plants displaying root rot symptoms

Figure 5. ***Pythium*** **and** ***Fusarium*** **collection sites in Kabale district**

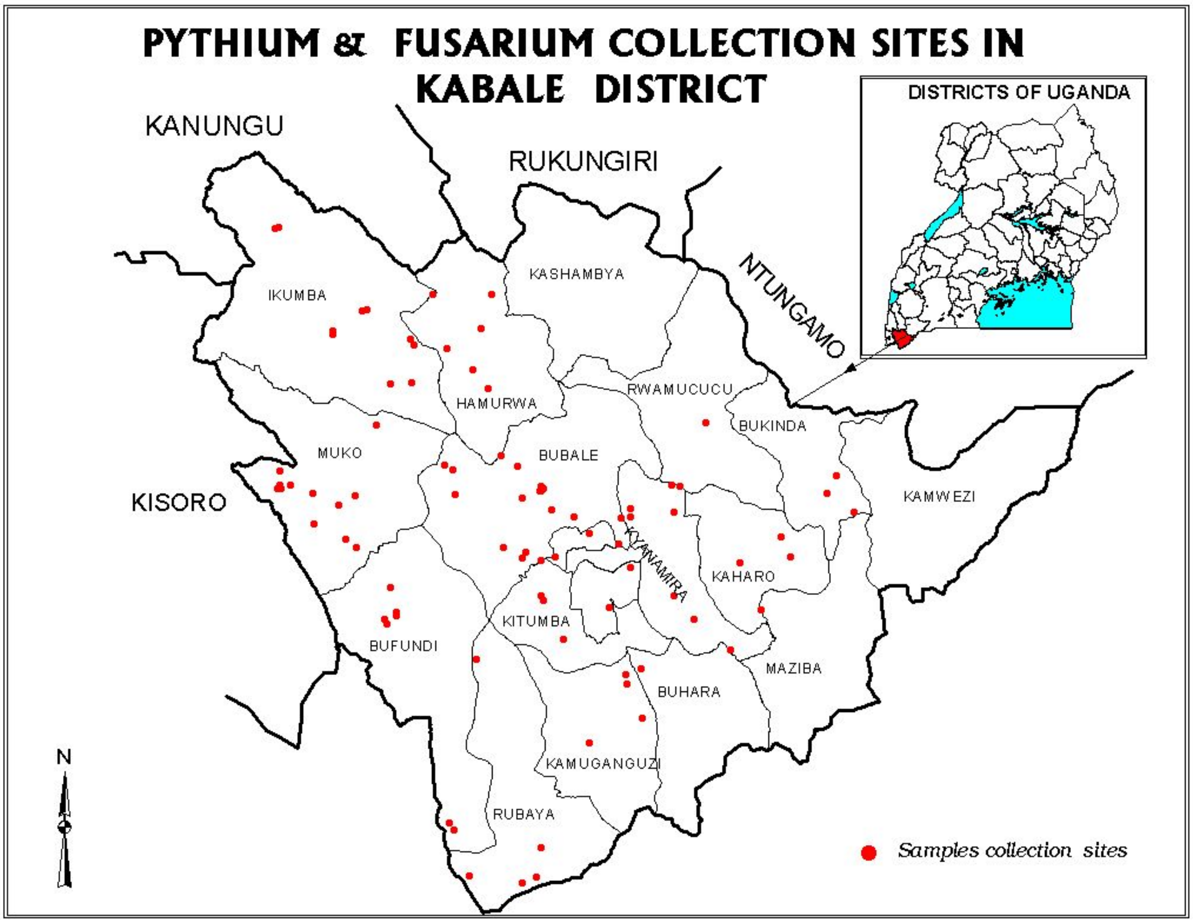


Figure 6. ***Pythium*** **and** ***Fusarium*** **collection sites in Kisoro district**

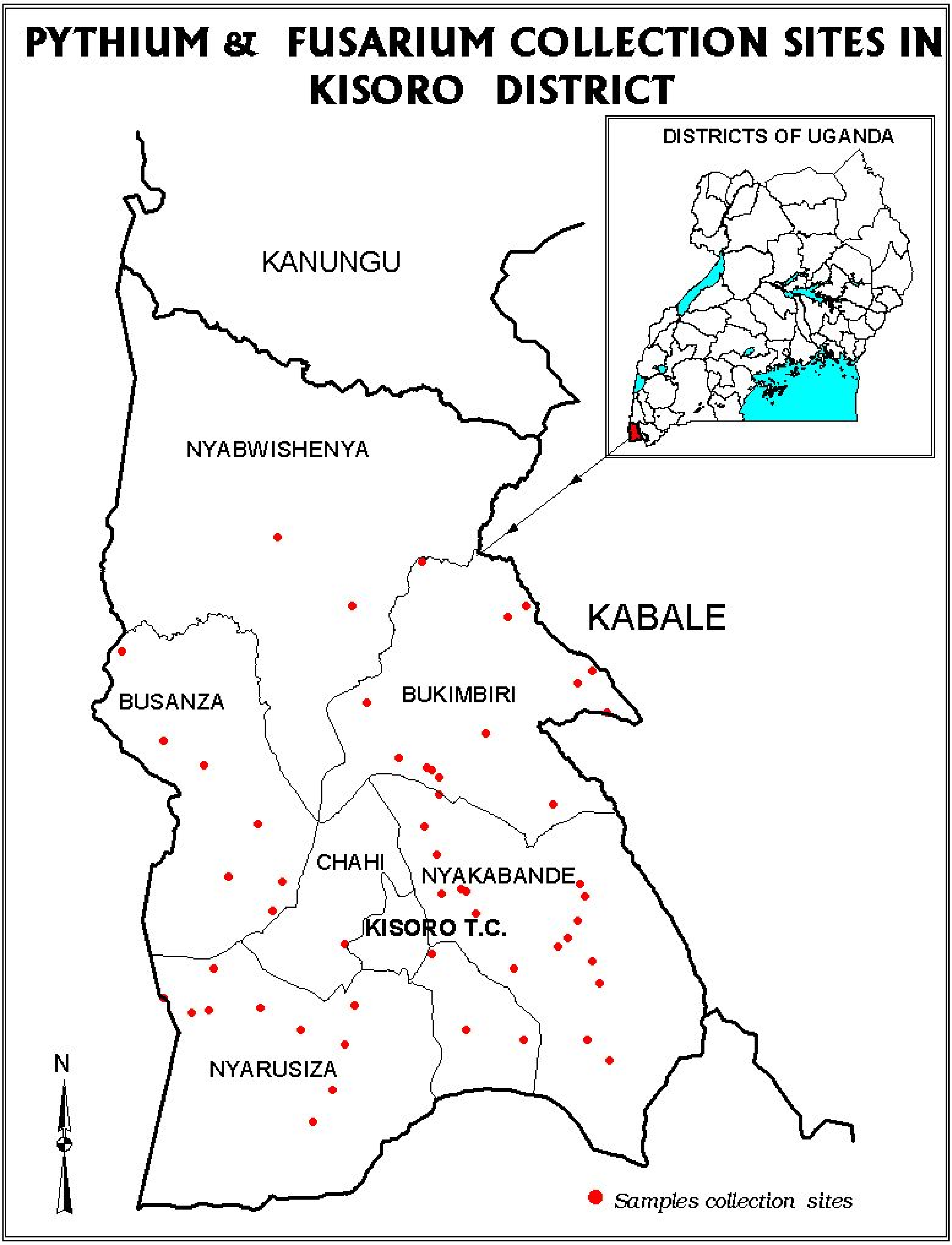


Figure 7. *Pythium* and *Fusarium* collection sites in Mbale and Sironko districts

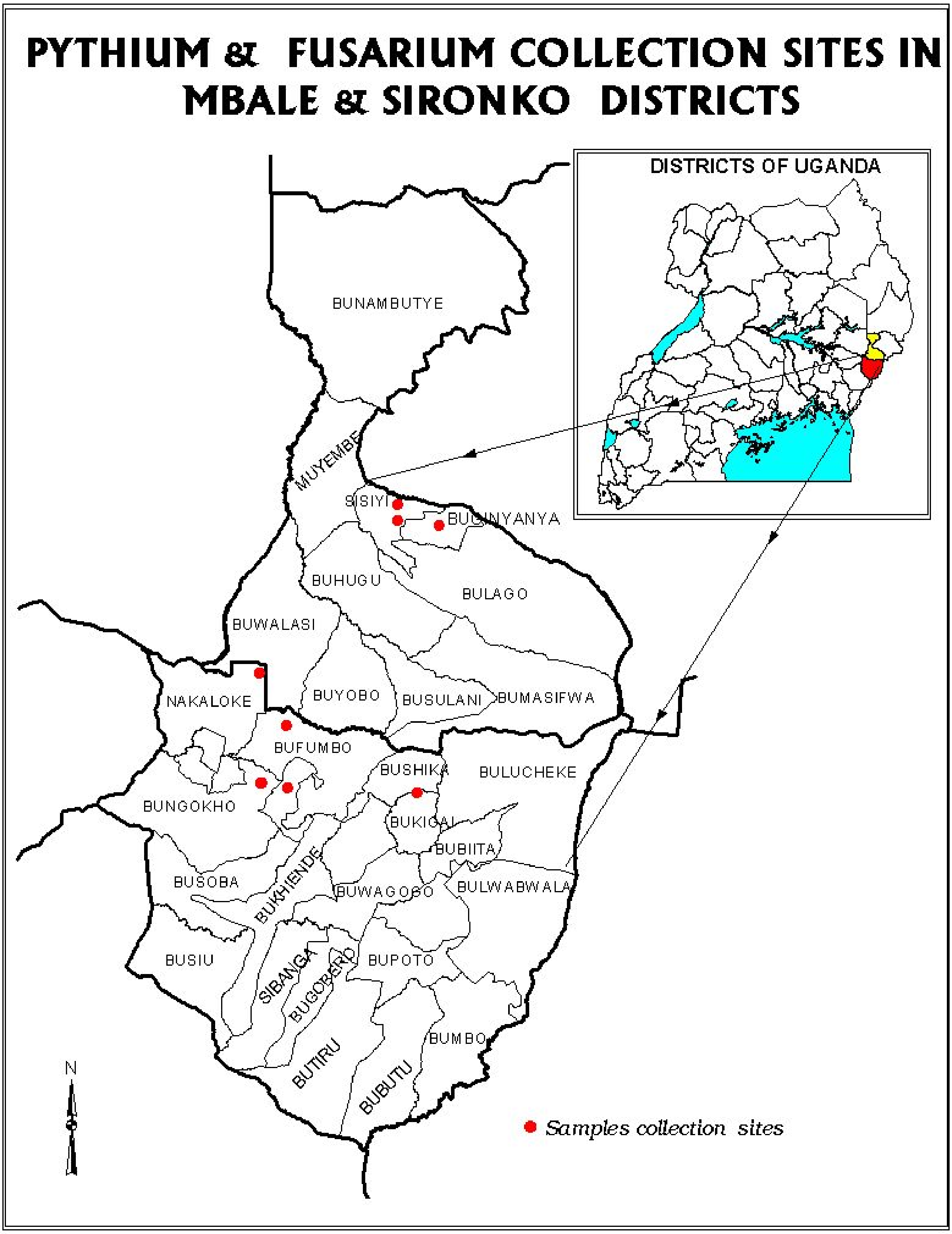


Table 1: Number and origin of *Fusarium solani* f. sp. p*haseoli* isolates collected

District	No. of sub-counties	No. of parishes	No. of samples collected
Kisoro (S. W. Uganda)	17	32	54
Kabale (S. W. Uganda)	20	53	95
Mbale (Eastern Uganda)	10	11	21
Total	47	96	170

3 Molecular diagnostic tools for identification, differentiation and quantification of *Fusarium* and *Pythium* developed and tested.

Identification and differentiation:

Pythium

Molecular analysis of *Pythium* isolates recovered from Ugandan bean plant samples with root rot using RFLP of PCR ITS products and sequencing the ITS region of the ribosomal gene has identified a wide diversity of species present.

The ITS spacer regions together with the 5.8*S* gene was amplified from a selection of 63 Ugandan isolates representing the 11 morphological groups identified so far. Fourteen selected *Pythium* species obtained from culture collections at CBS and HRI were also included in the study. RFLP analysis of the PCR products after digestion with four restriction enzymes was used to place the isolates into molecular groups. Sixty-five strains were placed into 6 molecular groups whilst 12 strains were found to have unique RFLP patterns.

Pathogenicity tests on all of the above isolates have identified both pathogenic and non-pathogenic species of *Pythium* within several of the RFLP groups. Further molecular analysis, including some DNA sequencing of the ITS region, of selected *Pythium* isolates recovered from Ugandan bean samples identified 11 species, some pathogenic and others with potential as biocontrol agents (see output 4, Table 5). Four of these species contained isolates always found to be highly virulent to beans (*P ultimum* var *ultimum*, *P. nodosum*, *P. pachycaule* and *P. spinosum;* most *P. salpingophorum* isolates were also pathogenic).

This information adds to the existing knowledge of *Pythium* species known to be pathogenic to beans and with the potential to cause Pythium root rots on beans. Resistant and intermediate reactions observed on RWR 719 following inoculation with isolates representing all species used in this study demonstrates the potential value of resistance in this variety

Fusarium solani

Species-specific PCR primers designed for *Fusarium solani* and *F. oxysporum* confirmed the presence of both fungi in root-rotted plant samples, sometimes separately but often together. The availability of these primers has made it easier to confirm the species identity of *Fusarium* isolates from culture plates.

Thirty-four isolates of *F. solani* recovered from Ugandan plant samples, seven from Republic of South Africa, two from Kenya, six from Rwanda and international culture collection strains of *F. solani* f. spp. *phaseoli, fabae, pisi* and *piperis* and *F. oxysporum* f. sp. *phaseoli* were included in molecular analyses. RFLP (restriction fragment length polymorphism) analysis of the PCR-amplified ITS region divided the isolates into two groups revealing that 22 out of the 34 Ugandan *F. solani*, two from South Africa and two of the three culture collection *F. solani*. f. sp. *phaseoli* had a unique *Rsa* I site (group R isolates). None of the isolates from Kenya or Rwanda had this restriction site present. RAPD (random amplified polymorphic DNA) analysis using four different primers on a subset of 20 strains also divided them into two distinct groups and these were congruent with the former RFLP groups.

Two examples of these 22 Ugandan group R *F.solani* isolates were inoculated onto beans of Cornell 49-24 and were found to be pathogenic and highly virulent. A total of 57 *F. solani* isolates were inoculated onto beans of variety K20. Of these, 28 caused severe root rot and all were group R isolates. Further pathogenicity tests of both types of isolate on 14 bean varieties confirmed that only group R isolates cause severe root rot and should be given the infraspecific identity f. sp. *phaseoli*.

AFLP (amplified fragment length polymorphism) analysis of the isolates divided them into the same two major groups that were identified using RFLP and RAPD analysis. Furthermore it was possible to identify group-specific DNA fragments associated with the pathogenic isolates. These were sequenced and then primers were designed and tested in PCR. Several of these primer pairs only amplified DNA from the virulent group R isolates. This technique was applied to DNA extracted from plant tissue displaying root rot symptoms and successfully amplified the expected size of product from over 95% of samples. Most of these samples had been stored at ambient temperatures for almost one year and from many it had proved impossible to isolate *F. solani*. f. sp. *phaseoli*. Often faster-growing *Fusarium* isolates were recovered from culture plates. These may have masked the presence of the much slower-growing *F. solani*. f. sp. *phaseoli*. These group R-specific primers are of great value for rapid and reliable detection and identification of *F. solani*. f. sp. *phaseoli* directly from infected bean tissue.

Fusarium oxysporum

SSR analysis of DNA extracted from 72 *F. oxysporum* isolates recovered from bean samples displaying root rots divided the isolates into two main groups but with significant variation between isolates within each group.

Part of the ribosomal RNA intergenic region (IGR) of 23 *F. oxysporum* isolates was amplified in PCR and the products sequenced. Sequence comparisons identified three distinct groups. One of these contained four Spanish isolates (race 6) and two Ugandan isolates. The second group contained a CBS culture collection *F. oxysporum* f. sp. *phaseoli*, two ATCC culture collection *F. oxysporum* f. sp. *phaseoli* (race 1 and race 4), a Colombian isolate (race 3), a Ugandan isolate, a Rwandan isolate and an HRI example of *F. oxysporum* f. sp. *narcissi*. The third and largest group contained four Rwandan and two Democratic Republic of Congo isolates from bean variety G2333, a race 5 isolate from Brazil, a second race 3 isolate from Colombia and a single Ugandan isolate. AFLP analysis of these isolates revealed closely related groupings. There was some correlation between these groups and virulence of isolates on the variety G2333. Only isolates from the third group caused severe browning of vascular tissue of this bean variety. The single Ugandan isolate from this group (placed according to IGR sequence) was not tested on bean plants and so its virulence is unknown. However this isolate was placed in a different group by AFLP analysis. More work with a larger number of isolates will be needed before molecular analysis can be used to identify virulent strains. The groupings found so far do not correlate with known races except for the placing of four race 6 isolates in a single group. The pathogenicity of the two Ugandan isolates also placed in this group requires further study.

Two glasshouse experiments to study the response of several bean varieties to a number of *F.oxysporum* isolates were undertaken at HRI. In the first experiment the varieties G2333, A211 and K20 were inoculated with four isolates: ATCC 18131 (race 1), SP1 (Spanish isolate, race 6), DRC1b and RW7 (both are African isolates recovered from wilted plants of G2333 in Democratic Republic of Congo and Rwanda respectively). The only isolates to cause yellowing and/or wilting and the death of some plants of G2333 were DRC1b and RW7. Only SP1 caused symptoms on K20 and these were slight. Only RW7 killed any plants of A211, despite this variety's reported susceptibility to all known races of the wilt pathogen except races 3 and 7 (Alves-Santos *et al*., 2002). When the lower stems of all plants were examined for signs of vascular browning it was found that this symptom was widespread in most isolate/variety combinations. An exception was the combination of isolate DRC 1b with K20 where no browning was seen in any plants. K20 plants inoculated with ATCC 18131 and RW7 also only showed vascular browning in 38% and 13% of plants respectively.
A larger number of isolate/variety interactions were examined in a second experiment. Inoculations were done in November and the plants were grown in much cooler conditions than in the first experiment. This may explain why very few plants showed any foliar symptoms and even fewer plants died. Only isolate RW7 caused plant death and only in varieties A211 (14% dead plants cf. 50% in the earlier trial) and IPA 1 (36% dead plants). Vascular browning was recorded in only half of the isolate/variety interactions (see Table 2). The following isolates caused no vascular browning in G2333: Race 1 (this isolate did cause browning in the first experiment), Race 2, Race 4, FON 9 (*Fusarium oxysporum* f. sp. *narcissi*),TG 012, TG 032 (both Ugandan isolates collected from plants with root rot symptoms), CBS935.73 (culture collection isolate

described as *Fusarium oxysporum* f. sp. *phaseoli*) and RW17 (a n isolate from a diseased bean plant from Rwanda; RW4, RW7 and RW23 [Table 2] were from similar plant samples).
RW7 has been shown to be an aggressive isolate on all bean varieties except Calima (resistant to races 1, 2 and 5) and BAT477 (resistant to races 2 and 3). This would suggest that RW7 most resembles Race 2 but HF 465-63-1 should be resistant to this race yet suffered severe vascular browning by RW7. It is possible that it represents a new race as yet unreported.

Table 2: Vascular browning scores for isolate/variety interactions

Variety	isolate								
	Race 1*	Race 2*	Race 3*	Race 4*	Race 6a*	Race 6b*	RW4	RW7	RW23
G2333	0[br]	0	0.46	0	0.09	0.09	2.00	1.09	1.00
A211	-	-	1.57	-	-	-	-	1.50	-
Calima	0	0	0.22	0.78	-	-	-	0	-
HF 465-63-1	0	-	-	-	-	-	-	0.86	-
BAT477	0	-	-	2.36	-	-	-	0.07	-
IPA 1	0	1.27	0.27	0.82	-	-	-	2.09	-

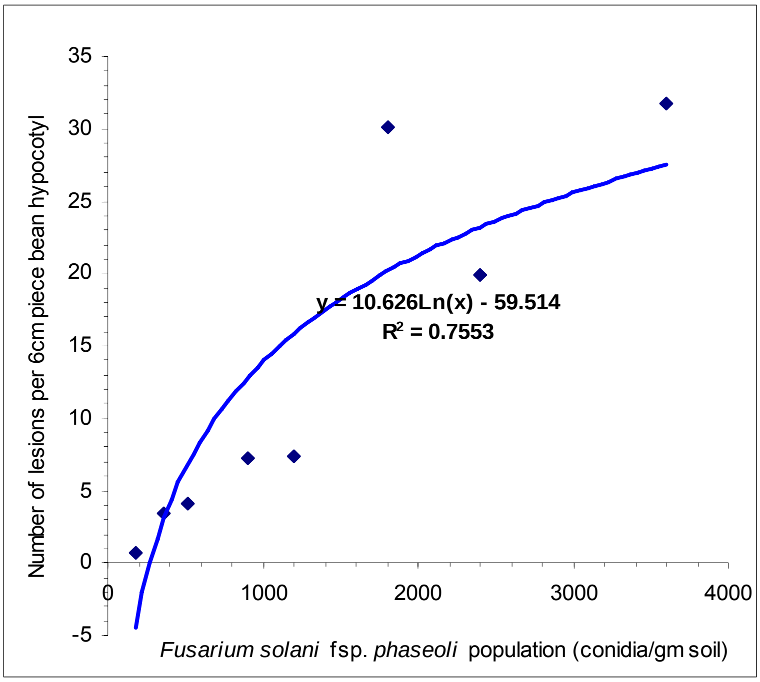
*: Race 1 (ATCC 18131), Race 2 (BRA 5), Race 3 (28 COL), Race 4 (ATCC 90245), Race 6a (SP 1) and Race 6b (SP 9).
br: this value is calculated by dividing the cumulative vascular browning score (0,1, 2 or 3 for none, <20%, <60% and >60% of xylem vessels brown) by the total number of plants inoculated.
-: this interaction was not tested

Quantification:

A novel 'bait' assay for quantification of *F. solani* f. sp. *phaseoli*

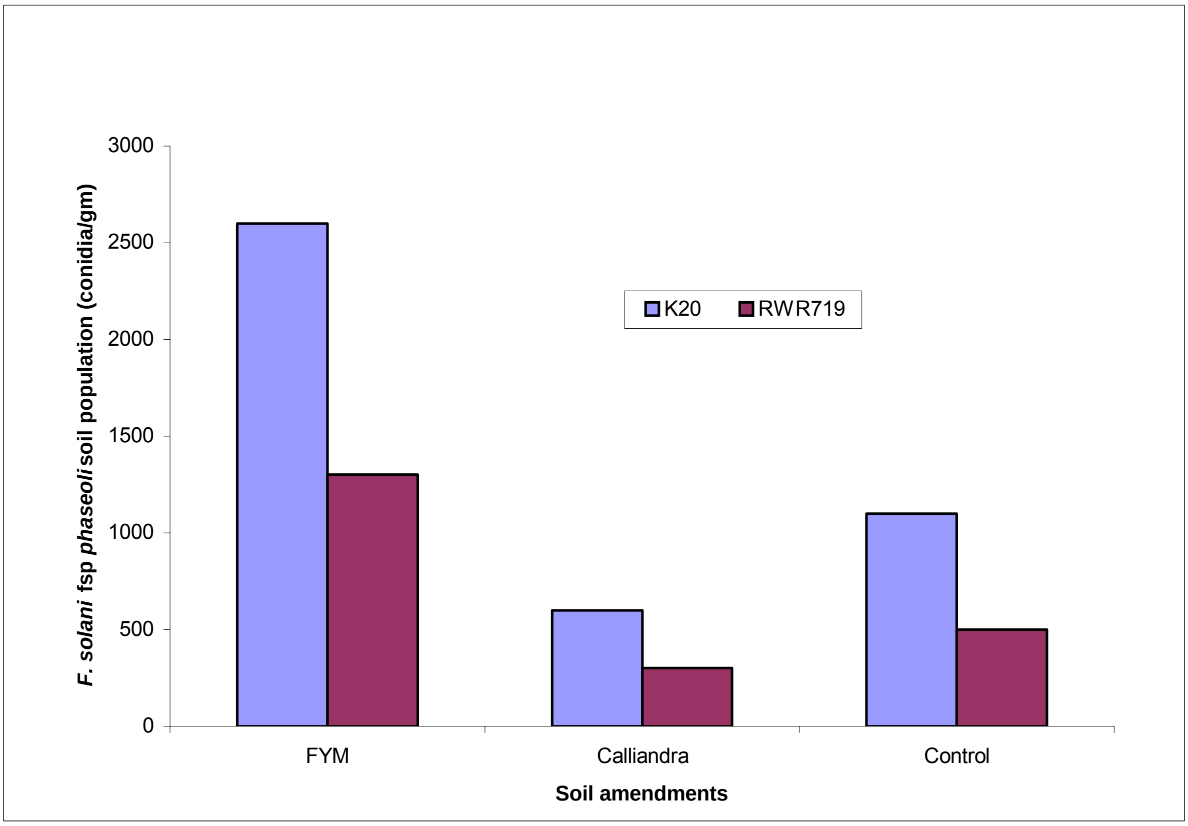
Results from the bean hypocotyl 'bait' assay for quantification of *F. solani* f. sp. *phaseoli* in soil were very encouraging.
Typical elongated, reddish coloured lesions became visible on hypocotyls after four days. By the seventh day, these lesions had expanded to between 2-3 mm long. In soils where propagule concentrations ranged from 200 to 4000 conidia.g^{-1} mean lesion counts on a single hypocotyl section varied from 0.9 to just over 30 respectively. A plot of soil pathogen concentration against mean number of lesions per hypocotyl resulted in a positive and significant relationship (R^2 = 0.755) (Figure 8). The experiment was done five times

Figure 8. Relationship between mean number of *Fusarium solani* f.sp. *phaseoli* lesions on 6cm long bean hypocotyls and soil population of the pathogen, Kawanda, Uganda 2002.



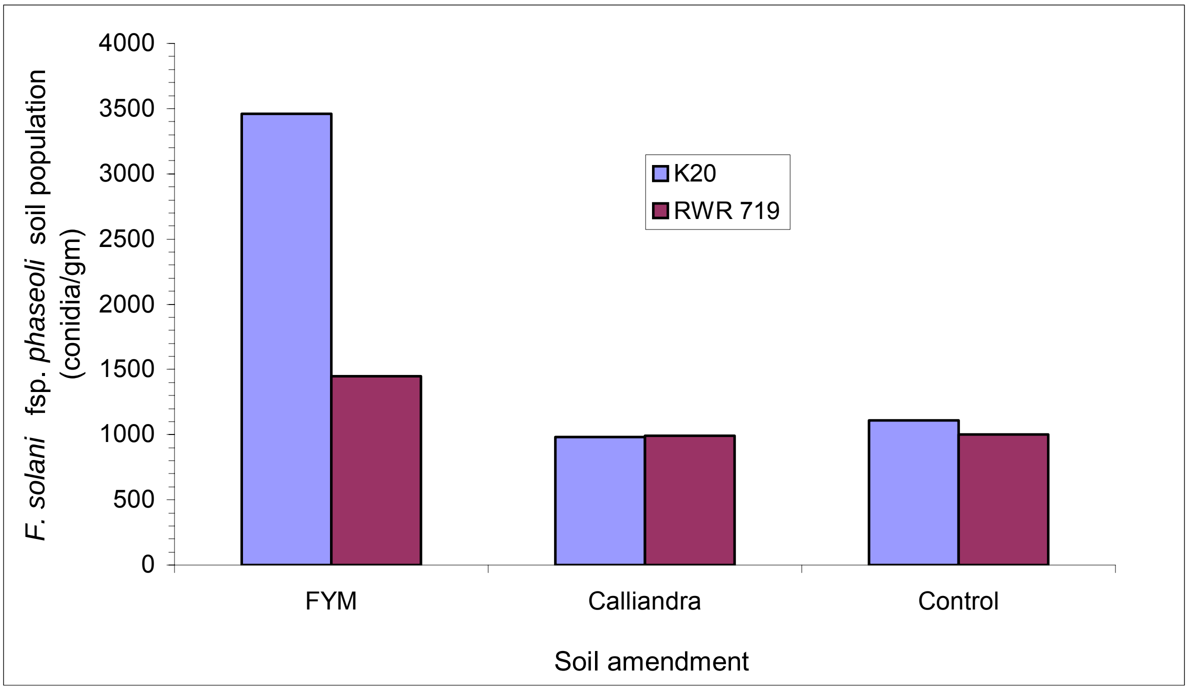
In the screen house root rot severity was affected markedly by the addition of manures and by the variety grown (see also output 6 for more details). When soil samples were analysed at plant maturity (9 weeks after sowing) using the bean hypocotyl assay large differences in pathogen numbers were observed. Values for soils that had grown the root rot-resistant variety (RWR 719) were approximately half those recorded for soils that had grown the susceptible variety (K20), regardless of amendment. The addition of *Calliandra* spp. green manure reduced pathogen populations by about 50% compared to unamended soils. By contrast, farmyard manure more than doubled the estimated numbers of pathogens and both of these effects were similar for each variety grown (Figure 9). These relative changes in pathogen populations were mirrored by similar differences in disease severity ratings (see output 6 Figures 11a and 11b).

Figure 9. Quantification of *F. solani* in screen house soils, with and without manures, and planted with a root rot-susceptible or –resistant variety, Kawanda, Uganda 2002.



The bean hypocotyl assay was also used successfully on soil samples from the field trial. Higher pathogen numbers were recorded for all combinations of variety and amendment than the equivalent values from the screen house experiment. Differences between the varieties were less apparent in the field except in treatments where farmyard manure was added. This was surprising since the differences between the two varieties disease ratings were quite large for all treatments (see output 6, Table 14). However, it is important to remember that *F. solani* was the only organism present in the screen house experiment but a large range of microorganisms will be present in field soils, many of which are likely to interact with each other.

Figure 10 Quantification of *F. solani* in field soils, with and without manures, and planted with a root rot-susceptible or –resistant variety,at Rubaya, Kabale, Uganda 2002.



*Data from the second site, Kicumbi, is similar to this.

A dilution plating method for quantification of Pythium in soil:

- Soils infested at ratios of 1:5 and 1:10 consistently produced large numbers of colonies when 1 ml of suspension from the 50 or 100ml volumes was plated out. It was difficult to count these because by the second day the colonies had merged. On further dilution to 200ml the number of colonies were countable (15 –20 colonies per plate; equivalent to 1500-2000 $cfu.g^{-1}$)
- Soils infested at ratios of 1:15 and 1:20 v/v consistently produced fewer colonies. Colony counts ranged from zero to three for any dilution.
- Earlier work has indicated that a threshold of about 300-500 $cfu.g^{-1}$ is necessary for *Pythium* to cause disease. Some soils that were known to induce disease were processed using this dilution plating method but plating out 0.7ml of a suspension of 2g soil in 100ml of sterile water. The numbers of colonies growing on each plate varied between five and ten (equivalent to a soil concentration of 250-500 $cfu.g^{-1}$.

Quantification of *Pythium* spp. in artificially infested soil samples from a screen house experiments

Table 3 shows the population changes over a period of 14 weeks in a screen house experiment to study the effect of manure amendments on disease and pathogen numbers using two bean varieties (CAL96-susceptible and RWR 719-resistant)

Table 3. Quantification of *Pythium* spp. (colony forming units/gram of soil) from a screen house experiment at Kawanda, 2002

		Weeks after planting							
Variety	Soil amendment	start	2	4	6	8	10	12	14
CAL 96									
	Green manure	305.0	381.0	643.0	745.0	533.0	595.0	614.0	436.0
	Farmyard manure	262.0	333.0	476.0	745.0	640.0	716.0	597.0	566.0
	Control	283.0	309.0	333.0	438.0	267.0	376.0	531.0	459.0
RWR 719									
	Green manure	250.0	286.0	452.0	519.0	348.0	524.0	511.0	336.0
	Farmyard manure	309.0	405.0	571.0	1038.0	634.0	745.0	556.0	633.0
	Control	336.0	452.0	690.0	343.0	318.0	347.0	412.0	276.0
LSD (P= 0.05)		140.1	239.1	268.0	347.3*	169.6**	353.7	455.2	356.0
CV(%)		11.5	6.9	7.9	23.1	4.9	8.1	36.4	31.0

LSD: * and ** significant at 5 and <1% respectively. Values without star are not significant at 5%

Quantification of *Pythium* spp. in naturally infested soil samples from field experiments

Table 4 shows the population changes over a period of 14 weeks in a field experiments to study the effect of manure amendments on disease and pathogen numbers using two bean varieties (CAL96-susceptible and RWR 719-resistant)

Table 4. Quantification of *Pythium* spp. (colony forming units/gram of soil) from a field experiment at Rubaya, Kabale 2002

		Weeks after planting							
Variety	**Soil amendment**	**start**	**2**	**4**	**6**	**8**	**10**	**12**	**14**
CAL 96									
	Green manure	131.0	155.0	231.0	107.1	192.8	174.0	128.5	121.4
	Farmyard manure	107.0	107.0	226.0	95.2	109.5	138.0	126.1	176.1
	Control	124.0	155.0	181.0	126.1	102.3	150.0	147.6	119.0
RWR 719									
	Green manure	102.0	107.0	126.0	102.3	164.2	114.0	149.9	90.4
	Farmyard manure	114.0	145.0	131.0	107.1	114.2	188.0	142.8	123.8
	Control	90	143.0	143.0	90.4	142.8	164.0	145.2	107.1
LSD (P= 0.05)		79.4	97.5	11.7	57.6	76.6	105.7	45.2	67.0
CV(%)		11.3	27.2	13.0	18.3	14.0	10.2	12.4	7.3

LSD: * and ** significant at 5 and <1% respectively. Values without star are not significant at 5%

It is clear from Table 3 that screen house *Pythium* popoulations in all treatments tended to increase during the first 6 weeks of the experiment and then declined over the remaining 8 weeks. Population numbers were affected by the addition of manures; both types of amendment causing increases relative to the control (see also output 6 for more details). These relative changes in pathogen populations were mirrored by similar differences in disease severity ratings over the first 6 – 8 weeks but not thereafter (see output 6 Figure 16). There, disease severity continued to increase throughout the duration of the experiment despite the decreases in pathogen population seen here.

The situation in the field is less clear. Table 4 shows that population numbers were quite constant throughout the experiment and generally unaffected by the amendments. This is in contrast to the continued increases in disease severity that were observed at one of the two field sites and the detrimental influence of both amendments on overall levels of disease (see output 6 Figure 17). The differences seen between the screen house and field experiments may well be due to the many more complex interactions that are likely to occur in a field situation compared to the more controlled environment of the screen house. Furthermore, only *P. ultimum* var *ultimum* was present in the screen house experiment whereas a vaste range of microorganisms are likely to be found in field soils.

4 Distribution of root rot causing pathogens mapped.

***Pythium*:**

Eleven *Pythium* species were identified from samples collected previously by comparing the ITS1 sequences with those of known species. Their pathogenicity was tested by inoculating bean plants. Results are presented in Table 5.

Table 5. Pathogenicity of *Pythium* species

Pathogenic	Species with both pathogenic and weakly pathogenic isolates	Non pathogenic
P. ultimum var *ultimum* *P. nodosum,* *P. pachycaule* *P. spinosum*	*P. torulosum* *P. salpingophorum*	*P. oligandrum* *P. echinulatum* *P. vexans* *P. dissotocum* *P. deliense*

The distribution maps (Figures 11, 12 and 13 clearly show that *P. ultimum* var *ultimum* is the most frequently recovered isolate in all three regions, closely followed in Kabale by *P. salpingophorum*, in Kisoro by *P. torulosum* and in Mbale & Sironko by *P. vexans*.

Figure 11. Distribution of *Pythium* species identified in Kabale district

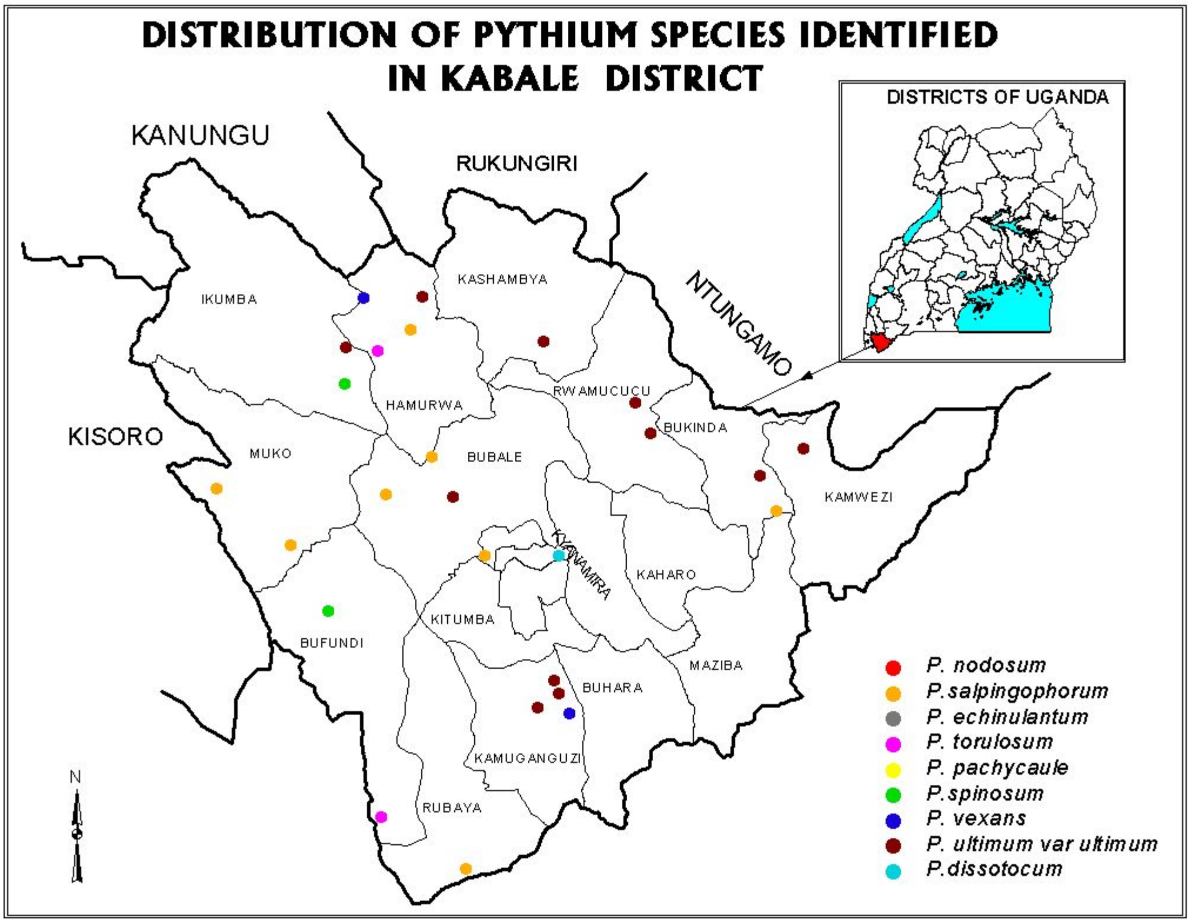


Figure 12. Distribution of *Pythium* species identified in Kisoro district

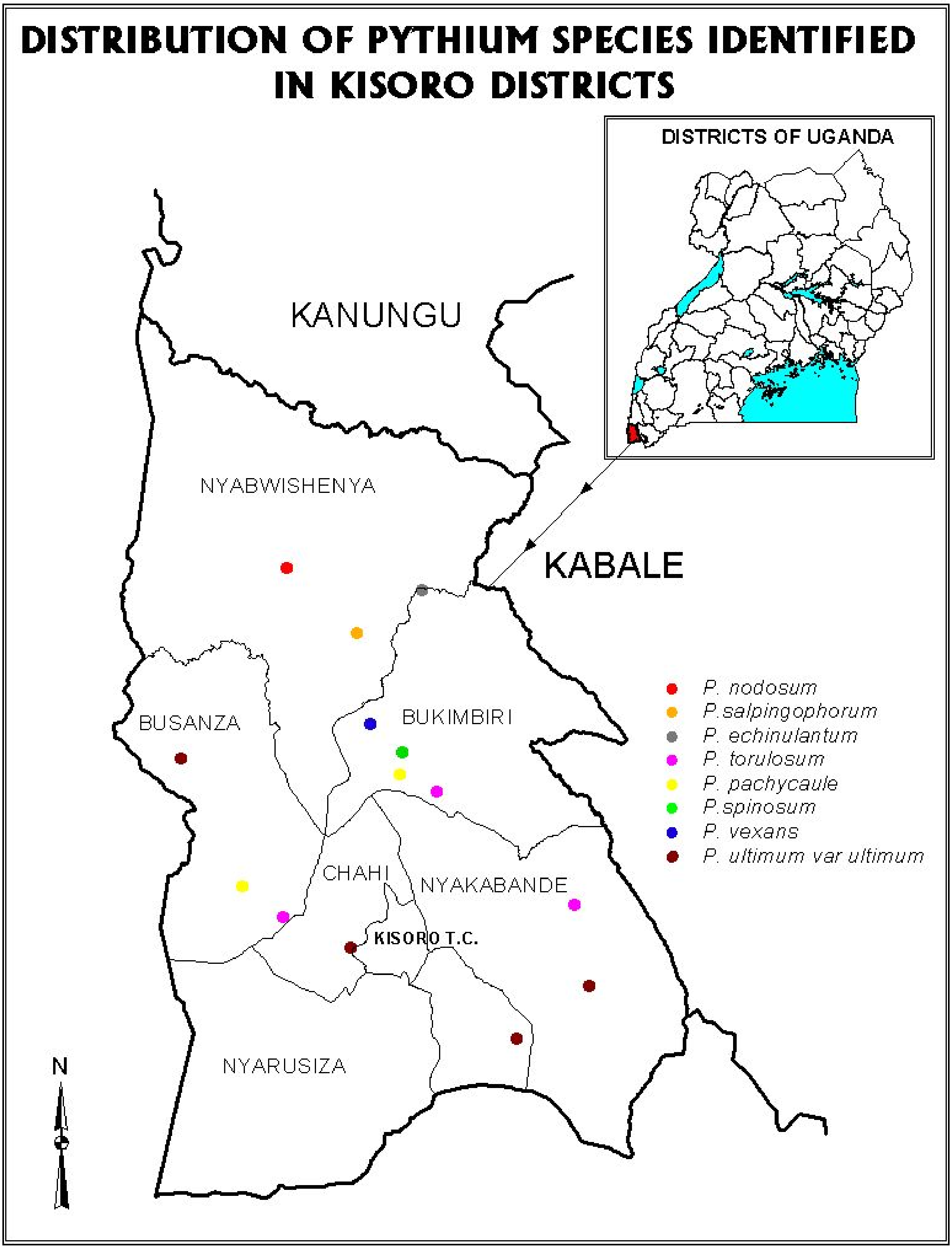
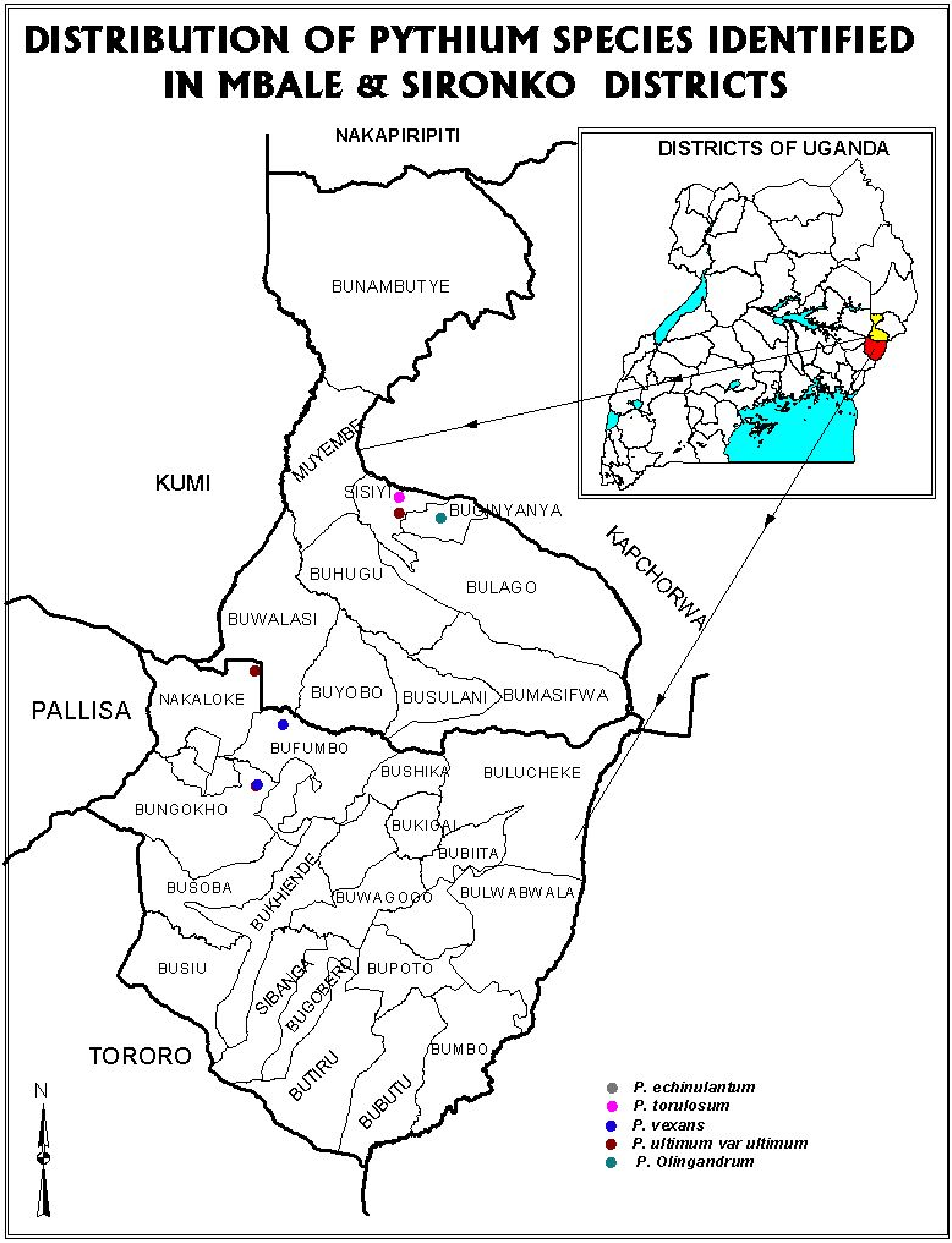


Figure 13. Distribution of *Pythium* species identified in Mbale and Sironko districts



***Fusarium*:**

F. oxysporum and *F. solani* were both recovered from bean tissue samples with root rot symptoms. Two types of *F. solani* isolates were recovered from bean plants: fast-growing and slow-growing on potato dextrose agar. Pathogenicity tests of both types of isolate on 14 bean varieties confirmed that only the slow-growing isolates are highly virulent and should be given the infraspecific identity f. sp. *phaseoli* (see Output 3 for more details). Both types of isolate (and *F. oxysporum*) were found in all areas sampled and so distribution maps for *Fusarium* were not constructed. The same locations sampled for *Pythium* were also sampled for *Fusarium*.

5 Interactions between pathogens causing root rots and other biotic and abiotic factors influencing disease epidemiology identified.

Interactions between fungi :

In the laboratory at CIAT-Kawanda dual inoculation of culture plates with *Pythium* and *Fusarium* spp identified some *Fusarium* isolates which are antagonistic towards pathogenic *Pythium* spp. Greenhouse experiments are in progress to assess their potentially beneficial impact on root rots by using selected isolates of *Fusarium* and *Pythium* spp. Initial results show that *Pythium* alone caused seed rot whereas *Fusarium* alone resulted in lesions on the root but less effect on plant growth. A combination of the two organisms resulted in less vigorous and more chlorotic plants than those where *Fusarium* alone was present. However, antagonism by *Fusarium* on *Pythium* was demonstrated resulting in a reduced impact of *Pythium* when combined with *Fusarium* than with *Pythium* alone.

Laboratory evaluations of antagonistic interactions between *Pythium* spp., between *Fusarium* spp, and between *Pythium* and *Fusarium* spp were made by allowing the organisms to grow together on agar media (for results see Figure 14 and Tables 6 and 7).

Figure 14. Interaction between pathogenic *Fusarium solani* f sp *phaseoli* (isolate 01/047) and *Pythium ultimum* (isolate MS061) showing the former restricting growth of the latter.

Table 6. Number of *F. solani* isolates showing antagonistic effects on *Pythium deliense* and *Pythium ultimum*

Reaction level[1]	*F. solani*	
	P. deliense	*P. ultimum*
1	3	0
2	5	26
3	0	0
4	9	25
5	0	0

[1] = Reaction of 1 to 5 where 1 = Mutual intermingling of two organisms and 5 = Mutual inhibition at a distance

Table 7. Number of *Mortierella* spp. isolates showing antagonistic effects with *Pythium deliense* and *P. ultimum*

Reaction level[1]	*Mortierella* spp isolates	
	P. deliense	*P. ultimum*
1	0	3
2	2	4
3	0	0
4	4	2
5	0	0

[1] = Reaction of 1 to 5 where 1 = Mutual intermingling of two organisms and 5 = Mutual inhibition at a distance

In the glasshouse at HRI *Pythium* (pathogenic Ugandan isolate KIS 2 [from molecular data this is believed to be *P. torulosum*]) and *F. solani* f. sp. *phaseoli* were inoculated singly and together on bean variety K20. *Fusarium* alone caused much more stunting than *Pythium* but *Pythium* alone caused severe chlorosis. The combined inoculation reduced both chlorosis and stunting indicating antagonism between these two isolates. No stem lesions were found when *Pythium* alone was present. All of the crop parameters recorded (Table 8) were affected detrimentally when either or both pathogens were present. However, *Fusarium* caused the largest reduction in plant biomass and this impact was moderated when *Pythium* was present as well. *Pythium* alone only caused minor reductions in mean height and weight.

Table 8: Interaction between *Fusarium solani* f. sp. *phaseoli* and *Pythium* sp. on variety K20

TREATMENT	Mean height	Mean disease rating[1]	Mean root dry weight	% root dry weight change on control	Mean shoot dry weight	% shoot dry weight change on control	Total dry weight	% total dry weight change on control
Water	23.9	1.3	352	0	1121.5	0	1473.5	0
Pythium 120g + PLE Fusarium $3x10^6$	17.9	7.5	307.5	-12.6	946.5	-15.6	1241.4	-15.8
Pythium 120g	20.4	1.3	315.6	-10.3	856.4	-23.6	1161.7	-21.2
PLE Fusarium $3x10^6$	15.4	8.2	145.1	-58.8	650.7	-42.0	737.0	-50.0

[1] The CIAT scale (Abawi and Pastor Corrales, 1990) was used to calculate disease ratings

The second pathogen interaction experiment (data not presented) was set up using vermiculite as a growing medium in order to minimise the nutrients available to the plants. The same *Fusarium* isolate was used together with *Pythium spinosum*. Once again *Fusarium* alone caused the largest reduction in plant growth and the greatest number of stem lesions. Some lesions were also observed when *P. spinosum* was present, either alone or with *Fusarium*. However, the oatmeal used to grow the *P. spinosum* inoculum increased the nutritional status of the plant growing medium wherever it had been added and in fact these plants grew more vigorously than the water controls making it difficult to interpret the impact of this pathogen.

The variation between the results of these interaction experiments carried out at HRI in the UK and at CIAT-Kawanda in Uganda may well be due to the use of different isolates. The identification of *Mortierella* spp. as potentially useful antagonists of *P. ultimum* is an encouraging development. More work on interactions between *Fusarium* and *Pythium* and between individual *Pythium* spp. is needed before firm conclusions can be drawn.

Seed borne inoculum:

Pythium and *F. solani* have not yet been recovered from any seed samples already tested from southwest Uganda. The main organisms found on seed plated on PDA and other selective media were other *Fusarium* spp. and *Phoma* spp. Large numbers of *F. oxysporium* were recovered (between 0.5 and 48% of samples) but it is not known whether the isolates are pathogenic or saprophytic (Table 9).

Table 9. Levels of *Fusarium oxysporum* on seed on KOMADA medium

Sample	No. of seeds infected per 200 seeds	Percentage infection (%)
1	35	17.5
2	96	48.0
3	12	6.0
4	42	21.0
5	16	8.0
6	1	0.5
7	1	0.5
8	3	1.5
9	45	22.5
10	14	7.0
11	3	1.5
12	32	16.0
13	10	5.0
14	1	0.5
15	34	17.0
16	23	11.5
17	27	13.5
18	8	4.0
19	3	1.5

Further evaluation of more seed samples from root rot affected areas of eastern Uganda showed no recovery of *Pythium*. Mostly *Fusarium* spp not known to be pathogenic to beans were isolated.
Pythium spp have not yet been recovered from any samples already tested. However, a number of Fusarium spp were recovered and are being characterized.

Interactions with nematodes:

At flowering there were relatively fewer galls and lower fusarium wilt severity on a sole crop of bean than when in association with other crops. However, at pod filling, there were more galls in a sole bean crop than in association with maize, Similarly, a significantly high number of nematodes (adult and juveniles) were recovered from soil with sole bean crops than from other combined crops.

Results from a nematode survey in Uganda indicated that root-knot nematode [RKN] is not a major factor in the study area (see below). However, in DRC

the effect of different cropping patterns grown in the first season: maize, bean and tomatoes alone and a mixture of the three (known to influence RKN populations), was assessed in the second season by growing a fusarium wilt-susceptible bean variety. Results obtained clearly showed that the association of maize, bean and tomato increased nematode populations and fusarium wilt severity causing a reduction in grain yield.
At R6 crop growth stage organic amendments resulted in a reduction in the number of pupae per plant and in a reduction in severity of fusarium wilt on variety G 2333.

A nematode survey in Uganda revealed that although slight galling due to root knot nematodes (RKN) was found in many fields, severe galling was rare and there was no association between root rots and RKN (see publications for BTOR).
No correlation was found between the incidence or severity of root rot and the incidence or severity of RKN. Severe root knot nematode attack was found at very few sites and mainly where the soil was sandy, whereas the root rots were not prevalent on the sandier soils. Root-knot nematode therefore, is not a major constraint to bean production in the two districts surveyed. The conclusion drawn from these results was that no further work on root-knot nematode was justified for the project target areas. High incidences of root rot seem to require poor fertility and high soil moisture content. Root-knot nematode becomes a problem on free-draining soils.

Table 10 Summary of bean survey in Kabale and Kisoro district - incidence and severity of bean root rot, root-knot nematode damage and incidence of bean stem maggot damage.

	Incidence Fields/district (%)	Incidence* per field (%)	Severity Score (0–10)
Kabale			
Root rot	93	50	1.71
RKN	62	24	0.43
BSM	59	32	-
Kisoro			
Root rot	97	74	3.84
RKN	71	41	1.14
BSM	48	10	-

* Means derived from 10 plants/field and 29 fields (Kabale), 31 fields (Kisoro).

Interactions between *Fusarium* and bean stem maggot (BSM):

Studies on the interaction between fusarium wilt and BSM at Mulungu showed that incidence and severity of fusarium wilt were significantly reduced in plots where BSM was controlled (Table 11). This implies that the presence of BSM results in an increase in incidence and severity of fusarium wilt. This means therefore that in the development of management practices to control Fusarium wilt, the possible influence of BSM has to be considered. Further studies are underway in both on-farm and on-station trials.

Table 11. Number of BSM pupae, severity of fusarium wilt and yield of the climbing bean G 2333 gown on soils amended with farmyard manure and Tithonia

Treatment	No. of pupae	Severity of fusarium wilt	Yield (kg/ha)
Control	2.8 a*	4.1 a	204 b
FYM	2.5 a	3.3 b	610.3 a
Tithonia	2.4 a	3.2 b	475.1 ab
C.V.(%)	6.4	13.7	30.3

*Values in the same columns followed by the same letter are not significantly different at p = 0.05

Interactions with viruses (BCMV/BCMNV):

Evaluation under field conditions showed a number of root rot resistant genotypes to have the I-gene and the potential to suffer from black-root (Table 12). Further evaluation is planned with artificial inoculations.

Table12. Root rot resistant genotypes suffering from black root under natural infection at Kawanda, Uganda.

Line / Entry	**Reaction**	
	Mosaic	Black root
BACO (ML) C-1		X
BOA 5-1/5		X
EX-RICO		X
BOA 1-5/21		X
BOA 5-8/12		X
BACO 4-5/25		X
BOA 1-4/4		X
DOR781		X
DOR766		X
DOR711		X
DOR708		X
DOR710		X
DOR765		X
DOR771		X
DOR622		X
DOR633		X
RWR719		X
DOR755		X
MLB-40-89A		X
CC 906		X
CAL 96	X	X

6 Management strategies for control of bean root rot diseases, appropriate to resource-poor farmers, evaluated in terms of their effect on pathogen populations, disease levels and crop yield.

***Fusarium*:**

When manures were added to screen house soils to investigate the impact of improved soil fertility on root rots caused by *F. solani*, significant differences were seen between the effects of green manure (from *Calliandra* spp.) and farmyard manure (Figures 11a and 11b). Disease severity ratings steadily increased over time in all treatments with both varieties. Farmyard manure caused increases in disease in both varieties. When green manure was added to soils reductions in disease (compared to untreated plots) were seen and these were most noticeable where the susceptible variety was grown. Similar effects of the manures were observed when pathogen population values were estimated using the bean hypocotyl assay (see output 3, Figure 9). When dry matter values were examined both types of manure greatly increased screen house yields by up to ten-fold over control values (Table 13). This suggests that crop yield would be improved by the addition of either type of manure despite any increase in root rot that may accompany some treatments.

Table 13. Effect of amending soil infested with *Fusarium solani* fsp. *phaseoli* on dry matter of a susceptible (K20) and resistant (RWR 719) bean varieties, Kawanda, Uganda.

Variety	**Soil amendment**	Dry matter (g.plant^{-1})		
		Shoot	Root	Total
K20	Farm yard manure	9.27	0.34	9.61
	Green manure	7.45	0.1	7.55
	Control	1.07	0.09	1.16
RWR 719	Farm yard manure	9.03	0.22	9.25
	Green manure	8.23	0.10	8.33
	Control	1.06	0.08	1.15
	LSD[1] (P=0.05)	1.8 ns	1.07**	1.74***
	CV(%)	13.6	19.0	13.0

LSD[1]: ** , * = significant at 1 and <1%, respectively; ns = not significant at 5%.**

Figure 15a: Bean root rot disease progression in the resistant variety RWR 719

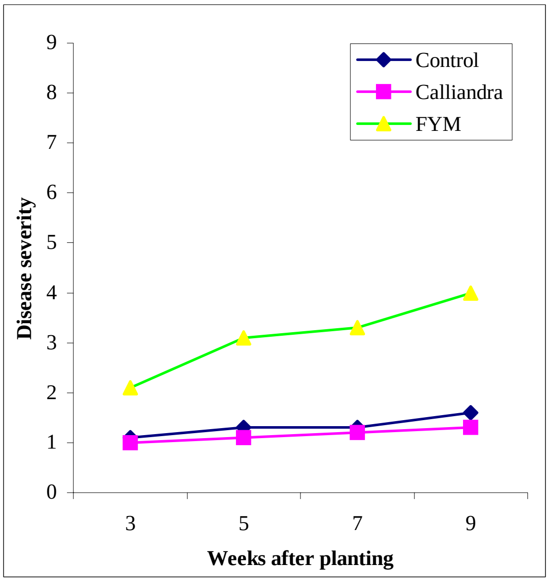
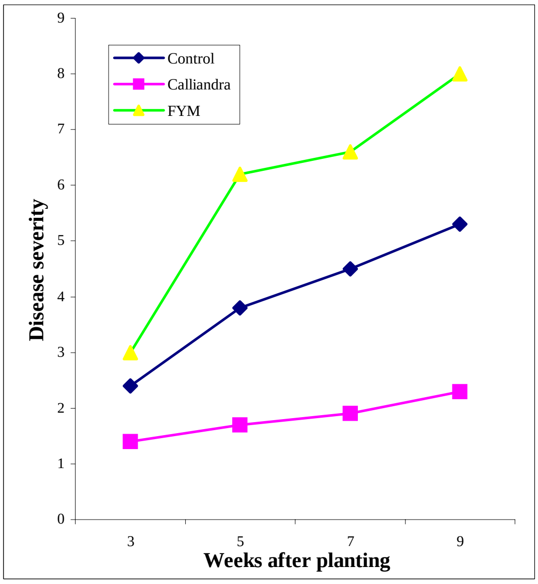


Figure 15b: Bean root rot disease progression in the susceptible variety K20



Similar sets of data were recorded from the two field experiments (Table 14). Generally, disease was slightly greater at Rubaya than Kicumbi as evidenced by the unamended plot values. The application of green manure caused a slight reduction in disease, most noticeable in the variety K20, but this was not as marked as that found in the screen house experiment. Farmyard manure had no impact on disease levels in RWR 719 and was ambiguous in its effect upon the susceptible variety; increasing disease compared to the control at Kicumbi but causing a slight reduction at Rubaya. Pathogen numbers were estimated using the bean hypocotyl assay (see output 3, Figure 10) and for the resistant variety the relative constancy of pathogen populations in all three treatments was mirrored by similarly constant disease severity ratings. The application of farmyard manure to plots growing the susceptible variety caused a three-fold increase in the pathogen population even though the change in disease severity compared to the control was quite small.

There are benefits to be gained by growing the resistant variety RWR 719. Disease severity was always lower than that seen in K20, especially at both of the field sites. Pathogen populations were also lower in situations where the resistant variety was grown. However, this was not translated into significantly higher yields in the screen house experiment.

Table 14. Effect of soil amendments on Fusarium root rot disease severity at 2 sites in southwestern Uganda, 2002.

		Kicumbi			Rubaya		
		Weeks after planting			Weeks after planting		
		6	8	10	6	8	10
Variety	**Soil amendment**	**Disease rating[1]**			**Disease rating[1]**		
K20	Farm yard manure	4	7.8	8.8	4.0	5.7	7.3
	Green manure	3	5.0	5.9	4.2	5.1	5.3
	Control	3	8.2	5.7	3.8	8.0	8. 7
RWR 719	Farm yard manure	1.2	1.7	2.33	1.6	2.0	3.3
	Green manure	1.1	1.3	2.0	1.9	2.2	2.8
	Control	1.1	1.3	2.5	2.3	2.5	3.4
	LSD (P=0.05)[2]	2.08 ns	0.78***	1.96**	1.6 ns	1.4*	0.68***
	CV(%)[3]	49.1	8.5	11.2	34	17.8	7.2

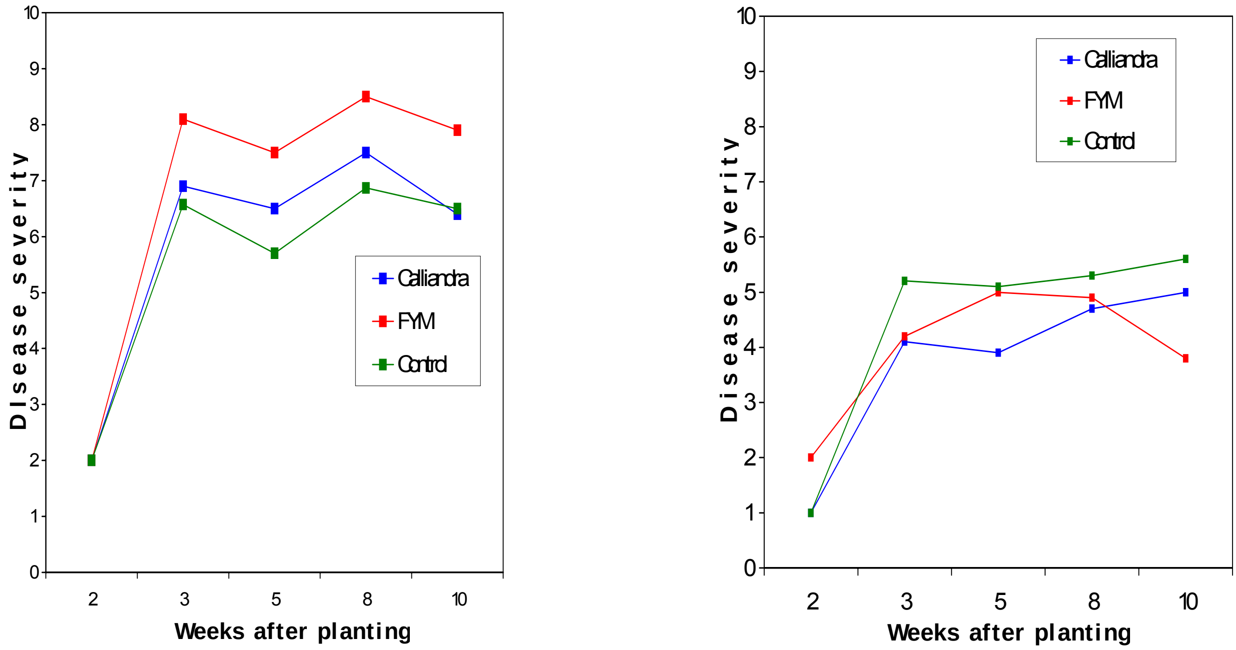
[1] The CIAT scale (Abawi and Pastor Corrales, 1990) was used to calculate disease ratings
[2] LSD: *, ** , *** = significant at 5, 1 and <1%, respectively; ns = not significant at 5%.
[3] CV (%): Coefficient of variation

***Pythium*:**

The same two manures were added to screen house and field soils to investigate the impact of improved soil fertility on root rots caused by *Pythium* spp. Generally, the effects of the manures on disease ratings were much less pronounced than were observed for *Fusarium*. In the screen house experiment, where *P.ultimum* var *ultimum* was the only pathogen present, farmyard manure caused a slight increase in disease in the susceptible variety (Figure 16a). This also corresponded with an increase in pathogen numbers but only over the first six weeks (see output 3).

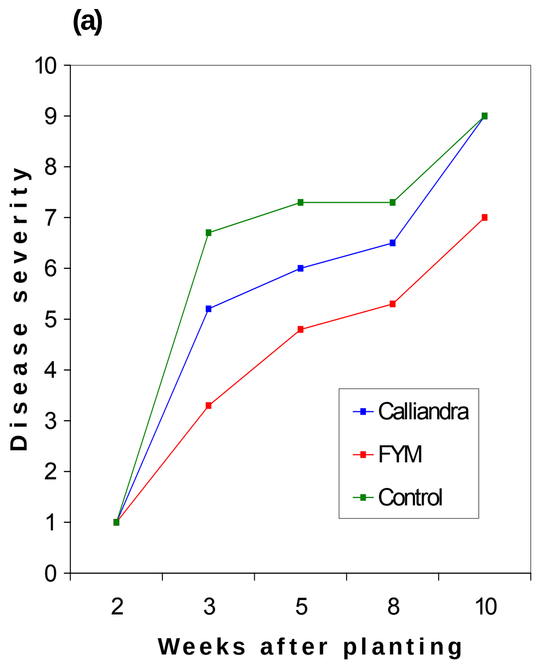
Figure 16. Disease progress in the susceptible variety CAL 96 (16a) and the resistant variety RWR 719 (16b) and the effect of soil amendments in the screen house at Kawanda, 2002

(a) (b)



Two contrasting data sets were recorded at the two field sites (Figures 13 and 14). At Rubaya, both manures decreased disease levels but at Kicumbi they had little impact.

Figure 17. Disease progress in the susceptible variety CAL 96 (17a) and the resistant variety RWR 719 (17b) and the effect of soil amendments in the field at Rubaya, 2002



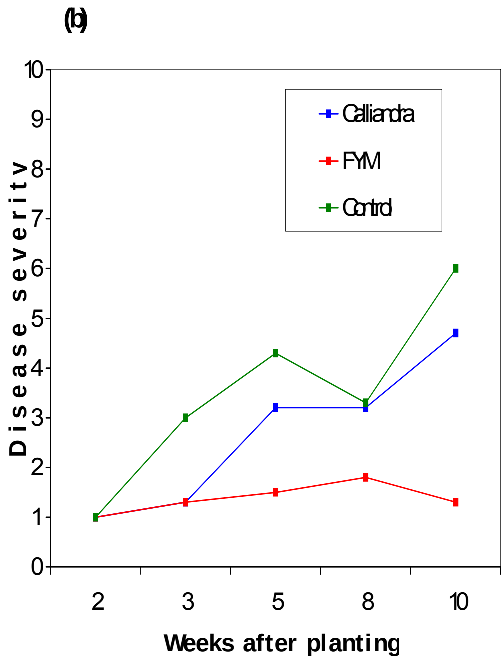
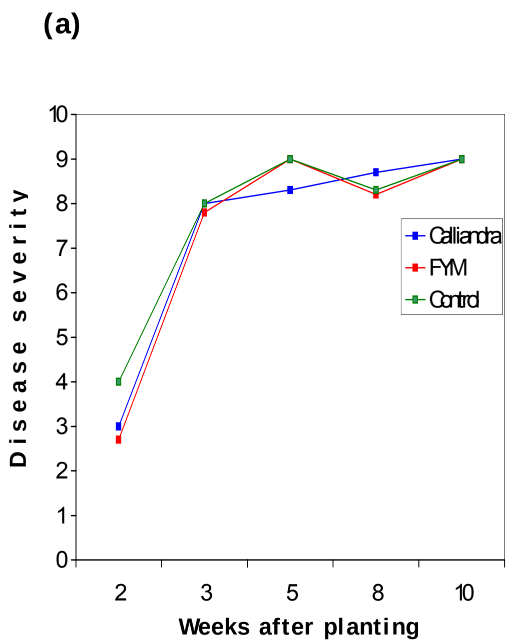
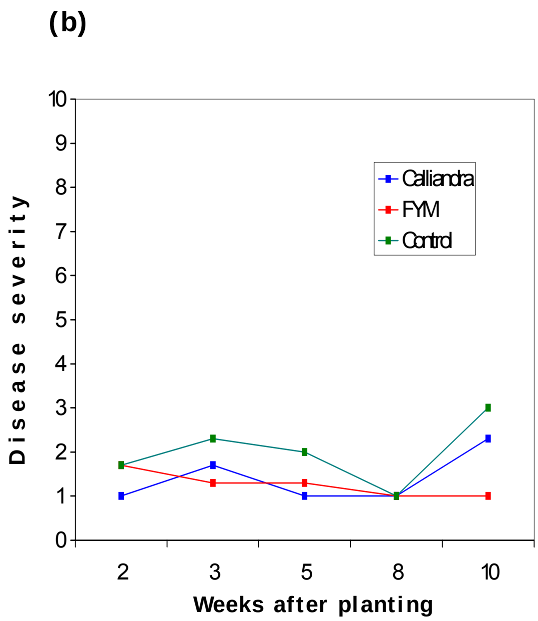


Figure 18. Disease progress in the susceptible variety CAL 96 (18a) and the resistant variety RWR 719 (18b) and the effect of soil amendments in the field at Kicumbi, 2002





When crop yields were examined, both types of manure almost always increased yields compared to control values (Table 15). This effect was also observed when the same treatments were applied to soil infested with *F. solani* (see above). This confirms the immediate crop yield benefit to be gained by adding either type of manure despite any increase in disease levels or pathogen numbers that may accompany some treatments. However, the long-term effects of such a root rot management strategy are unknown and should be investigated. The advantage of growing a resistant variety such as RWR 719 is obvious, particularly in the field. Yields were considerably higher than with CAL 96 and disease levels were always lower. It is difficult to make direct comparisons with the *F. solani* experiments since a different susceptible variety was used there. However, RWR 719 performed well when either pathogen was present and suggests that the use of disease resistant varieties is another valuable management strategy in the control of root rots.

Table 15. Crop yields (kg.ha^{-1}) from field experiments at Rubaya and Kicumbi and from the screen house at Kawanda, 2002

Variety	Soil amendment	Rubaya	Kicumbi	Screen House
CAL 96	Green manure	170.0	220.0	420.0
	Farmyard manure	237.0	2884.0	513.0
	Control	86.0	303.0	249.0
RWR 719	Green manure	342.0	1526.0	848.0
	Farmyard manure	516.0	1248.0	1782.0
	Control	289.0	1050.0	452.0
LSD (P= 0.05)		194.9**	3532.7	432.0**
CV(%)		7.0	40.0	11.6

LSD: * and ** significant at 5 and <1% respectively. Values without star are not significant at 5%

Bioassay for germplasm:

Researchers at PRI reported that the excised coleoptile inoculations resulted in spreading lesions when a susceptible bean variety was challenged with a pathogenic isolate of any one of four bean pathogens *viz*.: *Pythium* spp., *Rhizoctonia solani*, *Fusarium solani* and *F. oxysporum*. Optimum temperatures for each pathogen were found to be 15^{o}C for *Pythium* spp., 30^{o}C for *Rhizoctonia solani* and *F. solani* and 25^{o}C for *F. oxysporum*.

When these interactions were repeated at HRI only bean pathogenic isolates of *F. solani* caused spreading lesions. Pathogenic examples of *Pythium* spp. and *F. oxysporum* grew over the surface of the tissue but not cause lesions. *Rhizoctonia solani* was not tested. G2333 and K20, two varieties with contrasting resistances to Fusarium root rot, both responded in a similar manner.
The reasons for the different results obtained at each of the institutes is unclear.

7 Root rot resistance identified and resultant germplasm integrated into the programmes of target institutions.

None of the entries evaluated in the screen house were resistant, but 3.3 % gave intermediate reaction (Table 16) while the rest were susceptible indicating the need to evaluate more germplasm. Six entries were selected for inclusion in the Regional Root Rot Nursery for distribution and evaluation at sites where root rots are important. Given that few resistance sources to Pythium root rot are available, it was significant that 12 entries gave a reaction of less than < 5.

Table 16. Reaction of the best entries from the IBN and SOH against Pythium root rot (*Pythium* spp) in the screenhouse, Kawanda.

Entry	Nursery	Reaction[x]
DRK 145	IBN	4.2
MX9065-14B	IBN	4.0
CIFAC 91136	IBN	4.6
LM 93204487	IBN	4.0
ROSADO	IBN	4.3
BRB 192	IBN	4.8
IS-49078A	IBN	3.3
DFA 62	IBN	4.3
ICA-GUAYTARA	IBN	4.3
ARS-R-930032	IBN	4.8
L94BO22LE	IBN	4.5
PR93201597	IBN	4.2
DICTA 103	IBN	5.3
FOT 68	IBN	5.5
TLP 29	IBN	5.2
187/1	SOH	5.3
315/1	SOH	5.5

[x] = Based on a CIAT scale of 1-9 where 1 is resistant and 9 is susceptible.

Of the 68 entries in the Root Rot Resistant nursery grown by farmer groups, several entries were more resistant than the rest and have been selected (on the basis of farmer criteria) by the groups for further evaluations. Some trials

were utilised by the modified farmer field schools as learning tools to address identified farmer knowledge gaps.
Initially, insufficient rains affected two farmer-groups resulting in inconclusive assessments. Two other research groups selected 29 and 24 entries respectively on the basis of actual and perceived performance specifically considering survival, vigour and yield. Seventeen entries were common to the two groups, an indication of commonality in selection criteria, whereas those specific to each group implied local preferences or possible targeting of local niches. Most of the preferred entries were small seeded because they were said to yield better and are "tolerant to rain". Some entries were expected to perform better on different areas of the farm (high areas are considered poor while the lower fields are considered more fertile). Late-maturing varieties were not preferred but great flexibility was shown with respect to seed colour and taste as some farmers are happy to grow mixtures with diverse seed colour and flavour characteristics.

In subsequent trials (seasons), a total of 44 (out of 68) entries were selected for further examination by four farmer groups. Selection criteria included adaptation to their conditions, resistance to root rots, vigour, yield and seed characteristics. Only thirty of the 44 entries were chosen by any one of the four groups. However, eight entries (FEB 181,VAX2, CC 814, MLB-40-89A, A 686, G 2858 and MLB-68-89A) were selected by two groups, four entries (SCAM-80CM/5, AB 136, Ihumure and MLB-22-89A) selected by three groups and two entries (MLB-48-89A and CC 906) selected by all four groups. A number of these selected entries will be grown in communal plots to multiply seed but several will be grown in individual farmer's plots. The relatively large number originally selected (44) illustrates the interest amongst farmer groups for many and diverse types of materials and the potential value of using this approach to incorporate and take advantage of farmer selection criteria.

8 Dissemination methodologies identified for effective technology transfer to resource-poor farmers.

Following in-depth informal and formal surveys carried out in the project study areas of southwest Uganda, a better understanding was gained of local knowledge, farmers' perceptions of bean diseases, their relative importance compared to other constraints, and traditional management strategies of bean root rots. The gained insights, coupled with a better understanding on how information flows within communities, were used as a basis to develop learning approaches and dissemination strategies that should influence the technology uptake by small-holder farmers. As a result, we recognised the fact that we need to use dissemination approaches that incorporate group action, participatory and knowledge enhancing methods. For example, the surveys showed that farmers recognise and have a good knowledge of the above-the-ground symptoms and overall crop damage caused by bean root rot (BRR). However, because the above-the-ground symptoms due to bean root rots, bean stem maggot (BSM) and soil fertility look similar, most farmers do not distinguish the effect of BSM from that of BRR. This is a diagnostic weakness that can result in the use of wrong or rejection of appropriate management practices. Similarly, some farmers routinely use organic manures, and in Kisoro there is widespread use of raised beds. Although useful, these practices are not linked or considered so in the management of bean root rots.

A participatory learning approach using a modified Farmer Field School methodology (MFFS) was established with two groups to focus mainly on deficiencies in farmer knowledge, while building on (and linking to) indigenous knowledge and practices in the management of root rots. Three other groups simply received demonstrations of root rot management technologies. Results obtained clearly show the need for using a learning approach in introducing and disseminating IPM technologies against root rots (and BSM) among the communities studied.

Our observations showed that MFSS groups improved their knowledge on the root rots, distinguished root rots for BSM and fertility effects, and better understood the predisposing factors. They also appreciated the value of new technologies. Most important was the groups increased confidence that they knew more about the problem, had the capacity to evaluate potential technologies and could identify technologies that would manage the problem. They also felt capable of becoming agents of technology dissemination. One group has participated in training and demonstrating to neighboring and visiting farmer groups the beneficial effects of some of the technologies; mainly tolerant varieties and fertility improvement options (farm yard manure, green manure, inorganic fertilizers) and various combinations. This group is willing to be a focal training point for several farmer groups in the region. Extension personnel from major NGOs (CARE and Africare) and extension offices of the Ministry of agriculture and National Agricultural Advisory Services (NAADS) have visited the demonstration plots belonging to these farmer groups. As a result, some plan to replicate and disseminate successful technologies to many of the large number of farmer groups they work with.

Publications

Scientific

MUKALAZI, J., WHITE, G., MUTHUMEENAKSHI, S., PETTITT, T., CARDER, J. H., BURUCHARA, R., ADIPALA, E. and SPENCE, N.J. (2000). Morphological and molecular identification of *Pythium* species pathogenic to common beans in Uganda. BSPP Presidential Meeting, Imperial College at Wye, Kent, 28-20 December 2000. [Science, academic poster] (see Appendix)

TUSIIME, G., CARDER, J. H., BURUCHARA, R., ADIPALA, E., SPENCE, N.J., GRANT, C. L. and MAYANJA S (2000). Detection and diversity of *Fusarium solani* f.sp. *phaseoli* from common beans in south-western Uganda. BSPP Presidential Meeting, Imperial College at Wye, Kent, 28-20 December 2000. [Science, academic poster] (see Appendix)

BURUCHARA, R., OPIO, F., OTSYULA, R., MUSONI, A., MUKALAZI, J., TUSIIME, G., CARDER, J.H., MAHUKU, G., ADIPALA, E. and SPENCE N.J. (2001). Development of Integrated Management of Bean Root Rots in East and Central Africa: Past, Present and Future. PABRA Millennium Conference, Arusha, 28 May –1 June 2000. [Science, academic presentation] (see Appendix)

MUKALAZI, J., BURUCHARA, R., CARDER, J.H., MUTHUMEENAKSHI, S., ADIPALA, E., OPIO, F., WHITE, G.F., PETTITT, T. and SPENCE, N. J. (2001). Characterization of *Pythium* spp. pathogenic to common beans in Uganda. African Crop Science Conference. October 2001, Lagos, Nigeria [Science, academic presentation] (see Appendix)

MUKALAZI, J., BURUCHARA, R., CARDER, J.H., MUTHUMEENAKSHI, S., ADIPALA, E., OPIO, F., WHITE, G.F., PETTITT, T. and SPENCE, N. J. (2001). Recent developments in the characterization of *Pythium* spp. causing bean root rots in Uganda. National Agricultural Research Organization (NARO). Third Scientifica Conference 4-7 December 2001, Kampala, Uganda [Science, academic poster] (see Appendix)

TUSIIME, G., BURUCHARA, R., ADIPALA, E., CARDER, J.H., SPENCE, N. J. and OPIO, A. F. (2001). Molecular and pathogenic variation among *Fusarium solani* isolates from beans with root rot symptoms. African Crop Science Conference. October 2001, Lagos, Nigeria. [Science, academic poster] (see Appendix)

AMPAIRE, E. L. 2002. Farmers' indigenous technical knowledge of bean disease management and communication systems in southwest Uganda. [Science, MSc Thesis]

TUSIIME, G., BURUCHARA, R., ADIPALA, E., CARDER, J.H., OPIO, F. and SPENCE, N. J. (2002). Development of a quantification technique and the effect of soil amendments on soil populations of *Fusarium solani* f. sp. *phaseoli*. Rockefeller Conference on Biotechnology, Breeding and Seed Systems for African Crops 4-8 November 2002, Kampala, Uganda. [Science, academic poster] (see Appendix)

TUSIIME, G., BURUCHARA, R., ADIPALA, E., CARDER, J.H., OPIO, F. and SPENCE, N. J. (2002). Characterisation of *Fusarium solani* isolates from root rot infected *Phaseolus* beans in Uganda Rockefeller Conference on Biotechnology, Breeding and Seed Systems for African Crops 4-8 November 2002, Kampala, Uganda. [Science, academic poster] (see Appendix)

MUKALAZI, J BURUCHARA, R., ADIPALA, E., CARDER, J.H., OPIO, F., PETTITT, T. and SPENCE, N. J. (2002). Developing a method for quantification of population levels of *Pythium* species pathogenic to beans. Rockefeller Conference on Biotechnology, Breeding and Seed Systems for African Crops 4-8 November 2002, Kampala, Uganda. [Science, academic poster] (see Appendix)

<u>Internal reports</u>

SPENCE, N.J. and TEVERSON, D.M. (1999) Report of visit to Uganda for Stakeholders Workshop and field visit to examine bean root rots in Kabale and Kisoro districts. Report VS6909 DFID, London, 2pp [BTOR] (see Appendix)

SPENCE, N.J. AND TEVERSON, D.M. (2000) Report of visit to Uganda to conduct preliminary PRAs on indigenous knowledge of bean root rots in Kabale and Kisoro districts of south west Uganda and for discussions with NARO and CIAT collaborators, 19 February – 3 March 2000. Report VS7191 DFID, London, 3pp [BTOR] (see Appendix)

AMPAIRE, E., DAVID, S., MUKALAZI, J., TUSIIME, G. and BURUCHARA, R. (2000). A report on a participatory rural appraisal (PRA) exercise to investigate root rot problem in Kabale and Kisoro districts, 28 February – 1 March and 25 – 28 April 2000. (see Appendix)

HILLOCKS, R. (2001) Report of a visit to Uganda to investigate the association between bean root rot s and root-knot nematodes, 19-24 April 2001. [BTOR] (see Appendix)

AMPAIRE, E. L. 2002. Farmers' indigenous technical knowledge of bean disease management and communication systems in southwest Uganda. Final report on ITK (see Appendix)

Other disseminations

MANZI, G., OPIO F. and BURUCHARA R. (2002)

- Development of bean root rot disease and predisposing factors.
- Distinguishing field symptoms of bean root rots from other leaf diseases.
- Distinguishing symptoms due bean root rot from those due to bean stem maggot

Concepts of experimentation Farmer field school

Contribution of Outputs to developmental impact

1 A better understanding has been gained at farmer-level of factors that influence occurrence and distribution of root rots.
The different routes for sharing of agricultural technology (particularly seed) and information within communities have been determined and their importance rated.
Farmer-preferred methods of learning about new technologies were identified and prioritised.
We now have a better understanding of ITK, primarily on root rots but also on other bean diseases and have identified gaps in farmer's knowledge of root rots. This should form the basis for developing, training and dissemination of root rot management practices and other farmer activities relating to beans.
Six farmer groups that evaluated root rot resistant / tolerant entries in community plots selected several entries based on their own criteria.
A PRA has provided invaluable information about the extent of the disease, its impact on local communities, their perception of the problem and existing attempts at control.
Beneficial root rot management practices traditionally used by farmers are limited to varietal manipulation leading to reduction or elimination of large seeded and introduction of small seeded components in varietal mixtures.
A teaching strategy is needed to improve farmer diagnosis of root rots and to reinforce the beneficial use of manuring and sowing beans on mounds or ridges, currently practiced for reasons other than IPM.

The use of resistant varieties was the type of technology preferred by all farmers despite the diversity of criteria that influence their acceptance or rejection. Effects of fertility improvement were also appreciated with farmyard manure (FYM) preferred over inorganic fertilizers. Strategies to reduce the high labour input associated with FYM need consideration as this limits its use.

2 Improved methods and media for the selective isolation of fungal pathogens of beans have been developed and are now routinely used in Uganda. We now have a large collection of isolates of *Pythium* spp. and *Fusarium* spp. recovered from beans growing in Uganda and other east African countries. This has been and will continue to be a valuable resource for studies on characterisation and distribution of these important fungal pathogens of beans.

3 Eleven *Pythium* species, including potential biological control agents, were identified from the Ugandan isolate collection by sequencing the ITS regions of the ribosomal DNA. Previously, *Pythium* isolates recovered from beans have never been identified to species level so this is a major advance in our understanding of *Pythium* populations in Uganda. The pathogenicity and virulence towards beans of many of the isolates has been determined thus identifying the key species involved in root rots in Uganda.

It has been possible to rapidly identify to species level *Fusarium* isolates recovered from bean plants or soils thanks to species-specific PCR primers designed from the ribosomal gene regions of *F. solani* and *F. oxysporum*.
F. solani isolates can be further divided into bean pathogens or non-pathogens using PCR primers derived from AFLP (Vos *et al*., 1995) fragments and RFLP analysis of ITS products.
A bean hypocotyl assay has been developed for quantifying soil populations of *F. solani* f. sp. *phaseoli*. The technique developed is easy to perform, economical and relatively fast.

The pathogenicity of and molecular variation within a collection of isolates of *F. oxysporum* f. sp. *phaseoli* has been determined. Some correlation between molecular groups and virulence towards bean varieties (particularly the African variety G2333) was identified but an examination of more isolates is needed before firm conclusions can be drawn. The potential for development of pathogen-specific molecular probes is real but identification of races or virulence groups within collections of pathogenic isolates is not yet possible.

4 *Pythium ultimum* var *ultimum, P. torulosum* and *P. salpingophorum* were the most prevalent and widely distributed *Pythium* species. All three were found to contain isolates pathogenic to beans (all *P. ultimum* var *ultimum* isolates were highly virulent) and are likely to contribute most towards Pythium root rot in Uganda. Conversely, we now know that *Fusarium solani* f.sp *phaseoli* is distributed all over the areas where collections were made. This could make it a primary cause of root rots almost everywhere although in this study it has not been possible to determine the relative importance of *Pythium* and *Fusarium* spp. as causal agents of root rot.

5 The combined *Pythium*/*Fusarium* inoculation experiments on agar media have demonstrated antagonism rather than synergism. Two experiments conducted in UK also showed antagonism between *F. solani* and two *Pythium* spp. and that *F. solani* caused more root rot symptoms than *P. torulosum* or *P. spinosum* and also most seriously affected plant growth. Conversely, experiments in Uganda showed that *Pythium* caused the more serious symptoms. These results suggest that interactions between individual isolates of *Pythium* (particularly different species) and *Fusarium* can vary and so a wider range should be used in any future studies.
Pythium and *F. solani* were not recovered from any seed samples tested from southwest Uganda and so it is unlikely that these pathogens are spread by infested seed. Significant contamination of seed by *F. oxysporum* was found but it is not clear what proportion of the isolates were pathogenic to beans.
No correlation was found between the incidence or severity of root rot and the incidence or severity of RKN. Indeed root rot nematode itself is unlikely to be a constraint to bean production in the districts surveyed.

The presence of BSM results in an increase in the incidence and severity of Fusarium wilt. This means that in the development of management practices to control Fusarium wilt, the possible influence of BSM has to be considered.

Some of the valuable sources of resistance root rots were affected by black root implying that there is need to develop a concurrent strategy to manage both black root and root rot.

6 Soil amendment studies in the screen house and the field both indicated that both green manure and farmyard manure can give large increases in bean crop yield. Farmyard manure increased both dry matter and bean yield but it also increased *F. solani* inoculum in the soil. The *Calliandra* spp. green manure did not result in such high yields as farmyard manure but it did not cause increases in the soil population of this pathogen. Neither manure had a significant impact on *Pythium* populations. Farmyard manure may be able to compensate for the negative impact of increased disease by causing a larger increase in soil fertility, thereby increasing yield, but it still stores up potential problems for the future in the form of increased pathogen numbers. *Calliandra* spp. green manure would therefore be the preferred choice as part of a series of management practices to reduce the impact of root rots.

7 Germplasm evaluation has demonstrated how limited are the numbers of potential sources of resistance against root rots, particularly *Pythium* root rots. The majority of resistant or tolerant materials are small or medium sized beans. This shows the need to integrate and combine the use of resistant varieties together with other useful management practices already demonstrated in this project (e.g. improved soil fertility). We also have a better understanding of some of the criteria that farmers use to select from a collection of root rot-resistant germplasm. It is clear that farmers are interested in many and diverse types of material some of which they integrate with their own mixtures that they cultivate. Farmers have selected a number of new bean varieties and these are being evaluated at test sites and some are being grown in farmers' fields.

8 We learnt from this project that farmers have a good understanding of some of the aspects of the root rot problem (e.g. characteristics of the above-the-ground symptoms, how and when they occur), which are based on their observations. We also learnt that there are aspects that they neither know nor understand or which they confuse (causal agents, predisposing factors or basis of some of the management practices). Therefore in the dissemination of management technologies that are knowledge intensive, the use of a modified farmer field school offers a good opportunity to fill farmers' knowledge gaps and enhance their capacity and basis for the choice and application of management technologies. We were also able to determine the kind of extension materials that need to be developed.

General contributions to impact:

This project has provided the opportunity for researchers interested in bean root rots and other bean pests and diseases to communicate and collaborate on this topic in Uganda, in other African countries and world-wide. A valuable biotechnology capacity has been established at Kawanda in Uganda and this has been built on by other donor organisations (e.g. Rockerfeller Foundation, currently funding molecular studies on marker assisted selection of bean varieties resistant to root rot and angular leaf spot). Links between researchers, farmers and national and international agencies with interest in beans have also been strengthened as a result of this project.

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Appendix

BURUCHARA, R., OPIO, F., OTSYULA, R., MUSONI, A., MUKALAZI, J., TUSIIME, G., CARDER, J.H., MAHUKU, G., ADIPALA, E. and SPENCE N.J. (2001). Development of Integrated Management of Bean Root Rots in East and Central Africa: Past, Present and Future. PABRA Millennium Conference, Arusha, 28 May –1 June 2000. [Science, academic presentation]

In late 1980s and early 1990s, much of Rwanda, western Kenya and south-western Uganda started experiencing recurrent bean crop failures, associated with increased incidence and severity of root rots. The areas affected are characterized by small land holdings, intensified land use, and declining soil fertility. In response, research efforts through a variety of partnerships were initiated to characterize root-rot diseases, their causal organisms, and through participatory approaches develop and make available to farmers promising disease-management technologies that could be applied in an integrated manner. Results obtained in Rwanda were directly evaluated in on-farm trials in western Kenya and south-western Uganda, enabling the latter countries to omit the usual on-station stage and resulting in faster adoption in some areas.

Root rots were prevalent in the three countries, and fungi associated with the diseases were *Fusarium oxysporum* f. sp. *phaseoli, F. solani, Rhizoctonia solani, Pythium* spp. and *Sclerotium rolfsii*, often occurring in a complex of two or more. *Pythium* and *Fusarium* spp. were more widespread but Pythium root rot was the most important disease. A prediction model based on increased human population density, intensity of bean production and reduced soil nutrients was developed, and was used to predict areas where root rots were expected to become a serious problem.

A regional nursery consisting of resistant or tolerant varieties was constituted but germplasm showing resistance across the three countries included MLB-49-89A, MLB-40-89A, SCAM-80-CM/15, RWR 719, and RWR 1092. Resistant climbing-bean varieties included G 2333 (Umubano), G 865 (Vuninkingi), Flora de Mayo and Puebla. Cultural practice options observed to be useful through increasing plant vigour and creating less favourable conditions were application of fast-decomposing green manures (e.g., *Calliandra, Acanthus, Sesbania, Tithonia* spp.), cow manure, DAP, NPK, combinations inorganic and organic amendments, and ridging or planting on raised beds in areas with high moisture soils or high rainfall

Despite the research efforts so far made, important gaps still exist in our knowledge and understanding of particular aspects of this disease complex such characterization and distribution of major pathogens species. Very few resistance sources are available but not in desirable seed backgrounds. The paper discusses efforts initiated, based on our perception of the way forward, and centred on the use of biotechnology tools to better understand the characteristics and epidemiology of the major pathogens and the basis of some of the management approaches, and also to develop a varietal improvement programme based on marker assisted selection. Expected results will hopefully permit better targeting, refinement, development and application of effective disease-management strategies.

MUKALAZI, J., BURUCHARA, R., CARDER, J.H., MUTHUMEENAKSHI, S., ADIPALA, E., OPIO, F., WHITE, G.F., PETTITT, T. and SPENCE, N. J. (2001). Characterization of *Pythium* spp. pathogenic to common beans in Uganda. African Crop Science Conference. October 2001, Lagos, Nigeria [Science, academic presentation]

Characterization of *Pythium* spp. pathogenic to common beans in Uganda

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Abstract

In the last ten years, common bean yields in Uganda have declined by about 50%. The main causes of this reduction are declining soil fertility, insect pests and diseases, most importantly root rots. One of the major genera causing severe bean root rots in Uganda is *Pythium*. Others include *Fusarium* and *Rhizoctonia.* The identification of *Pythium* species pathogenic to beans in this disease complex is critical for effective epidemiological studies leading to development of control strategies. The aim of this study was to identify bean pathogenic strains of *Pythium* spp. using morphological and DNA-based molecular markers. Samples of bean plants displaying root rot symptoms were collected from three districts in Uganda where root rots are a major problem. Sixty-six *Pythium* strains identified and grouped using morphological structures were considered for the preliminary study. The ITS spacer regions flanking the 5.8*S* rRNA gene were amplified and digested with the following enzymes: *Cfo*I, *Mbo*I and *Hinf*I. Groupings arising from RFLP pattern were compared with results from sequence analysis of the ITS I and pathogenicity tests. The morphological and various molecular analyses revealed the wide diversity within the collected *Pythium* spp. Initial pathogenicity tests have identified pathogenic and non-pathogenic groups of *Pythium*. Further pathogenicity tests on *Pythium* species are in progress and pathogenic variation will be compared with molecular variation based on AFLP markers. The information will be useful in developing specific probes for the application of reverse dot blot hybridization, a method aimed at faster and simpler detection and possibly quantification of pathogenic *Pythium* spp in soil.

African Crop Science Conference, Lagos Nigeria, 22-26 October 2001

SPENCE, N.J. and TEVERSON, D.M. (1999) Report of visit to Uganda for Stakeholders Workshop and field visit to examine bean root rots in Kabale and Kisoro districts. Report VS6909 DFID, London, 2pp [BTOR]

FILE NOTE
(Visit Number VS6909)

Visit to Uganda for Stakeholders Workshop and field visit to examine bean root rots in Kabale and Kisoro districts

N J Spence and D M Teverson

File circulation	Loose copy	Separate copies
1. Prof. R J Cooter	1. Dr R Hillocks	1. Dr S Eden-Green
2. Dr N J Hayden	2. Richard Lamboll	2. Prof. J M Lenne
		3. Dr N J Spence

Background

1. The project CPPP136 ‘Characterisation and epidemiology of root rot diseases caused by *Fusarium* and *Pythium* spp. in beans in Uganda’ has been accepted by NRInternational for DFID funding pending some necessary revisions to the PMF.

2. Bean root-rot diseases cause significant yield losses in East Africa, especially Uganda. The project objective is to reduce inoculum, and thus disease, through elucidation of the interaction of the different components of the disease complex with both biotic and abiotic factors, leading to an understanding of appropriate management strategies. Diagnostic tools will be developed by the two Ugandan PhD students at HRI Wellesbourne to identify components of the disease complex to facilitate study of disease epidemiology. The NRI contribution to the project will focus on farmer perceptions and practices which will be assessed in relation to biotic and abiotic factors and their management.

3. A stakeholders’ workshop was held in Kampala, with a trip to Kabale and Kisoro in the SW - areas most hit by the root-rot problem in Uganda. There are several Institutes and research networks collaborating in the project and some root rot work has already been done by the National Programme and CIAT in Uganda. It was necessary for stakeholders to discuss project activities in detail, both to co-ordinate activities and address comments by the CPP PAC.

Objectives

- To introduce project stakeholders to each other and encourage co-ownership of the project.

- To systematically discuss each of the project activities in detail and finalise i) what should be done, ii) how it should be done and iii) who should do it. This was necessary because both the National Programme and CIAT have had ongoing activities on root rots and also to address specific comments by the CPP PAC. It is very important that project activities should build upon these activities rather than duplicate them.
- To observe the problem in the field. Project stakeholders visited Kabale and Kisoro in the South West of Uganda. Agriculture is very intensive in these areas and beans, (especially climbing types) are the major crop in the second season. As a result of this intensity, root rots are an increasing problem.

Activities and Achievements

The PMF for this project was revised in the light of activities already conducted by NARO and CIAT and the requirements of the CPP PAC. Drs Nicola Spence and Dawn Teverson will prepare the revised PMF for resubmission to the PAC and it is hoped that the project will formally start as soon as the document is accepted and contracts signed.

The participation of Dr E Lubbe, plant pathologist from PPRI, Pretoria, South Africa, and Dr Kijana Ruhebuza from DRC was welcomed and their activities as stakeholders tailored to complement those of other project participants.

Itinerary

Friday 5 November 1999	Leave UK for Entebbe, Uganda
Saturday 6 November 1999	Arrive and meet up with project stakeholders
Sunday 7 November 1999	All day meeting to discuss project activities
Monday 8 November 1999	Drive to Kabale by road
Tuesday 9 November 1999	Visit farmers' fields in Kisoro
Wednesday 10 November 1999	Drive back from Kabale to Kampala, workshop continued pm.
Thursday 11 November 1999	Workshop continued discussing project activities.
Friday 12 November 1999	Discussions with Dr Theresa Sengooba. Travel back to UK.
Saturday 13 November 1999	Arrive in UK.

SPENCE, N.J. AND TEVERSON, D.M. (2000) Report of visit to Uganda to conduct preliminary PRAs on indigenous knowledge of bean root rots in Kabale and Kisoro districts of south west Uganda and for discussions with NARO and CIAT collaborators, 19 February – 3 March 2000. Report VS7191 DFID, London, 3pp [BTOR]

<u>FILE NOTE</u>
(Visit Number VS 7191)

Visit to Uganda to conduct preliminary PRAs on indigenous knowledge of bean root rots in Kabale and Kisoro districts of SW Uganda and for discussions with NARO and CIAT collaborators, 19 February - 3 March 2000 (Project No. ZA0373).

N J Spence and D M Teverson

File circulation
1. Prof. R J Cooter
2. Dr N J Hayden

Loose copy
1. Dr R Hillocks

Separate copies
1. Dr S Eden-Green
2. Prof. J M Lenne
3. Dr F Opio
4. Dr Robin Buruchara
5. Dr Soniia David
4. Dr J Carder
5. Dr J W White
6. Dr T Pettitt
7. Dr P Mills

Background

1. The project ZA0373 ‘Characterisation and epidemiology of root rot diseases caused by *Fusarium* and *Pythium* spp. in beans in Uganda,’ has been accepted by NRInternational for DFID funding pending signing of contract.

2. Bean root-rot diseases cause significant yield losses in East Africa, especially Uganda. The project objective is to reduce inoculum, and thus disease, through elucidation of the interaction of the different components of the disease complex with both biotic and abiotic factors, leading to an understanding of appropriate management strategies. Diagnostic tools will be developed by the two Ugandan PhD students at HRI Wellesbourne to identify components of the disease complex to facilitate study of disease epidemiology. NRI expertise will focus on the evaluation of farmer perceptions and practices, which will be assessed in relation to biotic and abiotic factors and their management, both at project initiation and at the end of the three-year study, as well as in areas severely and less affected by the problem. Farmer acceptability of alternative control strategies for root rots will be evaluated and uptake pathways for research outputs assessed.

3. Preliminary PRAs were conducted at two sites in SW Uganda - areas most hit by the root-rot problem (DMT with CIAT staff and students - see below).

4. Meetings with collaborators were held at Kawanda Agricultural Research Institute and in the Equatoria Hotel, Kampala.

Objectives

- To carry out PRA exercises to evaluate farmer perceptions of root rot diseases at two sites in SW Uganda (Kisoro and Kabale).

- Discuss project activities and accounts with Ugandan stakeholders in the root rots project.

- To meet and discuss research priorities with Dr Sophy Musaana, Head of the NARO Horticulture Programme.

Activities and Achievements
PRA to assess indigenous technical knowledge (ITK), to evaluate farmers' problems, perceptions and practices in relation to root rots and other soil microorganisms, bean diseases and pests.

This included:
- indigenous knowledge of root rots including current control measures
- perceptions of root rot damage and relative importance to other constraints
- interactions between root rots and other organisms, such as bean stem maggot
- coincidence of low soil fertility and root rots
- constraints on improved control measures, such as cost
- social and cultural variations in farmer perceptions and practices.

Approximately 50 farmers participated in each exercise. A mixture of men and women, old and young farmers took part in the discussions and activities.

A detailed report of the PRA results and the methodologies used, is being written by Dr Soniia David and the students.

The PMF for this project was revised in December 1999 the light of activities already conducted by NARO and CIAT and the requirements of the CPP PAC. Drs Nicola Spence and Dawn Teverson had meetings with key CIAT and NARO personnel to discuss progress and finalise plans for research activities.

Drs Nicola Spence and Dawn Teverson met Dr Sophy Musaana, Head of the NARO Horticulture Programme and her team and discussed research priorities for vegetable production. Four areas were identified : Brassica IPM., indigenous vegetable IPM, viruses of tomato and passionfruit viruses. A note was forwarded to S. Eden-Green and J. Lenne with details.

Itinerary

Weds 23 February 2000	Leave Nairobi for Entebbe, Uganda. Travel to Kampala.
Thurs 24 February 2000	All day meeting to discuss project activities
Fri 25 February 2000	All day meeting to discuss project activities (NJS departs)
Sun 27 February 2000	Drive to Kabale SW Uganda, by road
Mon 28 February 2000	PRA in Kabale area
Tues 29 February 2000	PRA in Kabale. Identification of sites
Weds 1 March 2000	PRA in Kisoro
Thurs 2 March 2000	Identification of sites. Drive back from Kabale to Kampala,
Fri 3 March 2000	Meetings with CIAT and NARO personnel.
Sat 4 March 2000	Arrive in UK (DMT).

AMPAIRE, E., DAVID, S., MUKALAZI, J., TUSIIME, G. and BURUCHARA, R. (2000). A report on a participatory rural appraisal (PRA) exercise to investigate root rot problem in Kabale and Kisoro districts, 28 February – 1 March and 25 – 28 April 2000.

Introduction

In Uganda, beans are grown in most districts. They are grown twice a year during the two main rainy seasons i.e March to June and September to December. Area under bean production has been steadily increasing over the years; it has risen by about 100ha in the last ten years. Currently, Uganda has 630ha under beans and these yield 349kg/ha (FAO, 1999). Southwestern region has been the greatest bean producer, being responsible for 30% of the beans produced in Uganda. Beans are the biggest source of proteins for majority of the people in the region. Unlike in other regions where bush beans are the predominant, southwestern produces both bush and climbing varieties. Unfortunately, bean yields in this region have drastically gone down despite an increase in area under the crop. In some years bean yields have dropped to 25 % and this has been a result of insect pests and diseases most specifically root rot.

There was an outcry from farmers in the region some of whom had lost entire bean crops due to the bean root rot disease. The Uganda National Bean Programme (UNBP) intervened in 1995 by initiating studies in Kisoro District. These studies were designed to: identify organisms responsible for root rots, determine the cultural practices of managing root rots and bean stem maggot and understand the effect of soil fertility on the root rot disease. Other objectives were to identify resistant material to the disease and to find the best combination of control measures in order to develop an integrated control package.

In 1996 a study was conducted by UNBP in Kigezi County, Kisoro District to determine organisms responsible for root-rot. This study was done on ten farmers' fields in different villages of the County. The study revealed that 18% and 80% of the beans were affected by the stem maggot and root rot, respectively. Beans that were affected with both stem maggot and root rot were 29.5%. Further studies to determine the severity and incidence of root rot and stem maggot were carried out in 3 Counties (Kigezi, Mutanda and Bufumbira) in the second season of 1996 and early 1997. In this study, 90% of the bean crop was affected by the root rot, 8% by the stem maggot alone and about 30% had a duo infection of the stem maggot and the root rot. Studies on control of these pests began in season 1 of 1997 with evaluation of various organic amendments. In the same year, bean varietal evaluation for resistance to the pests was initiated. To-date, studies to come up with the best combination of variety and cultural measures are going on. So far, major organisms responsible for root-rots in southwestern Uganda have been identified as: *Pythium* spp., *Fusarium* spp. and *Rhizoctonia solani.* It has also been established that the root-rot problem is made severe by the presence of the bean stem maggot.

Meanwhile, organisations like the Uganda National Farmers Association (UNFA), CARE International and AfriCare were intervening by supplying farmers with bean varieties that seemed to have some good levels of tolerance to the bean root rot.

In order to carry out a successful intervention, there is need to know farmers views about the disease. Therefore, to understand farmers' perception of the disease, its effects and how they responded to the epidemic, a Participatory Rural Appraisal (PRA) exercise was carried out in selected communities in Kabale and Kisoro Districts where no root-rot management intervention had taken place. In Kabale District, the PRA study was done in Buhara and Ikumba Sub-counties while in Kisoro district PRA was conducted in Nyarubuye and Kanaba Sub-counties.

The Study Communities

In Buhara Sub-county, the PRA exercise was conducted at Nyarutojo village. Participants were from Kafunjo Parish comprising of Muhende, Ruhita and Nyarutojo villages. This community is located south of Kabale town. The area, accessed by road is about 15 km from Kabale town and includes a 5 km stretch on a Kabale- Mbarara road. The area is highly populated with up to 300-324 persons per sq. km (Ministry of Finance and Economic Planning, 1992a). The community is mainly composed of the *Abatabarwa* clan. Other clans include: *Abashogi, Abashanja, Abazigaba, Abahundu, Abalegeza, Abeinika,* and *Abagoma,* all tracing their origin in Rwanda. In Ikumba Sub-county, a PRA was conducted at Katooma village with more than sixty farmers from Katooma and Rwesanziro villages participating. This community is located in the northwest and furthest part of the county, close to R. Ishasha, the boundary between Kabale and Rukungiri districts. The area, accessed by a murram road is about 50km from Kabale town and includes a 13km stretch through the Bwindi Impenetrable Forest, home to mountain gorillas. The area is one of the least populated in the district with up to 149 persons per sq. km (Ministry of Finance and Economic Planning, 1992a). The *Abagabira* clan is the biggest in the community. The others are: *Abakimbiri* and the *Banyarwanda* (people of Rwandese origin).

The PRA in Nyarubuye Sub-county was conducted at the Sub-county headquarters, about 7 km from Kisoro town along Kisoro-Bunagana road. Participants came from Kirwa, Rutundwe and Kanyando villages totaling to about 65 farmers. The community is occupied by over ten clans most of which originate from Rwanda. Major clans comprise of *Abazigaba* from Zaire, *Abasinga* and *Abasig*i. In Kanaba Sub-county, the exercise was conducted about 6 km from Kisoro town along Kisoro-Kabale road. Participating villages included Rubuli, Gisanza and Busonga. The community mainly has the Bafumbira, an ethnic group closely related to the Rwandese. The two communities are among the highly populated areas in the district with up to 499 persons per sq. km (Ministry of Finance and Economic Planning, 1992b).

Methodology

Various methods were used to elicit information on farming system, gender division of labor, soil fertility status, bean varieties and crop production constraints. The methods include; listing and ranking, pie charts, tables, simple and pairwise matrix rankings.

Findings of the Study

Farming system

The two communities in Kabale district grow a number of crops, most of which are annual. In Buhara, the five most important crops in order were sorghum, beans, sweetpotato, bananas and maize. Other crops grown are: peas, Irish potatoes, cabbage, tomatoes, passion fruit and pineapples. In Ikumba, almost similar crops to those grown in Buhara were grown. With the exception of pineapples, they also grew finger millet, wheat and tea. Their most important crops were sweet potatoes, field peas, sorghum, beans and Irish potato.

A comparison was made on the status of crops grown in the 1960s and 1990s (Fig 1 and 2). In the Buhara community, even in the 1990s, sorghum remains a major crop; as was in the 1960s though it has reduced slightly due to land shortage. Many families changed from growing beans to sweet potatoes in 1990s. The change is attributed to increasing occurrence of pests more especially aphids, low yields due exhausted soils, blight and wilts. More households were reported to be growing sweet potatoes in 1990s mainly because they are a reliable source of food security; they do well in poor soils and it is rare to get a total sweet potato crop loss. Bananas and cabbages were reported as major crops in 1990s because they provide a stable income and are a source of food. Households growing maize reduced in 1990s because of continuous low yield obtained from the crop, competition from bananas and the crop does not do well in the highlands. The number of households growing Irish potatoes increased mainly because of the introduction of improved varieties and is a source of food and income. Peas were no longer on the list of major crops because of continued low yield due to soil infertility, pests and diseases.

Figures 3 and 4 shows a similar comparison for Ikumba Sub County. In the 1960s sorghum was reported as the crop that was grown by the largest number of households. In the 1990's, however, this was overtaken by sweet potato. The reduction in number of households growing sorghum in 1990s is attributed to especially its sensitivity to drought
and soil infertility compared to sweet potato. Families in the 1990s were growing more beans than peas because beans are a good source of house hold proteins compared to peas, secondly there are only local pea varieties which yield poorly compared to beans. Further, there are a variety of bean seed sources for both climbing and bush types, beans are said to be more tasty, are eaten in many forms and can be grown many times a year compared to peas. There was a decrease in the number of households growing millet mainly because it does not perform well in infertile soil.

Fig.1 Proportion of households growing major crops in 1960s in Buhara

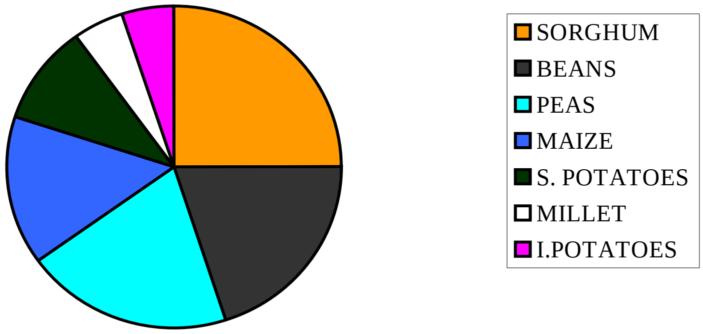


Fig. 2 Proportion of households growing major crops in 1990s in Buhara

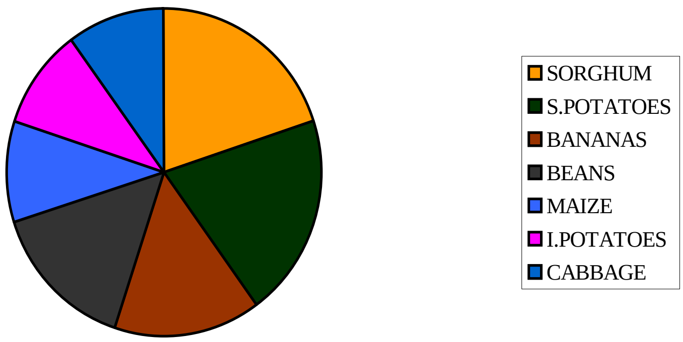


Fig. 3: Proportion of households growing major crops in 1960s in Ikumba

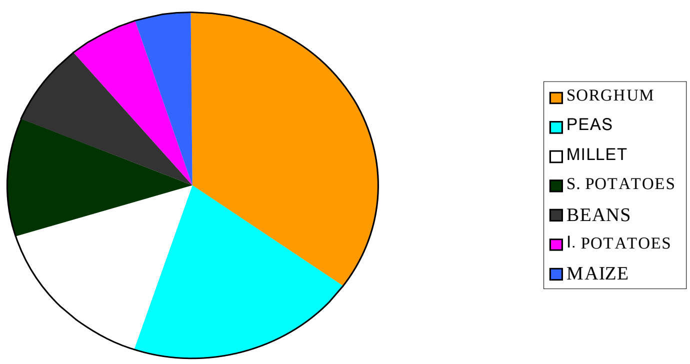
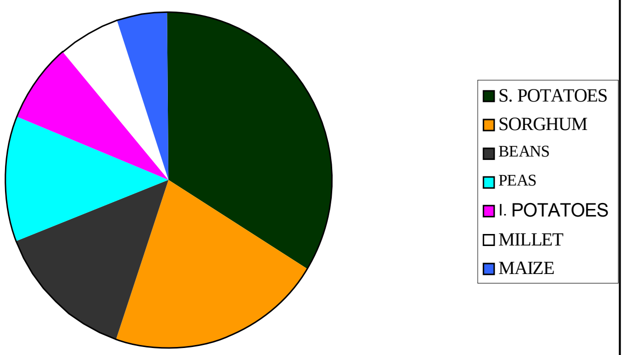


Fig. 4 Proportion of households growing major crops in 1990s in Ikumba



In Kisoro District, the two communities also grew a range of crops. The five most important crops grown by the Nyarubuye community were beans, bananas, sweet potato, maize and sorghum in that order. The other crops were finger millet, bananas, pumpkins, wheat, Irish potato, coffee, cocoyams, peas, cassava, cabbage, tomatoes, onions, passion fruit and avocado. In Kanaba, the most important crops were almost similar to those in Nyarubuye, though the order of importance differed. Here, the five most important crops in order were sorghum, beans, sweet potato, maize and peas. They also grew finger millet, bananas, pumpkins, wheat, Irish potato, coffee and cocoyams.

In Nyarubuye the number of households growing beans increased in 1990s (Figures 5 and 6). The main reason for the increase is because beans provide food security, the crop can be grown twice a year, families that used to keep livestock turned to cultivation due to limited land and it is a basic traditional sauce. Millet was reported as a crop that was no longer a priority because it no longer yields well as a result of infertile soils and high labour demand. It was replaced by maize, which has a dual purpose (food and income). Households growing bananas increased mainly due to income generation. Irish potatoes replaced peas because they are a source of income and peas no longer yield well.

In Kanaba sub county (Figs 7 and 8) in the 1960s farmers used to grow crops mainly for food. By then few households grew bananas which were mainly for home consumption. In the 1990s households preferred growing crops for income generation making banana unimportant for the 1990s. They were replaced by Irish potato because this contributes more to household income. Households growing sorghum reduced because of land shortage and persistent drought resulting into poor yield. Households growing peas lessened because of increased low yields.

Fig. 5 Households in Nyarubuye growing major crops in 1960s

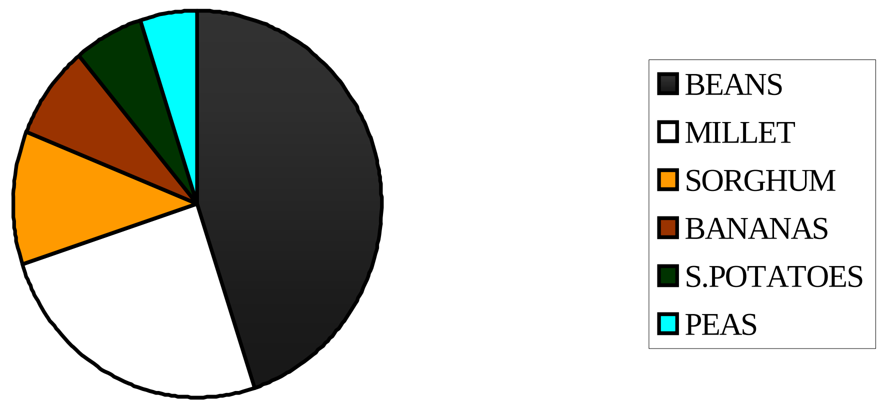


Fig. 6 Households in Nyarubuye growing major crops in 1990s

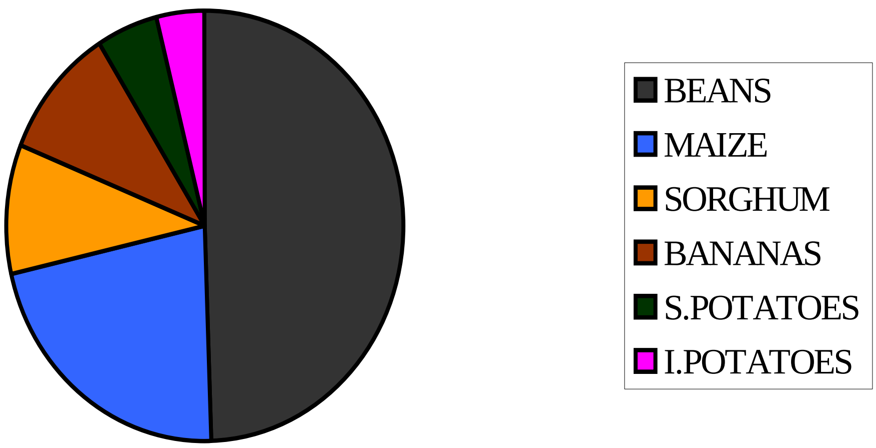


Fig. 7 Proportion of households growing major crops in 1960's in Kanaba

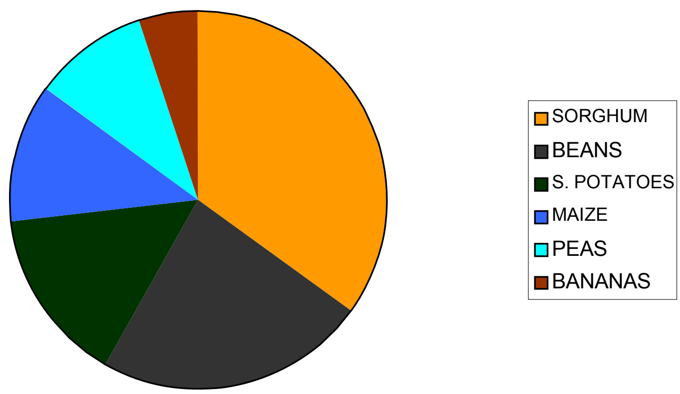
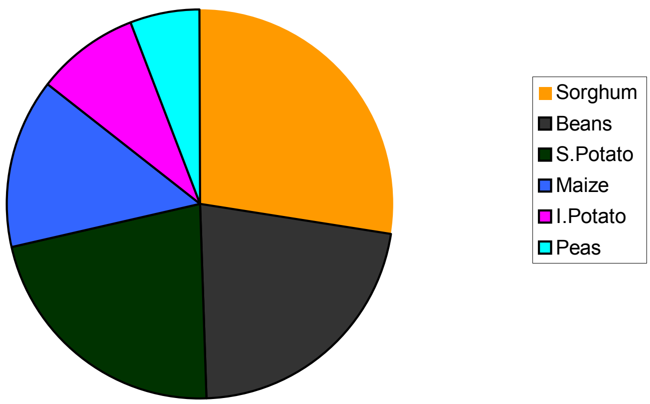


Fig. 8. Proportion of households growing major crops in the 1990s in Kisoro



Cropping Calendar of Major Crops In Kabale

Farmers in both study communities of Kabale reported that sweet potato, sorghum, peas. Were important crops (Table 1) They reported that the busiest months of the year were January and February and then August and

September (Table 1). More or less similar months were also the busiest for farmers in Kisoro district (Table 2)

Table 1 Cropping calendar for major crops in Kabale

FARMING ACTIVITY	J	F	M	A	M	J	J	A	S	O	N	D
SORGHUM												
Ploughing											■	■
Planting	■	■										
Weeding		■	■	■								
Harvesting							■	■				
SWEET POTATO*												
1st ploughing	■	■										
2nd ploughing			■	■	■							
Planting			■	■	■							
Weeding				■	■	■						
Harvesting												■
PEAS												
Slashing								■				
Planting			■						■	■		
Harvesting		■	■			■	■					
CLIMBING BEANS[2]												
1st ploughing		■							■			
2nd ploughing		■							■			
Planting			■							■		
Staking				■							■	
Weeding					■							■
Harvesting		■					■	■				
BUSH BEANS												
1st ploughing		■	■					■	■			
2nd ploughing			■	■					■			
Planting			■	■					■	■		
Weeding					■					■	■	■
Harvesting	■	■					■	■				

* Sweet potato husbandry is done throughout the year. Planting during July and August is done in the swamp only.

Table 2 Cropping calendar for major crops in Nyarubuye Sub-county, Kisoro

FARMING ACTIVITY	J	F	M	A	M	J	J	A	S	O	N	D
SORGHUM												
Ploughing	■	■										■
Planting		■										
Weeding			■	■	■							
Harvesting							■	■				
SWEET POTATO*												
1st ploughing												
2nd ploughing												
Planting												
Weeding												
Harvesting												
MAIZE												
1st ploughing		■	■						■			
2st ploughing		■	■						■	■		
Planting		■	■						■	■		
Weeding			■	■						■	■	
Harvesting		■				■	■					
CLIMBING BEANS												
Slashing		■							■			
Ploughing		■	■						■	■		
Planting		■	■	■					■	■	■	
Staking			■	■						■	■	■
Weeding				■	■					■	■	■
Harvesting		■					■	■				
BUSH BEANS												
Ploughing	■	■							■			
Planting		■							■	■		
Weeding			■	■	■						■	
Harvesting		■					■	■				

* Banana husbandry practices are carried out throughout the year. Planting is done during the wet season.
Sweet potato husbandry is done throughout the year except in June and July when it is dry.
Bush beans are planted in mixtures with sorghum. The weeding done in May refers to the mixture.

Gender Division of Labor for the Major Crops in Ikumba Sub county, Kabale District

Women clearly did more work than men. Field operations solely done by women were seedbed preparation, planting sorghum and beans, and weeding of all crops. Men slash alone only if the vegetation is made up of thickets and tall bushes. In general, men

provide about 30% of labor while planting cash crops, namely: sorghum, peas and beans and only 10% of labor in planting Irish potatoes (Table 3).

Ikumba farmers generally agreed that women were responsible for selling and control of farm produce income. Only 20% of the men were involved because women distrust them as they often spend money on alcohol. They actually reported that development in their homes was due to the fact that women handled cash, who were considered more faithful in handling finances than men. In Buhara men were solely responsible for handling cash. Even when the women sell produce, men insist that cash be handed over to them. Banana growin g was basically done by men as an income generating activity.

Soil Fertility Status

The soil classifications with decreasing order in fertility in Buhara were described as as follows Orushenyi (sandy soil), Enombe (red soils), Orufunjo (swampy soils), Eibumba (clay soils), Orucucu(dusty soils). In Ikumba, the soil classifications in decreasing order in fertility were described as Eririkwiragura (black soils), Eryamabale (stony soils), Eriratukura (red soils), Eryorushenyi (sandy soils). Farmers used a variety of methods in an effort to improve soil fertility which include use of compost manure (Ebisingo), green manure, farm yard manure (FYM) and land fallowing. The major constraints to improving soil fertility were soil erosion, swamp overflowing, lack of animals to provide FYM, land fragmentation which makes it difficult to apply compost from home residues to distant plots, very steep hills making it difficult to transport compost, short fallows due to land shortage.

In Nyarubuye Sub-county farmers classified soils in decreasing order of fertility as; Urukoro (stony soils), Inombe (red soils), Urutsibo (volcanic type of soil), Urugwa Urusheregyenyi, and Ibumba (clay soils). In Kanaba sub-county, A similar classification comprised of Inombe (red soils), Urukoro (stony soils), Urutsibo (volcanic type of soil) Urusheregyenyi, Ibumba (clay soils), Ikigwa and Igitakazi. Measures for soil fertility improvement were similar to those reported by farmers in Kabale. The major constraints met by Kisoro farmers in improving soil fertility in order of importance were: lack of animals in their homestead, making it difficult to have FYM, distant/scattered gardens making transportation of compost and the available FYM difficult. Land makes it difficult to practice crop rotation and fallowing, leading to overgrazing for those who own animals. Poverty was cited as a problem because people can not afford to own animals. Rampant soil erosion and the heavy infestation of most fields by couch grass (Digitaria scalarum) was reported to limit the effectiveness of any soil fertility improvement measure.

Table 3 Division of labor among the 3 major crops in, Kabale and Kisoro Districts.

(a) Ikumba and Buhara sub counties, Kabale

OPERATIONS	WOMEN	MEN
Sweetpotato		
Slashing	* * *	* * * * * * *
Selection /purchase of seed	* * * * * * *	* * *
1st ploughing	* * * * * * * * *	*
2nd ploughing	* * * * * * * * *	*
Planting	* * * * * * * * * *	
Weeding	* * * * * * * * * *	
Harvesting	* * * * *	* * * * *
Sorghum		
Slashing	* * *	* * * * * * *
Seed selection/purchase	* * * * * * *	* * *
1st ploughing	* * * * * * * * *	*
2nd ploughing	* * * * * * * * *	*
Planting	* * * * * * *	* * *
Weeding	* * * * * * * * * *	
Harvesting	* * * * *	* * * * *
Drying	* * * * * * * *	* *
Threshing	* * * *	* * * * * *
Winnowing	* * * * * * * * * *	
Fermenting	* * * * * * *	* * *
Storage	* * * * *	* * * * *
Selling/control of income	* * * * * * * *	* * (Ikumba) * * * * * * * * * * (Buhara)
Beans		
Seed selection/purchase	* * * * * * * *	* *
Ploughing	* * * * * * * * * *	
Planting	* * * * * * *	* * *
Weeding	* * * * * * * * * *	
Harvesting	* * * * *	* * * * *
Threshing		* * * * * * * * * *
Winnowing	* * * * * * * * * *	
Storage	* * * * * * *	* * *
Selling/ control of income	* * * * * * * *	*
Bananas		
Seed selection/purchase		* * * * * * * * * *
Ploughing	* * * * *	* * * * *
Planting		* * * * * * * * * *
Weeding	* *	* * * * * * * *
Desuckering		* * * * * * * * * *
Detrashing		* * * * * * * * * *
Harvesting		* * * * * * * * * *
Selling		* * * * * * * * * *

* Sale of beans is limited due to small quantities harvested
Women only harvest bananas for cooking but under instruction from men.

(b) Nyarubuye sub county, Kisoro District

OPERATIONS	WOMEN	MEN
Sorghum		
Slashing		* * * * * * * * * *
Seed selection/purchase	* * * * * * *	* * *
1st ploughing	* * * * * * *	* * *
2nd ploughing	* * * * * * * *	* *
Planting	* * * * *	* * * * *
Weeding	* * * * * * * * * *	
Harvesting	* * * * *	* * * * *
Drying	* * * * * * * * * *	
Threshing	* * * * * * * *	* *
Winnowing	* * * * * * * * * *	
Storage	* * * * * * * * * *	
Selling/control of income	* * * * * * * * *	*
Beans		
Seed selection/purchase	* * * * * * * * * *	
Ploughing	* * * * * * * *	* *
Planting	* * * * * * * * * *	
Staking	* * * * * * *	* * *
Weeding	* * * * * * * * * *	
Harvesting	* * * * *	* * * * *
Threshing	* * * * * * *	* * *
Winnowing	* * * * * * * * * *	
Storage	* * * * * * * * * *	
Selling/ control of income	* * * * * * * *	*
Maize		
1st Ploughing	* * * * * * *	* * *
2ndPloughing	* * * * * * * *	* *
Planting	* * * * *	* * * * *
Weeding	* * * * * * * * * *	
Harvesting	* * * * * * *	* * *
Threshing	* * * * * * * * * *	
Winowing	* * * * * * * * * *	
Storage	* * * * * * * * * *	
Selling	* * * * * * * * *	*

*Selling is mainly done by women but money is used to purchase household items and child-care.

Maize is threshed by placing cobs in gunny bags and beating until seed peels off the cobs.

Bean varieties and their Attributes

Tables 4 and 5 shows the varieties grown by farmers in Kabale, and Kisoro respectively. Kisoro reported more varieties than Kabale. In both cases both bush and climbing types were grown, except that the Buhara community in Kabale only grew bush types. Most climbing varieties were grown as sole varieties while bush types were either grown as sole varieties or in mixtures. The reason advanced for growing varietal mixtures was mainly insurance against crop failure. Both districts reported having lost some bean varieties. In Kabale, varieties were only lost in Buhara and they were: *Kaboko*, lost in the 1930s; *Ntemera*, lost in the 1970s; *Murofa*, lost in the early 1980s and *Gabangoobe*, lost in the 1930s. Reason for their loss was cited as poor yields due to declining soil fertility. In Kisoro, varieties were also reported to have been lost. They included: *Bwende butare*, *Bucecuru*, *Uruvuyunyanza*, *Karorina*, *Bwanarensi, Chicharo*, *Umunyamanza*, and *Kiryugeramye*.

Table 4 Bean variety description, growth habit and year of introduction in Ikumba and Buhara sub-counties, Kabale district.

Bean variety	Growth habit	Description	Year of introduction
Buhara			
Kacwekano	Bush	Big, White with red spots	Ever since
Rushare	Bush	Big, dark brown	Ever since
Kahura	Bush	Big, Black and white	Ever since
Kacence	Bush	Small, Black	Ever since
Bwiseri	Bush	Small, Red	Ever since
Kabanda	Bush	Small , Multi coloured mixture	Ever since
Kanyamunyu	Bush	Big, Black and white	Ever since
Ikumba			
Kanyamunyu	Climber	Spotted, white/ black, large	Ever since
Kanyobwa	Climber	Medium, spotted, red/ black	Mid 1980s
Kihura	Climber	Grey, large	Ever since
Umubano	Climber	Small, red	1993
Gisenyi	Climber	Spotted, white/ black, large	1993
Rushare	Climber	Red, large	1993
Rushare	Semi climber	Red large	Ever since
Kasaza	Bush	Medium, spotted, red/ white	Ever since
Kagali	Bush	Large, striped white/red	Ever since
Kachwekano (K 20)	Bush	Red/white spotted	Ever since
Katiiti	Mixture	Small multicolored consist of bush varieties	

Farmers in Kabale had a number of attributes they depend on when making varietal selections, and a number of them were similar for the 2 communities. In Buhara, six attributes were named and were ranked in importance as follows: yield, period to maturity, performance in infertile soils, resistance to rain, taste and size. In Ikumba, the six most important attributes were: yield, resistance to rain, taste, resistance to rat damage, early maturity and marketability. In both communities, high yield was interpreted as being production of many pods, with many large sized seeds, while resistance to rain was actually resistance to leaf blights. There was no consensus on what taste was. A marketable variety was preferred, and was said to be one that gets sold off very fast and/or at a higher price compared to others. They all preferred a variety that was resistant to rain, which was actually resistance to leaf blights. A variety that maintains reasonable yields in poor soils was also preferable to one that is sensitive to soil infertility.

In Kisoro district, bean variety attributes were obtained from Nyarubuye, The most important were early maturity, resistance to rain (leaf blights), tolerance to poor soils, resistance to rat damage, early maturity and taste. Tables 6 and 7 shows a ranking for the five most preferred varieties using a simple matrix based on the six 6 most important attributes in Kabale and Kisoro districts.

Table 5 Bean variety and growth habit: Kanaba and Nyarubuye sub-counties, Kisoro District.

Bean variety	Growth habit	Description	Year of introduction
Nyarubuye			
Mwizarahenda	Climber	Small, red	1997
Umwigondooro	Climber	Medium size, red	1997
Nyiragikooti	Climber	Big, Black and white	1997
Umushari	Climber	Big, Black and white	Eversince
Nyagacecuru	Bush	Small, multicoloured mixture	Eversince
Nyirakanada	Climber	Small, Red, white, yellow mixture	1997
Mutike/Nambaale	Bush	Medium, Spotted, Pink and white	1983
Nyiragifuka	Climber	Small, Red podded, red seed, inside pod is woolen	1997
Impuramugabo (Yellow)	Climber	Big, Yellow	mid 1970s
Impuramugabo (White)	Climber	Big, White	mid 1970s
Kanaba			
Nyiragikooti	Climber		
Mwizarahenda	Climber		
Nyiracyunyu	Bush		
Kenyerampure	Climber		
Intanshingirirwa	Climber		
Umushari	Climber		
Ruhomanara	Climber		
Nyakanada	Climber		
Biryeugarame	Bush		
Umubano	Climber		
Amaharare	Bush		
Nyirabukaara	Bush		
Mugoreutonsya	Bush		
Ntamwiza	Bush		
Kinganente	Bush		
Biganza	Bush		
Nyamanza	Climber		

Table 6 Weighted and simple matrix ranking for common bean varieties in Ikumba and Buhara sub-counties, respectively, Kabale district

(a) Buhara

Variety → / Attribute ↓	Kahura	Kacwekano	Bwiseeri	Rushare	Kabanda	TOTAL
High yielding	17*	25	3	20	15	**80**
Tolerance to poor soils	7	3	10	5	15	**40**
Early maturity	8	20	7	15	10	**60**
Seed size	1.5	3	0.5	4	1	**10**
Tasty	4	7	1	5	3	**20**
Resistance to 'rain'	5	3	10	4	8	**30**
SCORE	**42.5**	**61**	**31.5**	**53**	**52**	**240**
Overall rating	**4**	**5**	**12.5**	**2**	**3**	

***the higher the score, the stronger the attribute**

(b) Ikumba

Variety → / Attribute ↓	Kanyamunyu	Kanyoobwa	Kagali	Kihura	TOTAL
High yielding	2	2	1	5	**10**
Resistant to rain	2	2	1	5	**10**
Tasty	2	3	1	4	**10**
Resistant to rat damage	2.5	2.5	2.5	2.5	**10**
Early maturity	3	1	4	2	**10**
Marketability	1.5	1.5	3	4	**10**
OVERALL RATING	**2**	**3**	**4**	**1**	
SCORE	**13**	**12**	**12.5**	**22.5**	

Score: 1= low 10= high

Table 7 Weighted matrix ranking for common bean varieties in Nyarubuye sub-county, Kisoro district*

Variety → Attribute ↓	Nyiragikooti	Nyirakanada	Mwizarahenda	Nyagacecuru	Mwigondoro	TOTAL
Resistance to 'rain'	5**	10	7	8	30	**60**
High yields	4	20	6	10	40	**80**
Tolerance to poor soils	2	10	5	8	15	**40**
Tasty	4	0.5	2.5	2	1	**10**
Resistance to rat damage	10	5	4	3.5	2.5	**25**
Early maturity	2.5	3.5	4	10	85	**25**
SCORE	**27.5**	**49**	**28.5**	**41.5**	**93.5**	**240**
Overall rating	**5**	**2**	**4**	**3**	**1**	

***the higher the score, the stronger the attribute**
****this exercise was not done in Kanaba**

Constraints to bean Production

A range of constraints to bean production was reported. In Buhara, Kabale district, bean production constraints were: root rot and yellowing of leaves leading to death of the plant, aphids, destruction of the crop by rats, weevil damage in storage, destruction of flowers and pods by birds and leaf blight especially when it is raining heavily. The others were: poor bean performance due to drought, leaf yellowing at flowering proceeded by drying; powdery leaves resulting in poor pod set and pod-filling; lack of new varieties, lack of staking material, distant markets and lack of transport to markets. They further reported the following constraints: prevalent thieves, lack of farming equipment, poor soils, destruction by hailstorms and occasional destruction by farm animals. Similar, though fewer constraints were also reported by farmers in Ikumba. In Nyarubuye, Kisoro district, the constraints mentioned by the farmers include; rats, aphids, excess rain or drought, root rot and leaf yellowing (*Cyurisuka*), birds, bean weevils in storage, price fluctuations, lack of markets and hailstorms, expensive staking materials, cut worms, price fluctuations, lack of transport to markets and lack of proper weighing equipment. A similar list of constraints was given by farmers in Kanaba.

Pair-wise ranking was done and gave the relative importance of bean production constraints in the two districts. In Kabale, damage by aphids and lack of new varieties were the most important constraints (Table 8a and b), while in Kisoro, root rot ranked first in both communities(Table 9a and b).

Table 8 Pair-wise matrix ranking constraints responsible for low bean yields in Kabale district

(a) Buhara sub-county

BEAN PRODUCTION CONSTRAINTS	Storage weevils	Low soil fertility	Aphids	Birds	Lack of improved varieties	Lack of farming equipment	TOTAL
Storage weevils	-	Low soil fertility	Aphids	Birds	Lack of improved varieties	Lack of farming equipment	**0**
Low soil fertility		-	Aphids	Low soil fertility	Lack of improved varieties	Lack of farming equipment	**2**
Aphids			-	Aphids	Aphids	Aphids	**5**
Birds				-	Lack of improved varieties	Lack of farming equipment	**1**
Lack of improved varieties					-	Lack of improved varieties	**4**
Lack of farming equipment						-	**3**

(b) Ikumba sub-county

BEAN PRODUCTION CONSTRAINTS	Leaf yellowing and root rots	Aphids	Lack of staking material	Lack of new varieties	Rats	Storage weevils	TOTAL
Leaf Yellowing and root rots	-	Yellowing and root rots	Yellowing and root rots	Lack of new varieties	Yellowing and root rots	Yellowing and root rots	**4**
Aphids		-	Aphids	Lack of new varieties	Aphids	Aphids	**3**
Lack of staking material			-	Lack of new varieties	Rats	Lack of staking material	**1**
Lack of new varieties				-	Lack of new varieties	Lack of new varieties	**5**
Rats					-	Rats	**2**
Storage weevils						-	**0**

Table 9 Pair-wise matrix ranking constraints responsible for low bean yields in Kisoro district

(a) Nyarubuye sub-county

BEAN PRODUCTION CONSTRAINTS	Low yields due rat damage	Low yields due Root rots	Destruction by weevils in storage	Low yields due much rain	Poor taste	Low yields due to aphid damage	TOTAL
Low yields due rat damage	-	Low yields due Root rots	Low yields due rat damage	Low yields due rat damage	Low yields due rat damage	Low yields due rat damage	**4**
Low yields due Root rots		-	Low yields due Root rots	Low yields due Root rots	Low yields due Root rots	Low yields due Root rots	**5**
Destruction by weevils in storage			-	Low yields due much rain	Destruction by weevils in storage	Low yields due to aphid damage	**1**
Low yields due much rain				-	Low yields due much rain	Low yields due much rain	**3**
Poor taste					-	Low yields due to aphid damage	**0**
Low yields due to aphid damage						-	**2**

(b) Kanaba sub-county

BEAN PRODUCTION CONSTRAINTS	Low yields due to aphids	Low yields due to root rots	Low yields due to rat damage	Low yields due bird damage	Bean destruction by vermins	Low yields due to drought	TOTAL
Low yields due to aphids	-	Root rots	Aphids	Aphids	Aphids	Drought	**3**
Low yields due to root rots		-	Root rots	Root rots	Root rots	Root rots	**5**
Low yields due to rat damage			-	Rats	Rats	Drought	**2**
Low yields due bird damage				-	Birds	Drought	**1**
Bean destruction by vermins					-	Drought	**0**
Low yields due to drought						-	**4**

Diseases and Pests of other crops excluding beans

Table 10 shows the pests and diseases of sweet potato and sorghum in Buhara and Ikumba Sub counties and farmers views on their causes and their control.

Table 10 Major diseases and pests of major crops excluding beans and farmers views of the causes and control measures.

Crop	Disease/pests	Cause	Control
Sweet potato	1. Hairy stems (Kyooya)	Soil	Vine selection Unknown
	2. Tuber rot (Nyakajunda)	Drought	Unknown
	3. Sweet potato weevil	Exposed tubers, drought Unknown (Ikumba)	Unknown
	4. Mole rats	Unknown	Dug up
	5. Blight (Okubabuka)	Unknown	Roguing,vine selection
	6. S. Potato butter fly (Obulima)	Unknown	Spraying
Sorghum	1. Sorghum shoot drying	Unknown	Unknown
	2. Sorghum smut	Unknown	Unknown
Bananas	1. Fusarium wilt	Unknown	Uproot, burn and rest for 2 months
	2. Banana weevil	-	unknown

Table 11 shows the pests and diseases of major crops in Nyarubuye Sub county, Kisoro district.

Table 11 Major diseases and pests of major crops excluding beans and farmers views of the causes and control measures.

Crop	Disease/pests	Cause	Control
Sorghum	1 Sorghum shoot drying (Kuturagurika)	Poor soils, poor seed	Change of seed seed selection
	2 Sorghum smut (inopfu)	Poor seed	Seed selection Roguing
	3 Sorghum shoot fly (Cyumya)	Unknown	Roguing
Maize	1. Maize streak virus	Unknown	Roguing
	2. Maize smut	Poor seed	Seed selection
	3. Maize weevil	Over drying in garden	Timely harvesting
	4. Stalk borer (shokondwa)	Too much rain	unknown

Bean diseases

Farmers listed the diseases that affect beans in the study areas and they included the following: *Runiga* (probably root rot), *Okwoma* (wilting), *Kukorora amababi, Okusaana* (powdery substance on leaves), *Kuribwa obukooko* (probably aphids), *Okuhoha* (probably hallo blight), *Emugwe* (weevils), *Okubabuka enkeiga* (probably Anthracanose), *Kuhisa amababi* (yellowing of leaves; likely BSM) and *Okukokoota amababi* (probably Ascocyta blight).

With the exception of the Buhara community, *Runiga* was said to be the most important disease. *Runiga* (literally "suicide") was said to affect all bean varieties causing total loss of the bean crop in some seasons. It has resulted in lack of seed mostly of the local varieties, continued famine and poverty. Although farmers in Buhara reported that Kiniga existed in the 1940s, the rest of the communities revealed that the disease was first seen in the 1960's. However, all agreed that it only intensified in the 1990's. They recognise *Runiga* as leaf yellowing (commonly called *Kinekye*) which begins when beans are about 2-3 weeks old. This occurs concurrently with some holes on leaves. Soon the plant dies. In both districts, a white maggot (referred to as

Omura in Buhara) was associated with the disease. Symptoms normally begin from the top of the plant, then spread to the whole plant. Yellowing appears in patches and soon progresses to cover the whole garden in severe cases. This disease was said to occur both in wet seasons and when there is water stress. Much as they recognised the fact that it is more severe when there is much rain, they could not explain occasional severe disease in dry seasons. It was also said to be more severe on the hilltops than in the valleys, but that where there was a patch of good (fertile) soil there was no disease. It was also noted to be more prevalent in red type soils (*Eriratukura*).

There were many perceived causes of *Runiga.* These included land overcultivation, late planting, low soil fertility, an insect pest and late planting. Clearly farmers did not have a clear understanding and cause of the disease. They tended to associate it with “poor soil” because beans in virgin land were normally not affected. However, they did not imagine that some soil borne organism could be responsible. In both districts soil infertility has been associated with an increase in bean diseases (Tables 12 and 13). Most implicated a black or white insect (*Omura)* because it was often found on roots of affected plants. Besides, holes in leaves are normally associated with insect damage. Farmers did not relate this black or white insect with either the wet or the dry season yellowing. This meant that they did not have an idea that the two “similar” symptoms could be caused by two different organisms. More to this, late planting which coincide with water stress could not explain the severe disease that occurs when it is wet. In this PRA, there was a clear disregard of under ground symptoms. This showed that the disease was only haphazardly known, with obvious mixing of the root rot aspects and the bean stem maggot effects.

Some of the measures farmers were using to control *Runiga/Cyurisuka* included: crop rotation, fallowing, use of compost manure and growing tolerant varieties. Crop rotation, mainly a bean-sorghum-bean rotation, was only practiced on a limited scale due to limited land and was said not to be effective. Fallowing was also not sufficiently practiced because land is limiting. Farmers noted that wherever there was compost, there was less destruction by *Runiga/Cyurisuka.* However, the biggest hindrance to use of compost was excessive land fragmentation, which made it difficult to transport it to distant plots. Moreover, it was only said to be effective where sufficient crop rotation was effected. The varieties said to be tolerant to root rot are new, but these are said to be easily destroyed by rats. The local varieties mainly grown in mixtures are said to be tolerant to root rot, but on the basis of bean variety attributes (Table 6) they are not highly regarded. Farmers reported that *Runiga* used to be traditionally controlled by up-rooting a few diseased plants, and carrying them to the lake chanting ‘kuka *Runiga*’ (meaning root rot disappear). This clearly shows the extent of lack of understanding of the disease. Lack of understanding of the disease and its cause coupled with excessive land shortage made control measures only a gamble. Success of any intervention will have to consider educating farmers on these issues so that choice of control measures is done with a purpose.

Table 12 Relationship between soil fertility, bean diseases and bean yields in Kabale over a period of time

a) Buhara

	1960's	1970's	1980's	1990's
Soil fertility	* * * * * * * * * *	* * * * *	* * *	* *
Bean diseases		*	* * *	* * * * * *
Bean yields	* * * * * * * * * *	* * * * *	* * *	*

A total of 10 points were used for each item

b) Ikumba

	1960's	1970's	1980's	1990's
Soil fertility	* * * * *	* * * *	* *	< *
Bean diseases	*	* * * *	* * * * * * *	* * * * * * * * *
Bean yields	* * * * *	* * * *	* *	< *

A total of 10 points were used for each item

Table 13 Relationship between soil fertility, bean diseases and bean yields in Kisoro over a period of time

a) Nyarubuye

	1960's	1970's	1980's	1990's
Soil fertility	* * * * * * * * *	* * * * * * * *	* * * * *	* *
Bean diseases	*	* *	* * * * * * * *	* * * * * * * * *
Bean yields	* * * ** * * * *	* * * * * * * *	* * * *	* *

A total of 10 points were used for each item

b) Kanaba

	1960's	1970's	1980's	1990's
Soil fertility	* * * * *	* * *	* *	< *
Bean diseases		*	* * *	* * * * * *
Bean yields	* * * * *	* * *	* *	< *

A total of 10 points were used for each item

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Diffusion pathways for agricultural technologies

In both districts, a number of information sources were available to farmers. In all communities, places of worship, friends, members of the community, relatives, markets, local groups were the most important sources of information. There were many local groups in both districts, most of which were formed to offer credit facilities and as self –help initiatives to members. These are very important for diffusion of information. Some information was also said to be obtained from newspapers, public notice boards, local council 1(L.C.1) secretaries for information, local leaders, bars and burial places. Other sources of information though rarely used include seminars and workshops and film shows. Through the above methods, farmers get to know current affairs in agriculture. Some information especially about new varieties is obtained from someone after a promising variety has been seen in his garden. When some farmers identify varieties with desirable qualities including resistance to root-rot (*Cyurisuka*) from a neighbour's garden, they pick a few pods, identify the colour and later may request seed directly from the owner of the garden or buy similar seed from the market. Government and Relief organisations and cross-border traders have been instrumental in new variety introductions. Below is a table with some crop variety introductions by various sources in Kisoro. Buhara community in Kabale did not have sources of new crop varieties and much of their varieties are traditional.

Table 14 List of new varieties of crops available to farmers in Kisoro and their source

Crops	Varieties	Source
Tomato	*Money maker* (Bush)	UNFA Kisoro
Potato	*Kinigi*	Rwanda
Onions	*Vanish*, *African seed best*	UNFA-Kisoro
Cabbage	*Drumhead*	UNFA-Kisoro
Beans	*Ruhomanzara*	Rwanda and Congo
	Nyirakikoti (seed size expand when cooked)	By traders
	Nkenyerampure (tighten belt and thresh)	By traders
	Mwizarahenda (beaty makes one toil)	By traders
	Nyirarubenege (bush),	By traders
	Kacwekano (K20), *Biganza* 'the palm'	By traders
	Kanada (bush type yellow small size short beans)	By traders

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HILLOCKS, R. (2001) Report of a visit to Uganda to investigate the association between bean root rot s and root-knot nematodes, 19-24 April 2001. [BTOR] (see Appendix)

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HILLOCKS, R. (2001) Report of a visit to Uganda to investigate the association between bean root rot s and root-knot nematodes, 19-24 April 2001. [BTOR]

FILE NOTE

Report of a visit to Uganda to investigate the association between bean root rots and root-knot nematode. 19-04-01 – 28-04-01.
Project ZA0370 [R7568]: Bean root rot disease control in Uganda.
Rory Hillocks

Circulation

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Background and objectives

This project began in February 2000 and aims to investigate pathogenic variation and the interactions between bean root rot pathogens and other pests [Bean stem maggot [BSM], nematodes and bean common mosaic virus]. This information is to be used to develop a management strategy for root rots. The collaborative partners in this project are HRI, NRI, NARO and CIAT.

The objective of this visit was to conduct a survey to determine the incidence of root knot nematode on beans in relation to the occurrence of root rots in the Districts of Kabale and Kisoro in south-western Uganda. In addition, soil samples were collected for nematode extraction by CIAT staff in the nematology lab at Kawanda Research Station. I was accompanied on the survey by Mr Stephen Mayanja of CIAT, Kampala and Geofry Manzi a socio-economist with CIAT Kabale office.

Survey methods

A total of 29 fields were surveyed in Kabale and 31 in Kisoro. Fields were selected on the basis that they were accessible to the main road and contained a bean crop at a suitable growth stage [4 – 8 weeks after planting]. Ten plants were uprooted in each field and examined for root galls. As far as possible plants which looked deficient or diseased were uprooted. While it would have been desirable to uproot also healthy plants, this in practice was not acceptable to the farmers. Provided the plants chosen were in the early stages of disease, root systems were sufficiently in tact to allow assessment of nematode damage. Root rot severity and the severity of nematode galling were both scored on a 0 – 10 scale and the presence or absence of damage due to BSM was recorded. Information was also recorded on cropping systems and soil types.

Survey results

Farming systems in Kabale

The District is heavily populated with smallholdings covering the steep slopes and valley bottoms. With most of the land devoted to crops, there is little pasture available for livestock. The main cash crop is potato and beans/potato intercrop was one of the more common cropping systems. There are two cropping seasons, the first of the year beginning in March/April and the second in September/October. In Kabale September is the main bean season and although there were beans in the field during our visit in April, the predominant crops were sorghum and finger millet, planted into fields which earlier grew beans.

Farming systems in Kisoro

Many more fields contained beans in Kisoro than in Kabale, although most had been planted in January and were already too well established to sample [objections from the farmers]. The crops and cropping systems were similar to Kabale with beans/potato being a common intercrop. A greater proportion of the beans in Kisosro [65%] were climbers compared to Kabale [41%]. In the valleys around Kisoro the predominant soil type is a loose textured black volcanic soil which appears to be infertile. Root development was poor in many of the fields we visited with this soil type, despite the absence of obvious root rot. Many of the farmers were growing a climbing bean which they said was from Congo. This variety was known as 'Mwizarahenda' or 'Nyiramwigondore' and seems to grow much better than the local types on the volcanic soils.

Bean diseases and pests

Root rots were found in many of the fields but in Kabale, predominantly at higher altitudes and on the heavier soils. Symptoms caused by *Pythium* and *Fusarium solani* were in evidence but often in the same field or on the same plant. Associated factors were nutrient deficiency and damage caused by BSM. The mean incidence per field of root rot was 50% in Kabale and 74% in Kisoro [Table 1].

Galls caused by root-knot nematode (RKN) were observed in more than half of the fields surveyed in both districts but galling was not severe. There was a close association between the severity of RKN and soil type, with the more severe galling confined to light textured, sandier soils. Although the mean incidence per field of plants showing RKN galls was 24% in Kabale and 41% in Kisoro, mean severities were only 0.43 and 1.14 respectively. The slight galling observed at most sites was not sufficient to have a significant impact on yield.

Damage caused by BSM was more widespread in Kabale [32%] than in Kisoro [10%]. In most cases the plants were recovering from the attack but the damage may have facilitated the entry of root rot pathogens.

The predominant foliar diseases were anthracnose and *Ascochyta* and occasional incidences of angular leaf spot. Anthracnose occurred at 34% of sites in Kabale and 29% of sites in Kisoro. *Ascochyta* occurred at 41% of sites in Kabale and at 45% of sites in Kisoro.

Table 1. Summary of bean survey in Kabale and Kisoro districts.

	Incidence Fields/district (%)	Incidence* per field (%)	Severity Score 0 – 10
		Kabale	
Root rot	93	50	1.71
RKN	62	24	0.43
BSM	59	32	-
		Kisoro	
Root rot	97	74	3.84
RKN	71	41	1.14
BSM	48	10	-

* Means derived from 10 plants/field and 29 fields (Kabale), 31 fields (Kisoro).

Survey conclusions

Root rot was confirmed as a major constraint to bean production in Kabale and Kisoro districts. In Kabale, high incidences of root rot seemed to occur at sites at higher altitude and on heavy soil types. In Kisoro, high incidences of root rot were associated with poor soil fertility, especially on the black volcanic soils.

No correlation was found between the incidence or severity of root rot and the incidence or severity of RKN. Severe root knot nematode attack was found at very few sites and mainly where the soil was sandy, whereas the root rots were not prevalent on the sandier soils. Root-knot nematode therefore, is not a major constraint to bean production in the two districts surveyed.

No correlation was found between root rot severity and BSM incidence. However, BSM attack is periodic and no severe cases were seen. It would appear from this survey that root rot is a primary problem associated more with soil fertility and climate (temperature and rainfall which may be related to altitude).

[Root-knot is the only nematode which produces symptoms that are conspicuous and diagnostic. There may be other nematodes associated with root rots and this may be revealed after examination of nematodes extracted from soil samples collected during the survey. The most likely candidates are the reniform nematode *Rotylenchulus* spp. and the lesion nematode *Pratylenchus* spp. However, it is doubtful if these nematodes would be sufficiently important to justify control measures.]

Wider implications of the survey results

The scope for management of bean root rots in the project area is limited. While there may be an association between soil fertility and root rot incidence, at least in Kisoro, there is no readily available method of soil fertility management. Land shortage means that rotation is not a popular option and due to lack of grazing, the livestock population is too small to provide the amount of manure required for soil improvement. Root development and nodulation was poor at many of the fields visited on the black volcanic soils in Kisoro and there may be some scope for investigating nutrient levels, *Rhizobium* populations or mycorrhizal development in those soils. At some of the sites in Kabale that were worst affected by root rots, heavy soils and cool temperatures seem to be the predisposing factors.

The use of improved bean varieties with some field resistance to root rots would seem to be the only management option remaining. The evidence from Kisoro where a variety apparently obtained from Congo was doing well suggests that giving farmers a number of varieties to test for themselves might be a useful approach.

Survey in Masaka/Iganga

Two fields were visited in Masaka and 10 in Iganga in areas where CIAT have received reports of a root-knot problem on beans. Severe RKN galling was found in a patch at one site at Masaka although most of the beans in the field were unaffected by root knot. This area produces tomatoes and tomato cultivation on sandy soils eventually leads to the build-up of root-knot nematode. At the sites visited at Iganga, most of the fields were free of RKN or damage was very slight and severe galling was found only at a single site in a garden close to the homestead.

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Itinerary

Thurs 19 April	Flight Gatwick – Entebbe
Fri 20 April	To Kawanda, meet CIAT team Leader and plan survey.
Sat 21 April	Travel by road to Kabale
Sun 22/Mon 23	Survey bean fields in Kabale district.
Tues 24	Travel to Kisoro and survey on the way.
Wed 25	Survey Kisoro district.
Thurs 25	Travel by road to Iganga [visit bean fields at Masaka]
Fri 26	Survey Iganga and return to Kampala.
Sat 27	Depart.

Rory Hillocks 16-05-01

Appendix 1a. Survey results: Field means for Kabale (N=29).

Root rot Score[0-10]	Root rot %	RKN Score [0 –10]	RKN %	BSM %	Crop system type	Soil	Bean type	Other diseases		
5.7	90	0.1	10	10	BP	CL	C			
5.0	100	0.3	10	0	BP	CL	C	AN	AS	SC
1.2	50	0.3	20	100	BP	CL	C	AN	AS	
1.3	70	0.2	20	90	BP	CL	C			
4.1	100	0.3	20	100	BP	CL	B	AN	AS	
2.1	100	0	0	100	SB	L	B	AN		
0.5	30	0.1	10	20	BaSpB	CL	B	AN	WB	
1.1	70	0	0	100	BP	SCL	B			
0.2	10	0	0	0	BPM	LC	B			
2.0	80	0	0	20	B	L	B	AN		
3.9	100	0	0	70	BP	LC	B			
0	0	0	0	100	BSp	L	B			
0.5	10	0.2	20	0	BPSp	L	B	SC		
0	0	0.4	40	0	SB	SL	B	ALS	AS	
0.6	10	1.5	90	0	BaB	L	C	ALS	SC	
1.4	60	0	0	20	BSp	LC	C	AN	AS	
0.3	10	0	0	0	B	L	C	AS		
1.1	40	1.1	30	20	B	CL	C	AS		
0.3	20	0.6	40	0	BP	L	B	AS		
2.0	70	1.1	60	80	B	SCL	C	AS		
4.7	70	0	0	10	B	CL	C	AS		
1.8	40	0	0	0	B	CL	C	AS		
5.0	100	0	0	70	B	CL	C	AS		
0.5	30	0.8	50	0	BP	SCL	C	AN		
0.4	10	0.2	20	10	BP	SCL				
0.2	10	2.0	100	0	B	V	B	AN		
0.9	60	0.8	30	0	B	V	B	AN		
2.2	50	0.9	40	20	BSp	CL	B			
0.6	60	1.6	80	0	BP	SCL	C			

Cropping system: B = beans, P = potato, S = sorghum, m = maize, Sp = sweet potato, Ba = banana. Pe = peas.

Soil type: C = clay, CL = clay loam, L = loam, SC = sandy clay, SCL = sandy clay loam, SL = sandy loam, LS = loamy sand.
Bean types: C = climbing, B – bush (and semi-climbing)

Other disease: AN = anthracnose, AS = *Ascochyta* leaf spot, ALS – angular leaf spot, SC = southern blight [*Sclerotium rolfsii*].

Appendix 1b. Survey results: Field means for Kisoro [N= 31].

Root rot Score[0-10]	Root rot %	RKN Score [0 –10]	RKN %	BSM %	Crop system	Soil type	Bean type	Other diseases	
2.9	60	0.6	20	20	B	SCL	C	AS	
2.5	60	0.5	30	20	B	SCL	C		
3.8	80	0.6	40	60	B	SCL	C		
1.7	40	0.2	10	10	SB	SCL	C		
1.8	70	0	0	60	SBPM	CL	C		
3.8	80	0	0	20	B	SCL	C	AS	
5.7	100	0	0	10	B	SCL	C		
4.7	100	0	0	10	SB	SCL	C	AN	AS
2.2	50	1.3	40	0	BP	V	C		
0	0	0	0	0	BP	V	B		
0.1	10	0	0	10	BP	V	C	AS	
3.3	60	2.1	100	0	B	V	B	AN	AS
4.6	90	2.3	80	0	B	V	C		
5.2	90	1.1	50	0	B	V	C		
3.1	80	2.0	80	10	BP	V	B	AN	AS
5.5	100	4.0	100	0	BPPe	V	B	AN	AS
4.2	90	1.2	70	10	BP	V	B	AN	AS
5.1	100	0.6	30	0	BP	V	B		
2.8	80	1.0	40	10	BPPe	V	B		
5.1	100	2.8	90	30	B	V	C		
5.6	90	2.4	70	0	BP	V	B	AN	AS
4.5	80	5.2	90	20	BaB	SC	C		
0.6	10	1.1	60	0	BPe	V	B	AN	AS
5.2	90	1.0	50	10	B	SC	C		
5.8	100	1.4	70	0	B	SC	C		
6.5	100	0.1	10	0	BaB	CL	C		
4.1	80	0	0	0	B	CL	C	AS	
7.1	100	0	0	0	B	V	C		
7.1	100	0	0	0	BaB	V	C	AS	
2.0	60	2.9	100	0	B	V	B	AN	AS
2.3	50	0.9	50	0	BP	V	B	AN	AS

Key to abbreviations as for Appendix 1a.

Addendum: Nematodes identified in soil samples collected during the survey conducted in Kabale and Kisoro in April 2001-11-06

Nematode	Number extracted*	
	Total	per 100ml soil**
Scutellonema spp.	1325	23
Rotylenchulus spp.	775	13
Radopholus similis	500	9
Meloidogyne spp.	350	6
Helicotylenchus multicinctus	25	<1
Pratylenchus brachyurus	25	<1

*Total number of nematodes counted in 1ml taken from 25 ml water used to extract nematodes from 100 ml of soil.

** Mean of 58 samples

Comment

Numbers of plant parasitic nematodes were generally low. *Scutellonema* spp. are often found to be the most prevalent in African agricultural soils but little is known of their pathogenicity. *Rotylenchulus* spp. have been recorded in other surveys as important nematodes in legume-based cropping systems. Numbers of *Meloidogyne* were low as was shown by the few cases of severe root galling that were recorded during the field survey.

FARMERS' INDIGENOUS TECHNICAL KNOWELDGE OF BEAN DIEASES AND COMMUNICATION SYSTEMS ON PLANT DISEASE KNOWLEDGE IN SOUTHWESTERN UGANDA

Final Report on ITK

Edidah Ampaire

2002

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C H A P T E R O N E

1.0 INTRODUCTION

1.1 Background

Studies on Bean Root Rot (BRR) and Bean Stem Maggot (BSM) started in 1995 in response to complaints of severe attack of beans by root rots in Kisoro District. Between 1996 and 1997 Uganda National Bean Programme (UNBP) carried out a series of studies in Kisoro District to determine organisms responsible for BRR and BSM. Bean varietal evaluation for disease resistance was also initiated in 1997. Findings of the study revealed that *Pythium spp, Fusarium spp* and *Rhizoctonia solani* were the major organisms responsible for BRR in South Western Uganda. The three often occurred together but where the other two occurred without *Pythium spp*, the BRR problem was not so severe. It was also observed that BRR incidence is made severe by the presence of BSM (Opio, 1997; Synthesis of AHI-IPM activities, unpublished). A number of disease control measures appropriate to the farmer were identified and include resistant/tolerant varieties, soil fertility improvement and other cultural practices. Todate studies designed to come up with the best combination of variety and cultural measures plus other IPM strategies are going on.

Organisations operating in the area such as Uganda National Farmers' Association (UNFA), CARE International and Africare are intervening by supplying farmers with (or helping farmers to access) bean varieties that seem to have good tolerance to BRR. Government of Uganda extension staff are mainly advising farmers to improve soil fertility. UNBP is continuing with on-farm and on-station evaluation trials in the region. CIAT has continued to spearhead among others, identification of new sources of resistance, evaluation of regional root rot nurseries, improvement of resistance of local cultivars and evaluation of local cultivars and evaluation of on-farm and on-station components and options. All these interventions were designed and disseminated without an in-depth study into farmers' knowledge of the disease, their disease management practices and the communication channels used.

This ITK study was therefore designed to understand farmer's knowledge of bean diseases, their causes and what they are doing to control them so as to know what technologies to disseminate. It was also intended to identify the available communication networks to farmers through which the indentified technologies can be disseminated. It is hoped that integrating traditional and scientific technologies will help control bean diseases in a participatory manner thereby increasing farmer adoption.

1.2 Objectives of the study

The objectives of the study were to determine farmers ITK of bean diseases (with emphasis on root rots), to identify farmers' disease management practices and to find out how and through which channels farmers communicate knowledge about root rots to each other. The study would also find out how socio-economic factors such as education level, age, sex and wealth status influence knowledge of the BRR disease.

1.3 Methodology

The study was conducted in Kabale and Kisoro Districts where the bean root rot is prevalent. In Kisoro, Kirwa and Kanyando villages were selected from Karambi Parish in Nyarubuye Sub-county. In Kabale, Muhende and Nyarutojo villages were selected from Kafunjo Parish in Buhara Sub-county. The two parishes were selected to target areas where no BRR control interventions had been disseminated. Villages in each Parish were selected with the help of Parish authorities and were considered the most affected by BRR.

The research study began with Participatory Rural Appraisal (PRA) exercises in the study communities, which were conducted between January and April 2000. Methods such as listing and ranking, pie charts, frequency tables, simple, pair-wise and matrix ranking and cropping calendars were used to elicit information on farming systems, gender division of labour, soil fertility status, bean varieties and crop production constraints. A total of 140 farmers attended the PRA exercises.

An ethnographic study was conducted between September and November 2000. It was designed to target ‘‘knowledgeable’’ farmers who provided detailed information on farmers’ perception of bean diseases, their disease management practices and channels through which farmers use to share new agricultural information and technologies. Village meetings were held and community members selected key informants. Farmers’ groups conducted the wealth ranking exercise for all the households in the villages. A maximum of 35 farmers was used as key informants in both Kisoro and Kabale. Other individuals or groups met in the fields where bean diseases were prevalent were co-opted in the study and interviewed. Methods used to collect data included key informant interviews with individuals and groups, wealth ranking, participant observation and semi-structured informal discussions. Technology Diffusion Mapping (TDM) of knowledge-base technologies was done to supplement the communications study.

A formal survey was carried out between June and July 2001. A total of 50 farmers were randomly selected from each of the study communities making the total sample 100 respondents. Face to face interviews were conducted and researcher filled interview schedules (a translator helped in Kisoro due to language barrier).

Local bean samples were picked from the study communities and tested for resistance. Sterile soil was inoculated with a Pythium isolate prepared from bean extracts. A germination count was taken one week after planting to confirm the health status of the seedlings (i.e. to rule out other infections other than BRR). Evaluation of BRR was done on the survivor seedlings 3 weeks after planting using the CIAT scale and levels of resistance were determined.

C H A P T E R T W O

2.0 RESULTS AND DISCUSSION

2.1 Social –cultural Context

Bakiga and Bafumbira tribes majorly inhabit Kabale and Kisoro districts respectively, which are subdivided into clans that trace their ancestral origin from Rwanda. Both communities are highly populated with Kabale having 300-324 persons per sq km (Ministry of Finance and Economic Planning, 1992a) while the Kisoro Community has up to 499 persons per sq km (Ministry of Finance and Economic Planning, 1992 b). The majority of inhabitants are subsistence farmers.

The majority (69%) of household surveyed were male headed, 28% were female headed and only 3% were single individuals. The mean household size was 6.12 (std 2.92) with a minimum of 1 and a maximum of 13. Mean composition of households was children (0-14 years) 2.79, youths (15-20 yrs) 0.91 and adults (above 20 years) 2.42.

2.1.1 Social Organization

In both communities people belong to Local Councils (LCs) which owe their existence to the Movement System of governance. Formerly an elders' committee (*Abataka/Umuryango*) was responsible for the welfare of the people. Currently this committee works jointly with the LC to solve community problems. The church plays a major role in settling marital problems.

All people belong to social organizations which include farming groups, credit groups, funeral related groups and religious groups. Farming groups sell labour to earn money, which is shared by members. They also dig communally for members, which helps them to time seasons of major crops since work is done faster. Credit groups pool money, which they either loan out to both members and non-members or contribute to individual members at a time. These groups are a major source of income to the majority of the inhabitants who use it to set up iron roofs, pay school fees and purchase household items. Funeral related groups perform their roles according to gender. The men's group pools money and purchase timber, which is used to make coffins for burying the dead. They also carry the sick to health centers on a local carrier called *Engozi/Engobyi*. The women's group contributes and prepares food, which is served during burials. They also move with men and attend to the sick being carried to the health centre. Religious groups take care of and/or encourage the needy and desolate. Membership to these groups is subject to paying membership fees (100= to 500=) and honoring the monthly subscriptions (500= to 1000=). Other than funeral related groups which are village-based, obligatory and disciplines defaulters by fining them, the rest of the groups are optional and an individual chooses which groups to join whether within or outside the village.

Through these groups farmers have learnt to work together and to resolve their conflicts. Farming groups present a suitable channel for agricultural technology dissemination within the communities. It is during communal digging that farmers discuss farming constraints, possible solutions and new technologies available.

2.1.2 Land tenure and ownership

In both districts much of the land is acquired through inheritance although the majority of farmers buy extra plots to supplement the small inherited ones. On average farmers own 2.2 ha of land, which is located in 7.5 (Std. 9.90) different plots. The total plots owned range from 1-70 different scattered plots. Of these an average of 3.98 are located within the same village, 5.06 (Std 9.52) in neighbouring villages, 1.86 in a different parish and 2.33 in a different Sub-county. Thus farmers own many more plots outside rather than within the villages in which they live. The majority (74%) own 0.5 – 2 ha, few (25%) have more than 2.0 ha and very few (1%) are landless. The more the acreage the bigger the holdings the fewer the scattered plots and vice versa. Rarely does land exist as a single holding owned by a household. Some farmers either rent (21%) or borrow (20%) land for crop production.

Ownership of plots outside villages of residence implies that plots are scattered further apart since villages are commonly separated by hills. Thus a lot of man-hours are lost as farmers walk the long distances to carry out crop production activities. Some plots are actually inaccessible hence are left under fallow conditionally (Olson, 1996). The numerous scattered plots also present a big setback to management of crop diseases (bean root rot in particular) in as far as soil improvement practices such as manuring are concerned. Also farmers who rent/borrow land cannot effectively manage root rots because use of improved soil cannot be sustained since the land lord may opt to change the tenancy for more pay.

2.1.3 Settlement pattern

The settlement pattern is basically clustered with few scattered homes where people own more land. Close relatives (e.g brothers) live together sharing a homestead on one bigger plot while the other plots are reserved for crop production. The majority of homesteads are located on hill slopes due to the fear of flooding in the valleys. Settling on hilltops would present water shortage problem.

The above settlement pattern influences the location on which crop production is done thus crop-soil condition-disease relationships. For example the majority (66%) of farmers grow beans on valleys while others grow them on hill slopes (50%), near homesteads (49%), on hilltops (30%), in *Urukoro* (15%) and in the swamp (3%). In Kisoro valleys are lowlands and crops are grown on mounds to avoid flooding thus indirectly minimizing effects of the BRR. In Kabale, valleys are located at hill bottoms and over flood during the main wet season (September – December). The bean crop is only grown in valleys in season A (February – April) and is planted late when the water level has reduced. This exposes it to heavy infestations of BSM that is misinterpreted as BRR, "*Kiniga* of season A has many more black insects (*Omura*) than the *Kiniga* of season B", farmers explain. Those who grow beans on hill slopes (in both Kabale and Kisoro) have serious problems with erosion such that the soils are poor and less productive. Fewer farmers (49%) grow beans near homesteads because the rest have smaller plots, which they reserve for settlement only. It is these few who constitute the biggest percentage of those who manure bean fields (63%) since they have no transport problems. The hilltop sandy loams (*Orusheenyi*) and the volcanic stony soils (*Urukoro)* are fertile soils that are not prone to erosion but are accessed by few farmers. The *Urukoro* type of soil is only found in Kisoro.

2.1.4 Marriage pattern

Traditionally, Bafumbira and Bakiga marry within their tribes and from short physical distances. The elite and the town dwellers have recently opted for inter-tribal marriages in order to adjust to environmental conditions. Monogamy is considered the most fitting and less problematic although some still believe in polygamy. Traditional marriages are more common since they are less expensive than official ones. The traditionally close marriages have resulted into closely-knit family relationships such that relatives or people of the same clan (Umuryango) occupy whole villages and/or the immediate neighborhood. However, due to land shortage many people have migrated to other districts in search of enough land.

This marriage pattern has influenced diffusion of technologies within the communities, for example, sharing of resources, information and new seed varieties follows a relative-to-relative trend. It is common to find a farmer who gives a seed gift to a relative in a different village, parish or district but has never given to the immediate neighbour with whom there is no relationship (Appendix ii A).

2.1.5 Values and Beliefs

Sorghum, a major crop consumed as food, porridge and local brew, is believed to yield more if the daughter in-law sows for the in-laws first before sowing hers. To keep harmonious family relationships, young women observe this tradition to the dot. According to the area cropping calendar, field preparation and planting of sorghum is done earlier (November - February) than that of beans (February - March). Thus married women have to sow sorghum for the in-laws first, then theirs and later prepare and plant beans. Such a trend of activities is likely to cause delayed planting of the bean crop. No wonder the seasons A bean crop experiences a heavy infestation of BSM.

2.1.6 Major Crops grown

Major crops grown by both communities include beans (100%), sorghum (99%), maize (94%), S/potatoes (92%), Irish Potatoes (47%), Bananas (39%) and Peas (39%). Other crops grown on small scale by selected households include sugarcane, pineapples, passion fruit, yams, pumpkin, cabbages, cassava, tomatoes, carrots, onions, avocado and coffee. These crops provide food and are a source of income. Coffee is a newly introduced crop in both Kabale and Kisoro grown by few farmers who have not yet obtained a harvest.

Other income generating resources in the area include sell of labour, salary/wage earning, livestock, local porridge, trading in domestic consumables, brick making, pottery, carpentry, butchery, local brew and milk. Livestock mainly constitutes sheep, goats, local chicken, pigs and a few cattle raised by a few households. Generally the income generating enterprises are operated on small scales and by few individuals.

2.2 Beans in the farming system

Beans are a traditional crop grown by the Bakiga and Bafumbira. It is valued both as food and as a source of income (Table 1). Farmers who grow beans for food purposes are mainly those with little/limited land, the elderly or those with large families and fewer plots where beans can be grown. With such, the amount harvested is either insufficient or just enough for home consumption although occasionally they may give out some gifts. Those who produce beans with intentions of food but sell the surplus try as much as possible to plant many fields whether personal, rented or borrowed and aim at increased yields. However, those with limited land and little produce may also sell when there is no alternative source of income. The few who produce beans for both food and cash are in a way commercial. They have enough land, select the high yielding and marketable varieties and hire labour to manage the bean crop.

Table 1: Reasons for growing beans

Reason	Percentage response
Food only	45.0
Food and sell some	51.0
Both food and cash	4.0
Total	100.0

As food, beans can be eaten with different foods and is itself eaten in different forms such as the leaves, young pods, fresh beans and dry grain. It can also be mixed in many other different vegetables and is considered good for children. As a source of income beans fetch a relatively high price compared to other crops as indicated by tables 2 and 3 below.

Table 2: Farm gate prices (Ug. Shs) of major crops in Kisoro (October 2000)

Crop	*At harvest*	*Off-season*	*At planting time*
Beans (kg)	150-200	400-500	800-1000
Sorghum grain (kg)	200	400	1000
Germinated sorghum (kg)	400	500	400
Maize grain (kg)	150	400	500
Maize Four (kg)	200-250	400-500	300
Sweet potatoes(tin)	1000	5000	3000
Irish potatoes (tin)	500	5000	2000-3000
Cassava(pile)	500	600	300-400
Yams(tin)	3000	3000	3000

Table 3: Farm gate prices (Ug.shs) of major crops in Kabale (October, 2000)

Crop	At harvest	Off-season	At planting time
Sorghum grain (Kg)	100	300	400
Germinated sorghum (Kg)	150	350	450
Beans (Kg)	100	800	1200
Peas (Kg)	150	500	700
Irish Potatoes (Pile)	100	200	100 for 3 potatoes
Irish potatoes (Tin)	3000	5000-6000	9000
Maize grain (Kg)	150	400	100 per cob
Maize flour (Kg)	200	500	400

- According to farmers' measurements 1 tin (debe) is equivalent to 20 Kgs

Although prices of all produce change with varying seasons, bean prices remain relatively higher than other crops. Unlike other crops, beans are more expensive in Kabale than in Kisoro due to small quantities harvested. This is a result of extensive soil infertility problems, exhausted soils, prevalence of pests and diseases and poor seed varieties that result into low yields. Beans are grown twice a year although much of the crop is produced in season B than in season A. In season A some of the plots are used for sorghum production limiting the number of plots for beans. On average 2.4 (max 10) plots are planted in season B while 1.7 (max 7) plots are planted in season A.

2.2.1 Gender participation in bean crop management

Bean growing is basically a women's job (96%) although men (42%) and children (13%) participate. Men's participation depends on activities being done and varies from one area to another. Generally men participate in planting, harvesting, threshing, storage and selling. In Kabale, men do not plough or weed but do the threshing alone. In Kisoro, men do not select seed, plant, weed or store bean grain. They mainly participate in harvesting but are equally helped by women. Only women do the winnowing. Men who fully participate are either widowers and/or those who have elderly and/or sick wives with no dependants in the home.

Table 4: Division of labour in bean crop management in Kisoro.

Operations	Women	Men
Seed selection/purchase	* * * * * * * * * *	
Ploughing	* * * * * * * *	* *
Planting	* * * * * * * * * *	
Staking	* * * * * * *	* * *
Weeding	* * * * * * * * * *	
Harvesting	* * * * *	* * * * *
Threshing	* * * * * * *	* * *
Winnowing	* * * * * * * * * *	
Storage	* * * * * * * * * *	
Selling/control of income	* * * * * * * * *	*

Table 5: Division of labour in bean crop management in Kabale

Operations	Women	Men
Seed selection/purchase	* * * * * * * *	* *
Ploughing	* * * * * * * * * *	
Planting	* * * * * * *	* * *
Weeding	* * * * * * * * * *	
Harvesting	* * * * *	* * * * *
Threshing		* * * * * * * * * *
Winnowing	* * * * * * * * * *	
Storage	* * * * * * *	* * *
Selling/control of income	* * * * * * * * *	*

Although women mainly do the selling, money is used to purchase household items, foodstuffs and tending to general childcare. Since bean production is a woman's responsibility it implies that they shoulder the whole duty of BRR control. The fact that they are involved in other activities means they have less time to invest in some of the time demanding management practices like manure collection and composting thus the less effective practices like seasonal rotations and fallows are opted for (although they are done without direct intent to control the disease).

2.2.2 Bean Cropping Pattern

In Kabale mainly bush varieties are grown. Climbers are a new introduction still being tried by NGOs and a few innovative farmers. In Kisoro both bush and climbing varieties are grown. In both communities beans are either grown as a sole crop (91%) or in association with other crops (94%) depending on growth habit or season. Climbing varieties are normally grown as pure stands while bush varieties are intercropped. In Kabale, season A beans are planted as pure stands because the short rainy season would not be suitable for long term crops like maize. This is also the season when beans are planted in valleys so intercrops like peas would give low or no yields due to high moisture conditions that cause a lot of vegetative growth and is conducive for disease prevalence. In season B, which is the long rainy season, beans are commonly intercropped because this also is a suitable time for the intercrop components. In Kisoro, climbing varieties are grown sole while bush types are intercropped. Major crops intercropped with beans include maize (79%), sorghum (52%), peas (46%), Irish potatoes, sweet potatoes and yams. However, at least three crops exist in the same field at the same time. Such associations result into having the bean crop on the same field both seasons of the year. Reasons why beans are either grown sole or intercropped are indicated in tables 6 and 7 below:

Table 6: Reasons why beans are grown sole

Reasons	**%**
Season A not suitable for intercrops	26.0
Climbers intertwine and smoother the other crop	17.0
Climbers out compete the other crop	16.0
Tradition	16.0
High yield	14.0
Easy staking	6.0
Avoid nutrient competition	4.0
Fertile soils	3.0
Peas do not grow in valleys	2.0
Has enough land	1.0

The individual percentage responses are low because each community sole crops beans because of different reasons although a few tally. In Kisoro only climbers are sole cropped thus reasons are related to competition, staking and yield. In Kabale bush varieties are sole cropped depending on season hence reasons are related to intercrop components. Tradition is common to both communities.

Reasons for intercropping beans also vary slightly between the two communities. In Kisoro, they are related to growth habit while in Kabale reasons are based on season and field location. Food security and the need for other crops are important intercrop features in both communities.

Table 7: Reasons why beans are intercropped.

Reason	Percentage response
Food security (Control famine/harvest more than one crop)	36.0
Bush beans short and don't intertwine	34.0
Season b is season for suitable intercrops	19.0
Get something in case one crop fails	12.0
Tradition	8.0
Higher yield	6.0
Season B beans are planted on hills, a suitable location for other intercrop components.	6.0
Uses maize as stakes	1.0

Although few farmers (6%) had realized increased yields due to intercropping, no farmer linked sole crop or intercrop to disease or pest control effects. Hence, selection of cropping pattern to use is influenced by varietal growth habits, seasonal changes, tradition and food security reasons.

2.2.3 Varietal mixtures Vs mixes

Varietal mixtures are handled differently in the two communities. In Kisoro traditional varieties are grown in mixtures care being taken to match varieties with similar growth habits, same maturity periods and resistance to rain effects. Even when new variety seed is bought from the market as a mixture, it is sorted and planted singly until farmers have studied the growth habits of individual components. Later, a decision is taken whether to add the variety to the mixture or not. However, some farmers still plant bush types as traditional mixes while some maintain new varieties pure. In Kabale where mainly bush varieties are grown traditional mixes are grown. Much of the seed is bought in markets when mixed and is planted thus. Since the quantities bought are small, farmers think that separating individual components would reduce the quantities yet they do not have the money to buy more. Although some varieties in the mixture are know to be more resistant to rain than others (particularly the small seeded locally called *Nyakacecuru*), no sorting is done to maintain these varieties. Survival of the varieties in the mixes is believed to change with changing weather conditions therefore sorting and selection is not considered very helpful. In Kisoro there are many climbing bean varieties available on the local market. Farmers' preference on which varieties to plant is based on resistance to rain, taste, high yield potential, palatability of leaves or young pods, short cooking time and resistance to rats. In Kabale, although many varieties are sold in the markets, they are normally mixed with bush types such that farmers cannot differentiate between the too. Traders are also not willing to tell the truth so farmers who buy seed are disappointed when the growing crop turns out to be climbers for which they were not prepared. Many farmers do not grow climbers for fear of bird damage if grown by only a few people in the village.

2.2.4 Bean plot management

Plots where beans are grown have been cultivated for many years without rest. A mean of 2.98 plots have been cultivated up to 15 years, 2.27 plots for between 16 to 30 years and 2.14 plots for over 30 years. However, these years indicate the time the current owner has used the land yet all plots are bought when already in use. Generally farmers believe that plots have been cultivated for over 60 years. Only seasonal rotations are practiced on these plots due to land shortage. Few farmers with enough land can afford fallowing of some plots up to 3 years. The majority carries out seasonal or annual fallows particularly on plots where sorghum has been harvested or where sweet potatoes will be planted. Typically, infertile plots are fallowed while fertile ones are continually cultivated These observations tally with what Olson (1996) found out in the 'Initial results concerning the use of fallow in Kabale District'.

Continual use of land, coupled with the steep terrain and the high population density, has caused the area to experience serious soil infertility problems (Munro, 1998) such that soils cannot adequately support healthy crop growth. The severity of BRR and BSM has been enhanced by the poor soil conditions in the area (Nderitu et al, 1997) and in Kabale it is escalating unabated since there is no soil management practice being implemented.

2.3 Bean crop management practices

Farmers in an effort to manage the bean crop do a number of activities.

2.3.1 Seed Selection

Few farmers (45%) for different reasons do seed selection. Thirty five percent select for resistance against BRR and 27% for high yielding potential. Other reasons include taste, palatability of leaves or young pods, short cooking time and resistance to rats. Some farmers do the selection when the crop is still in the field by monitoring its agronomy. The variety wanted is then harvested, threshed, winnowed and stored separately away form the lot for sale or domestic use. Others make their choices soon before planting by buying form the market, buying form or exchanging with fellow farmers or selecting from the own saved lot. Kisoro farmers select seed more than Kabale farmers possibly because there are many new varieties in Kisoro from Rwanda and Zaire among which farmers can select. However, even within the local mixtures, farmers select the components unlike in Kabale where seed is mainly sorted just before planting.

Seed selection is one of the practices that farmers consciously apply as a disease or pest control measure. Its effects are evident among Kisoro farmers who practice it such that the BRR effect has reduced with time. Serious disease damage is only observed when susceptible varieties are planted. In Kabale where the practice is ignored, BRR prevalence is rampant and on the increase.

2.3.2 Seed sorting

The majority of farmers (69%) sort bean seed shortly before planting. Forty two percent sort to get viable seed, 33% sort to remove dead material, 20% want clean/quality seed while few (4%) sort to obtain a desired variety. Farmers consider viable seed to have the correct size and shape (depending on variety), right colour and must be from the previous season. Seed stored two seasons "may not give good results" due to poor storage conditions and methods, storage pests and disease effects. During sorting, care is taken to remove seed that is rotten, moulded, weeviled, broken, premature, deformed, discoloured, small seeds and unwanted varieties. Farmers believe that if these are planted they will either not germinate or their seedlings will die soon after germination. The rejects are later resorted for cooking or mixed in the lot for sale.

Seed sorting, although done by the majority of farmers may not be very effective in controlling seed borne diseases. This is because only the observable problems can be detected and eliminated. However, the amount of pathogen inoculum may be reduced (Trutmann et. al., 1993) especially where sorting is done from big seed quantities allowing even the slightly affected seed to be removed. Where seed quantity is little, which is common in Kabale, poor quality sorting may be done thus the pathogen levels may not be significantly reduced. On the whole, seed sorting is done routinely without conscious intention of controlling disease.

2.3.3 Field Preparation

In general two sets of ploughing are done although the reasons and timing differ for the different bean plot locations. Primary cultivation is done 1-2 months before planting. Secondary cultivation is done soon before planting but in case of enough labour, it is done simultaneously with planting. In Kisoro, piling the stones together and removal of grass and crop residues does primary cultivation of the stony volcanic soils (*Urukoro).* The removed grass and trash is left in the field to rot and provide manure while the clean seedbed scares away rats. In valleys (*Umubande),* first ploughing involves mounding and ridging. Previous crop residues and weeds are placed in between the ridges and new mounds are made on top. Of the 29% who plant beans on mounds, 15% do it to control flooding, 6% do it because it is tradition and 6% find it easy to apply manure in ridges. Mounds made in *Urukoro* are intended to pool together the thin soil to create a deep soil layer necessary to support healthy crop growth. Sometimes mounding is done on hill slopes to reduce erosion and to provide manure but this is on a limited scale. In swamps (*o/urufunjo*), slashing is done a month before planting and mounds are made when the grass is dry. Planting is done after the moisture content in the mud has reduced. In Kabale, mounds are mainly used in sweet and Irish Potato production. Beans are commonly grown on flat seedbeds for fear that mounds cause water to stagnate around plant roots thereby causing the bean crop to rot. However in a few localized places, mounds are used for bean production. In swamps, water trenches are constructed on given locations so that water moves freely in the fields, swampy areas are more commonly used in season A than in season B to avoid flooding.

Mounding, a land preparation practice, is done routinely mainly to control flooding. It is done for all crops grown in valleys or *Urukoro* and is traditional. In Kisoro, mounding influences manure application since ridges are considered suitable sites for organic material disposal. Although the manure applied is good for soil fertility improvement, its timing does not allow the bean crop to fully utilize the applied manure. A short interval is provided between ridging and planting such that the next crop benefits more than the intended. In Kabale where limited mounding is practiced, manure application, especially use of crop residues and weeds, is very limited. The trash is either used as firewood or thatch or is dried and burnt to maintain clean seedbeds. Only young weeds are buried as green manure if there was along interval between the first and second cultivations. Hence no land preparation operation is consciously done to control crop diseases.

Whatever reasons farmers may have for ploughing, ridging and incorporation of organic manure, these are practices scientifically known to control BRR (Nderitu et al. 1997). The two sets of ploughing before planting allow for deep tillage of the bean fields, which is known to reduce BRR. Deep ploughing, mounding and ridging have been shown to reduce plant mortalities caused by root rots favoured by high moisture (CIAT, 1992). This is because the practices increase aeration and drainage thereby creating less favourable conditions for disease development. Farmers' land preparation practices include manure application on top of deep ploughing and ridging and mounding. Hence the routine land practices play a significant role in controlling BRR particularly in Kisoro district.

2.3.3 Planting

In season A, planting is done when the rains start since there is no fear of "rain effect" due to moderate rainfall amounts received. Planting in season B fluctuates to avoid rain effect. In swamps, planting takes place in September and is done to target sowing of sorghum in the same plot in February the following year. If the field is not to be used for sorghum, planting is done in October. Some planting is done in November especially as an intercrop in banana plantations.

Table 8: Cropping calendar for Beans in Kisoro.

Farming activity	J	F	M	A	M	J	J	A	S	O	N	D
CLIMBING BEANS												
Slashing		■							■			
Ploughing		■	■						■	■		
Planting		■	■	■					■	■	■	
Staking			■	■						■	■	■
Weeding				■	■					■	■	■
Harvesting		■					■	■				
BUSH BEANS												
Ploughing	■	■							■			
Planting		■							■	■		
Weeding			■	■	■						■	
Harvesting		■					■	■				

- Bush beans are planted in association with sorghum. Weeding in May refers to the intercrop.

Table 9: Cropping calendar for beans in Kabale

Farming activity	J	F	M	A	M	J	J	A	S	O	N	D
CLIMBING BEANS												
Ploughing 1		■							■			
Ploughing 2		■							■			
Planting			■							■		
Staking				■							■	
Weeding					■							■
Harvesting		■					■	■				
BUSH BEANS												
Ploughing 1		■	■					■	■			
Ploughing 2			■	■					■			
Planting			■	■					■	■		
Weeding					■					■	■	■
Harvesting	■	■					■	■				

Planting is done by hand and the chop and plant method is used. Farmers do not plant in lines but seed is planted equidistant, care being taken to leave enough space for foliage development. In Kisoro, one seed per hole is planted while in Kabale 2-3 seeds per hole are planted. The rationale for planting more than one seed is that a single seed may die leaving empty space thus reduced yields. Planting density is regulated according to seasons and soil fertility. In season A, a higher density and close spacing are used because plants do not grow vigorously to become larger due to limited rainfall. In season B, a lower density and wide spacing are used to avoid destruction by rain. In fertile soils e.g the stony volcanic soils, valleys and banana plantations, a lower density is used because plants are likely to grow larger, touch and form thick canopies, a condition called “gufura”. This condition is known to result into flower and pod abortion and diseases like ascochyta blight and anthrachose flourish under such conditions, in poor soils e.g the eroded hill slopes, a higher density is used because no vigorous growth is expected thus low plant densities and wide spacing would result into reduced yields.

Farmers regulation of planting according to season and plot locations are effective preventive measures against disease. For example, the crop planted in October and November is likely to survive BRR and other “rain diseases” since rainfall amounts will have reduced. Timely planting, close spacing and high plant densities used in season A protect the crop against BSM (Nderitu et al. 1997) which is commonly severe in the short rainy season (season A) due to the early onset of drought. When these are added to other practices like intercropping and manure application, a significant amount of disease control may be realized.

2.3.5 Manure application

The majority of farmers (63%) manure their bean fields to improve soil fertility (48%), to increase yields (20%) and to get a healthy crop (14%). Of those who manure, 48% use grass, crop residues and household waste while 33% use animal waste. Farmers do not have a specific technical way of applying manure. Household waste, collected daily form homesteads and animal waste is thrown into fields whether they are dug or bushy. In mounds the manure is thrown within ridges which will make new mounds next season. During field preparation animal manure, grasses weeds and crop residues, are buried leaving behind a clean seedbed to be planted. No particular attention is paid to the collection and piling of organic substances so that they rot to form properly decayed manure. Only fresh organic substances are thrown on the fields to rot on their own but in the process are exposed to uncontrolled sunshine and rain which are likely to deteriorate the manure. There is also a short interval allowed between when manure is buried and planting thus the plants may not actually utilize the applied manure.

Since manuring is routinely done every season for all crops, it is hoped that the soil eventually improves due to constantly adding organic substances. The biggest hindrance is that the substances added are not high value so the amount of available nutrients for crop growth may not necessarily be substantial.

2.3.6 Staking

Traditionally, all farmers stake climbing beans. All farmers know that if climbers are not staked, the plants crawl on ground, develop thick foliage and will never pod. Staking is done when plants have fully germinated and latest when plants begin to bring up tendrils. Choice of stakes to use depends upon the variety. Long and strong stakes are used with big seeded vigorously growing varieties (e.g. *Nyiragikooti* and *Npuramugabo*), which are commonly grown in valleys. Because these tend to be affected by rain due to thick foliage, stakes are planted at a wider spacing so that ample spaces are left in between to allow light to penetrate the crop.
Small seeded varieties, known to be hardly are grown on less fertile soils (hill tops and slopes). A high density of stakes is used with these because they have smaller leaves and do not grow vigorously. In the same way short growing varieties (e.g *Mwigondoro*) are given

short stakes and tall varieties (e.g *Nyirakanada*) are given tall stakes. Farmers believe that bean plants climb stakes from the right hand side, thus stakes are planted in such a way that plants have access to stakes although the distribution is not even. Any kind of tree species available is used as stakes and when in shortage, elephant reeds are used. Although staking is not done to control disease, farmers are aware that staked plants are less diseased than the unstaked or bush types (Trutmann et al. 1997).

2.3.7 Weeding

Almost all farmers (95%) weed the bean crop. The few who may not weed beans are influenced by absence of weeds, severe disease incidence or absence of rats. If BRR incidence is very severe, especially when traditional varieties are planted, farmers do not see the need to weed as the whole crop is expected to be lost. Farmers' decision to weed or not changes with changing seasons, field location and cleanliness. Of those who weed, 44% want to control rats, 41% reduce competition, 22% want to promote vigorous crop growth and 18% want to control pests. Other reasons for weeding include control of flower and pod rot, ensuring a clean harvest, softening the soil and earthing up of bean plants.

Weeding is done 1-2 times depending on variety and soil types. Bush types and climbers planted in swamps and volcanic stony soils require two weedings, since these locations are known to contain a lot of weeds. The vigorously climbing varieties are weeded once because the thick foliage suppresses weeds. The first weeding takes place when the crop has 3-4 leaves or after staking. It is done using a hand hoe and is intended to remove competitive weeds, softens the soil and allows plant roots to penetrate, controls and promotes vigorous crop growth and enables earthing up of the young crop. Whether there are weeds or not, the first weeding takes place. The second weeding is done shortly before or at flowering and is dependent on presence of weeds and/or a lot of foliage. It is done to reduce rain effect by defoliating excess leaves and opening the crop to light and free air circulation, provide manure, control rats and allow fast ripening at maturity. It is done by hand care being taken to uproot only weeds and not the plants. The defoliation done prevents flower and pod drop and enhances flower production. In the banana intercrop, banana leaves are reduced to open up the crop. Where plant density is high or the crop is vigorous or there is no threat of rat damage, second weeding is not done but defoliation is done to reduce leaf canopy. All weeds and defoliated leaves are thrown within the field to provide organic matter to the growing crop. Surrounding bushes are cut down in an effort to control rat damage.

Although farmers do not consider weeding a disease management strategy, some principles can be seen to tally with cultural disease control practices e.g. the two weedings done at different stages allow the field to be free of wild and alternative hosts of insect pests and disease. The free air circulation and light penetration help reduce the soil moisture content thus BRR may be reduced. The earthing up help plants to survive BSM effects by sprouting adventitious roots. However, the diseased leaves and plants, which are thrown in the field, could be a source of inoculum build-up.

2.3.8 Harvesting

The first season crop is harvested between June and August while the second crop is harvested between December and February. Harvesting is done when the crop is dry. The top most undried pods are picked and separated for cooking. To avoid shattering, harvesting is done early in the morning. The cut or uprooted stems are bundled, tied and carried home for final drying and threshing. Seed scattered in the field is picked but some remain and make the volunteer plants in the next crop. These volunteer plants are never uprooted because they provide early food in time of scarcity. After harvest the filed is left undisturbed until the next season. Crop residues and other forms of manure are thrown in that field until preparation for the next season starts. When threshing is done in the field, residues are left there in and later spread when preparing the field for the next crop.

The volunteer plants left in the field after harvest and the undecayed crop residues left behind could be a potential source of pathogen carry-over. Farmers' harvesting methods and field treatment are likely to facilitate build up of disease and pest inoculum although farmers do not perceive such as a problem.

2.3.9 Storage

Only a small fraction of farmers (38%) use chemical to treat bean grain for storage in order to control weevils. The rest either do not treat at all or use local materials such as sorghum husks, ash, etc. Treatment is done to all harvested grain without separating the lot for household use. Chemicals used are Malathion dust (locally called chlorine), Ambush, Sumithion and Diazinon which are used to treat sorghum, bean and to a smaller extent maize grain. Storage facilities include granaries, gunny bags, old pots and traditional baskets. A few farmers are able to store seed beyond a season. The majority store seed between 1 and 3 months because of small quantities harvested due to limited land, effect of rain and drought. The small quantities are also sold to earn income and to purchase other foodstuffs.

Other than controlling weevils, farmers have neither chemical nor cultural strategies to control or reduce disease infection during storage. The inability of most farmers to separate seed from the rest of the lot is a likely cause for lack of or use of poor seed.
There is need to guide farmers on quality seed selection principles so that they can appreciate the need for good/quality seed. Farmers should also be guided on seed/grain protection since the insecticides used currently present a potential health hazard to the users.

2.3.10 Rotations, fallows and terraces

a) Crop rotation

Crop rotation in the strict sense was rare although all farmers (100%) claimed to practice it. Only dominance of crops in the fields shifted according to seasons. The majority of farmers (51%) rotate crops due to the need of other crops while 35% rotate to get increased yields. Others reasons include control of soil exhaustion, pest control, and tradition while others did not know why they rotate crops. Major rotations are Beans-Maize-Sorghum (71%), Beans-Maize-Beans (27%) and Beans-Irish potato/Maize-Sweet Potato. Maize and Sorghum are normally intercropped with beans and/or Irish potatoes such that bean crop appears in the field season after season.

Cereals grown two seasons before the bean crop are known to reduce severity of BRR (Nderitu et. al., 1997). Although cereals make an important part of the rotations BRR severity reduction may not be significant because the cereals are normally intercropped with beans. There is instead a likelihood of BRR pathogen build up due to permanent presence of host crop.

b) Fallows

The majority of farmers (54%) carry out seasonal or annual fallows mainly to rejuvenate soil fertility (50%). Some fallow because they have enough land. Due to land shortage not all plots are followed. Infertile plots are followed while fertile ones are continuously cultivated. Seasonal or annual fallows are common on plots where sorghum has been harvested or where sweet potatoes will be planted. A few farmers with enough land (the rich) can afford fallowing up to three years. These observations tally with what Olson (1996) found out in the 'Initial results concerning the use of fallow in Kabale District'.

The fallows are generally too short to allow disease pathogen reduction or even effect soil fertility regeneration, which is the farmers' major cause for fallowing. This is more so due to the fact that only infertile areas are fallowed. Although farmers know the benefit of fallowing, there is need to focus it to a result-oriented schedule. However, farmers could not relate fallowing to disease control.

c) Terraces

Terraces are traditional in the study communities and were established during the colonial era. To some extent these terraces have been maintained though some farmers have destroyed them in search of fertile sections of land. About 71% of respondents grow beans on terraces to reduce soil erosion/run off. Others see terraces as a borderline between fields while others deposit organic material there. Where terraces were destroyed, mounds or trash lines have been set up to help on erosion control especially where active cultivation still takes place.

Although terraces help to check erosion, the results are not significant due to the fact that soils are extensively exhausted due to continuous cropping and hilly terrain, yet with no soil management practices being implemented. Furthermore, some areas have no terraces and severe erosion is evident as gullies and shallow red soils characterise some hills where cultivation is done. Such places need viable appropriate soil fertility improvement interventions before other disease management strategies can be employed.

2.4 Traditional bean crop management practices; A comparison of Kabale and Kisoro districts

A comparison of Kabale and Kisoro districts was made to establish the distribution of the traditional bean management practices. The results were as shown below.

Table 10: Traditional bean management practices in Kisoro and Kabale districts

Management practice	Kabale (N=50)		Kisoro (N=50)	
	Frequency	Percent	Frequency	Percent
Selects seed	7	14.0	38	76.0

Sorts seed	24	48.0	45	90.0
Applies organic manure	25	50.0	38	76.0
Defoliates thick canopy	11	22.0	17	34.0
Weeds the bean crop	49	98.0	46	92.0
Rotates beans with other crops	50	100.0	50	100.0
Fallows bean fields	35	70	19	38.0
Beans grown on terraces	39	78.0	32	64.0
Seed dresses bean grain	13	26.0	25	50.0
Beans grown as solecrop	41	82.0	50	100.0
Beans grown as intercrop	47	94.0	47	94.0

From the above results seed selection, seed sorting, manure application and seed dressing are more common in Kisoro than Kabale. Seed selection in Kisoro is possible because there are many new varieties available that farmers can select from according to their preferred characteristics (section 2.3.1 and table 18). Seed sorting is also enabled by available large quantities such that farmers can afford to sort for desired seed quality unlike in Kabale where quantities are never enough (section 2.3.2). Seed dressing for reasons of weevil control is also possible in Kisoro where relatively large quantities are harvested (section 2.3.8). On the other hand fallowing is more practiced in Kabale (70%) than in Kisoro (38%). Generally farmers in Kisoro have fewer but more fertile plots of land that are continuously cultivated. Kabale farmers have many more scattered infertile plots, some of which are not suitable for cultivation. The infertile plots are fallowed in the hope that their fertility will improve while the far-off plots may not be cultivated because they are difficult to access (far from home)(Olson, 1996). Although all farmers grow beans as a sole crop, their reasons differ for the two communities. In Kisoro climbing beans are grown sole while in Kabale season A bush beans are grow sole (section 2.2.2). Intercropping is a traditional practice done to satisfy the need for other food requirements while rotation is done for food security reasons.

C H A P T E R T H R E E

3.0 Farmers' ITK of bean diseases

Many diseases attack beans in Southwest Uganda. Diseases that farmers consider economically important are BRR and Ascochyta Blight (AB). Other diseases not considered economically important are anthracnose, Bean Common Mosaic Virus (BSCMV), Angular leaf Spot (ALS), Rust and Southern Blight. Farmers' analysis of an economically important disease is mainly dependent upon the nature and extent of damage caused on the crop and the accruing effects. If destruction is significant, widely distributed and leads to reduced or no yields, the disease is important and vice versa. Farmers group all these diseases into two "soil diseases" and "rain diseases". BRR is called a soil disease because it is believed to originate form the soil as evidenced by rotting of roots. The rest of the diseases are termed rain diseases because they prevail in wet conditions. In Kabale, some farmers understand rain diseases as "rain effects" not disease.

3.1 Bean root rot

Bean root rot is considered the most important disease because it attacks a crop at a very young stage and does not give the farmer a chance to harvest any part of the crop, "not even leaves." It is also known to wipe out whole fields causing total crop loss. In Kabale it is called *Kiniga* meaning "is angry and commits suicide" while in Kisoro it is called *Churisuka* implying "coming home with only a hoe and no harvest". Both names depict the effect of the disease on the attacked crop. In Kabale BRR is known to have first appeared in the 1950s and was traditionally controlled through rituals that ‘‘chased it away’’. It later appeared in mid and late 1990s. The current BRR is described to be more severe and attacks like an epidemic. According to farmers, "it attacks within a short time and clears the crop before any control can be administered". In Kisoro, the disease first appeared in the late 1980s and early 1990s. Since then it has remained a threat to bean production in the area although introduction of new tolerant varieties from Rwanda and Zaire has reduced it in some places. Severity of BRR is known to change with changing weather conditions and may appear at different times in different localities. With the exception of some small seed varieties that show some tolerance to disease, all traditional varieties are seriously affected by BRR to such an extent that whenever they are planted whole fields are lost.

Farmers clearly understand and can describe BRR above-the-ground symptoms. Most farmers (94%) clearly describe yellowing of leaves, 64% observe rotting of roots while 35% recognize drying of roots. Some farmers understand that BRR may attack a whole plot or pockets of the field. The former wipes out a whole crop while the latter clears patches leading to reduced plant population. That plants which survive are stunted, have few bent pods and seed inside are small and discolored. Such seed is never planted but can only be eaten. Few farmers (13%) relate BRR to Ascochyta blight while others cannot differentiate BRR from BSM. The majority of farmers (86%) observe symptoms at the 2^{nd} and 3^{rd} leaf stage, which tallies with what Nderitu et al (1997) found out that beans are susceptible during 2-3 weeks of crop growth. Farmers were also aware that BRR disease prevails under conditions of low fertility (*enombe, ibeija, orucuucu, munyezi*) and that it is more severe on hillslopes than on valleys. However, hey claimed to observe disease symptoms in both rainy and drought conditions although the incidence is considered to be more severe in season B than in season A. These observations serve to confirm farmers' inability to differentiate BRR from BSM. Farmers attribute cause of disease to too much rain, poor soils, continuous cropping, use of poor seed and water stagnating in the fields. Too much rain implies heavy down pours causing high moisture content in the soil.

When farmers were asked to explain the effects of the disease on yield, 66% testified that no yields were obtained due to total crop loss while 27% had obtained reduced yields. Other effects included extinction of local varieties, rampant famine, poverty due to reduced income, reduced bean production and lack of good planting seed. In order to compare BRR and other constraints, farmers were asked to list all the constraints/problems they had experienced in bean production. The results obtained are as shown in table 8 below:

Table 11: Constraints/problems faced in bean production

Constraint/problem	Percentage response
BRR	66.0
Exhausted soils	43.0
Weevils in storage	42.0
Rat damage	36.0
Low market prices	23.0
Lack of seed	23.0
Bird damage	22.0
Poor seed/varieties	18.0
Soil erosion	14.0
Aphids	13.0

Other minor problems were lack of storage facilities, shortage of labour and shuttering when harvesting is delayed. Farmers were then asked to rank the five most important problems and BRR as the most important was ranked as shown in table 9.

Table 12: Ranks given to the problem of BRR

Rank	Percentage response
First	38.0
Second	8.0
Third	11.0
Fourth	4.0
Fifth	2.0

Tables 11 and 12 clearly show that BRR is an outstanding problem in SouthwestUganda, which control needs to be addressed with the co-operation of the beneficiaries.

3.1.1 Factors influencing knowledge of BRR

It was hypothesized that farmers' knowledge of BRR was related to factors such as farmer's age, education level, gender and wealth. Older farmers, the more educated, the rich and women farmers were hypothesized to be more knowledgeable than their counterpart farmers. Since different farmers perceived BRR differently (section 3.1) key issues were selected to represent knowledge. These were stage at which BRR symptoms were seen, above-the-ground symptoms and below- the-ground symptoms each of which was treated as an independent variable. Hence, Chi-square was computed to determine whether a systematic relationship existed between knowledge of BRR disease and the above selected variables. Cramers V statistic was used to measure the strength of the relationship.

a) Knowledge of BRR Vs education level of respondent

For all the variables used to describe knowledge of BRR, there was an insignificant relationship with respect to education level of the respondents (P>0.05). Cramers V showed negligible associations for symptoms seen at 2-3 leaf stage and rotting roots while low associations were shown for drying of roots, yellowing of leaves and drying up of the plant (table 13 below). The Null Hypothesis (Ho) was not rejected.

Table 13: Relationship between knowledge of BRR and education level of the respondent.

Variable	X^2	Df	**Asymp.sg. (2 sided)**	Cramers V
Symptoms seen at 2-3 leaf stage	0.352	2	0.839	0.060
Roots rot	0.193	2	0.908	0.045
Roots dry up	1.389	2	0.499	0.120
Yellowing of leaves	2.391	2	0.303	0.157
Affected plant dries up	3.745	2	0.154	0.200

Basing on the above results, education level is not a major factor influencing knowledge of BRR. Possibly both illiterate and literate farmers perceived BRR disease in the same way since they all relied on the 'easily observable symptoms'.

b) Knowledge of BRR Vs age of respondent

The relationship between age of respondent and knowledge of BRR was moderately significant (P<0.05) only in the case of affected plants drying up. An insignificant relationship with moderate association existed for symptoms seen at the 2-3-leaf stage. Rotting and drying of roots and yellowing of leaves showed insignificant relationships with low associations (table14 below):

Table14: Relationship between Knowledge of BRR and age of respondent

Variable	X^2	Df	**Asymp. Sig (2 sided)**	Cramers V
Symptoms seen at 2-3 leaf stage	11.255	3	0.10	0.341
Roots rot	4.125	3	0.248	0.207
Roots dry up	5.854	3	0.119	0.247
Yellowing of leaves	2.465	3	0.482	0.159
Plant dries up	10.433	3	0.015	0.333

From the results, older farmers seem to know that plants affected by BRR disease dry up more than the younger ones. This could be due to the fact that they have observed this disease effect over a long time in the past and the current re-appearances. Another possible reason could be their inability to disassociate other effects (e.g wilting, BSM, etc) from BRR damage. Stage of attack and other symptoms are not significantly related to age. Thus farmers of all age groups have equal opportunities of knowing these symptoms.

c) Knowledge of BRR Vs wealth status of respondent

The relationship between knowledge of BRR and wealth status of the respondent was insignificant (P>0.05) for all variables that describe knowledge. Low associations were shown for symptoms seen at 2-3-leaf stage, drying roots and drying up of plants. Rotting of roots and yellowing of leaves showed negligible associations (table 15) below. The Null hypothesis was therefore not rejected.

Table 15: Relationship between knowledge of BRR and wealth status of respondent

Variable	X^2	Df	**Asymp.Sig (2 sided)**	Cramers V
Symptoms seen at 2-3 leaf stage	1.537	2	0.464	0.126
Roots rot	0.102	2	0.950	0.033
Roots dry	1.992	2	0.369	0.144
Yellowing of leaves	0.358	2	0.836	0.061
Affected plants dry up	2.007	2	0.367	0.146

Basing on the above results, the wealth status of farmers does not significantly influence their knowledge of BRR disease. Both the rich and the poorer farmers have equal chances of knowing the disease as long as they physically participate in bean farming.

d) Knowledge of BRR Vs sex of respondent

For all the variables that describe knowledge, there was an insignificant relationship with respect to gender (P>0.05). Very strong associations were shown for symptoms seen at 2-3 leaf stage and rooting roots. Low associations were shown for yellowing of leaves while negligible associations existed for drying up of roots and whole plants (table16). For all cases, Ho was not rejected.

Table 16: Relationship between knowledge of BRR and sex of respondent

Variable	X^2	Df	**Asymp Sig (2 sided)**	**Cramers V**
Symptoms seen at 2-3 leaf stage	0.578	1	0.447	0.77
Roots rot	0.105	1	0.745	0.33
Roots dry	0.062	1	0.804	0.025
Yellowing of leaves	2.50	1	0.113	0.161
Affected plants dry up	0.006	1	0.100	0.008

Results show that knowledge of BRR does not necessarily depend on sex. Both male and female farmers perceive the disease in the same way particularly rotting of roots and observation of symptoms at the 2-3-leaf stage. This can be explained by the fact that all respondents were essentially bean farmers who were practically involved in bean production. As such male and female respondents were equally exposed to BRR.

d) A comparison of Kabale and Kisoro districts with respect to farmers' knowledge of BRR.

Results of Chi-square and Cramers V show that significant relationships exist with drying of roots and affected plants drying up. The former exhibits a low association while the latter shows a substantial association. For these two variables Ho was rejected. The rest of the variables showed insignificant relationships with low associations (table 17).

Table 17: A comparison of Kabale and Kisoro districts in relation to farmers' knowledge of BRR

Variable	X^2	Df	Asymp Sig (2 sided)	Cramers V
Symptoms seen at 2-3 leaf stage	2.681	1	0.102	0.102
Roots rot	3.000	1	0.083	0.177
Roots dry	5.44	1	0.020	0.238
Yellowing of leaves	3.160	1	0.075	0.180
Affected plants dry up	36.458	1	0.000	0.623

From the results, Kisoro farmers know drying up of roots and whole plants more than Kabale farmers do. Since BRR disease has been prevalent in Kisoro for a longer time than in Kabale, many farmers could have had an opportunity to observe symptoms at different development stages than those in Kabale where disease occurrence is recent. It could also be true that the pathogen species (or a combination of them) occurring in the two places are different thus manifesting different severity levels and hence symptoms. Knowledge of symptoms seen at 2-3-leaf stage, rotting roots and yellowing of leaves is not significantly different. Possibly farmers were exposed to the same opportunities of observing the symptoms.

3.1.2 Farmers' management practices of BRR

BRR management practices differ in the two study communities. In Kabale, when the disease first appeared in the 1950s, youths form affected communities would gather together, collect samples of diseased plants and singing "Kuka Kiniga" would throw them beyond the hills or across streams. The elderly believe that this method was effective in controlling the disease but that since today's youths are not willing to go dancing, drumming and shouting, they do not have hope of controlling it. Younger farmers consider the theory a myth that is not related to disease control. Currently, women collect fresh eucalyptus branches from across streams and plant them in affected fields. Others tie black polythene strips or threads on a few affected plants in the fields in order to control disease. However, farmers consider these measures ineffective although some have continued to use them. Some farmers had observed that beans planted on spots where manure was previously piled were not diseased thus believe that organic manure reduces disease severity. They however do not have enough manure to apply in the fields added to the fact that the majority of their plots are located on hilltops and slopes. Thus manuring is practiced on a limited scale on plots near the homestead. Some farmers imagine that spraying would be effective but its use is made difficult by the fact that disease attack and eventual destruction takes place within a short time leaving the farmer no chance to administer control. A few farmers who were growing climbers had been disappointed by bird damage and as such gave up. Farmers in Kabale had never received any technical advice on how to control BRR.

In Kisoro when BRR had just appeared, samples of diseased plants would be picked and tied on top of kitchen fire in the hope of "chasing away" the disease. Sedges collected form the swamp, crushed and stored over a year would be taken to diseased fields and tied to diseased plants. Like in Kabale, farmers would also collect eucalyptus branches (the whitish-leaf type) from sub-counties where BRR incidence was not severe and plant them in diseased fields. No positive results were realized through these measures thus they were no longer used. Currently, farmers manage BRR disease through use of resistant varieties and manipulation of existing seed. The resistant varieties are either bought from the local markets (38%) or got from Congo or Rwanda (22%). Samples of common varieties grown by the farmers were obtained from farmers' homes and evaluated for resistance in the screen house and results were obtained as shown in Table 18.

Table 18: Bean Varieties commonly grown by farmers.

Local name	Description	Preferred characteristics	Problems	Resistance Level	
				Rep 1	Rep 2
Mabenga	Small, pink	High yielding Resistant to BRR		5.7	5.6 MR
Mpuramugabo (Local climber)	Medium cream	High yielding Tasty	Susceptible to BRR	9.0	9.0 S
Mwizarahenda	Medium red	Resistant to BRR High yielding Sweet to taste Hard to cook	Rat damage	7.2	8.8 S
Nyiragikooti	Large Stripped black/white	Cooks fast Sweet to taste Swells on cooking	Susceptible to BRR Bird damage in flower	7.3	8.8 S
Nyiragifuka	Small Pink/yellow	Resistant to BRR High yielding Young pods sweet	Requires very tall stakes	7.8	5.8 MR
Nyakacecuru (Kabale)	Mix (all sizes)	None. The only available	Susceptible to all diseases	7.0	8.8 S
Nyirakanada	Small Orange/ red	Resistant to BRR High yielding Is hardy Green beans tasty Young pods are sweet (the red type)		8.7	5.7 MR
Mwigondoro	Medium Red	Resistant to BRR High yielding Sweet when fresh	Rat damage	7.2	8.8 S

*1-3 Resistant, 4-6 Moderately Resistant (MR), 7-9 Susceptible (S)
*To some farmers Mwizarahenda and Mwigondoro are one and the same variety.

Farmers' evaluation of resistant varieties tallies with experimental results. *Mabenga*, *Nyiragifuka* and *Nyirakanda* are liked for high yield and resistance to BRR, scientific results show that they are moderately resistant. Although screen house results indicate that *Mwizarahenda* is susceptible, farmers know it as resistant and it is the most grown variety in Kisoro. It is likely that different species of *Pythium* may react differently to different bean varieties. Thus ''it is possible that the isolate used in the screen house evaluation is of *Pythium* species different from those that are likely to be prevalent in Kisoro'' (Mukalazi, pers. comm. Nov.2001). Farmers are aware that *Nyiragikooti* is susceptible but like it because its big size enables it to expand when cooked, it is tasty and cooks faster. Other than *Nyakacecuru*, the rest of the varieties were obtained from Kisoro. The Kabale *Nyakacecuru*, a mix of all available varieties, has no characteristics farmers prefer but is the only seed available. In Kisoro, Nyakacecuru is a traditional mixture of small seeded varieties. They are liked for being short term, can be grown in association with almost all crops, are not limited by location and provide early food during scarcity. However, they are susceptible to root rots and *machechu.*

Other than use of resistant varieties, farmers manipulate available seed varieties in an effort to manage BRR disease. Sixty percent of the respondents changed bean varieties by stopping growing of susceptible big sized seed (49%), stopping growing of susceptible medium sized seed (40%), introducing small sized (48%) or medium sized seed (40%) which are resistant to BRR and high yielding. Sixty percent of farmers adjusted their traditional mixture components by either completely removing big seed from the mixture (36%) or reducing the proportions of big seed (14%) increasing small seed proportions within the mixture (16%) or planting only small and medium sized seed (17%).

As results in table 10 indicate, farmers know that small seeded varieties have the most resistance. Their adjustment to small and medium seed and increasing small seed in mixtures is a useful measure to reduce BRR incidence. Other cultural practices are routinely carried out for reasons other than managing root rots. These include manuring (63%) to improve soil fertility (48%) and increase yields (20%), `seasonal' rotation (100%) to meet needs of other crops (51%) and increase yields (35%), fallowing (54%) to improve soil fertility, ridging and mounding (90% in Kisoro) to avoid flooding, sole cropping beans (climbers in Kisoro and season A beans in Kabale) (91%), intercropping (94%) and terracing (71%). Although some of these practices are useful IPM components against BRR and BSM (Nderitu et. al, 1997; Trutmann et al, 1993) farmers do not appreciate them as such.

Generally, farmers have a good knowledge of BRR above-the-ground symptoms particularly yellowing of leaves although a lesser but substantial number observe rotting of roots. Development and appearance of symptoms and the damage caused to the affected crop is well understood. However, farmers associate the disease with BSM, deficiency symptoms, environmental factors and other foliar diseases. The cultural practices used in managing the bean crop are useful IPM components although farmers do not appreciate them as such.

3.1.3 Implication

- There is need to help farmers streamline knowledge of BRR and the importance of appropriate management practices so that they can appreciate the need to manage it and the technologies to use.
- Farmers’ knowledge should be the foundation in developing appropriate technology packages to fill in the identified knowledge gaps.

3.2 Other diseases

3.2.1 Farmers’ perception

Ascochyta blight is considered next to BRR in importance because it is also very destructive particularly in the main rainy season. It is known to affect the bean crop at all stages of growth, causes `burning’ of leaves, rotting of pods and in severe cases may destroy a whole crop. Farmers consider it less damaging than BRR because it commonly affects a few plants or patches in the field and “at least one can eat leaves and rarely does one get total crop loss. In Kabale, it is called *okubabuka* “burning” because affected leaves appear as if cooked or dipped in boiling water. In Kisoro it is called *okubora* “rotting” since the patches will eventually rot. It is known to be a traditional disease that is currently on the increase due to too much rain and poor soils. Its inception is known to begin with small dark patches which expand into lesions that rot and become holed. It causes leaves to rot/burn and fall off resulting into severe defoliation of the crop. The burning is transmitted to stems and pods that develop dark patches and may drop off. Affected pods become filled with smelly water and the young seed inside rots. If only part of the pod is affected, the undiseased part will yield. Although it prevails in wet weather, its severity is known to reduce with reduced rains. If rains persist, however, severity increases and may result into loss of the whole crop. Farmers attribute its cause to too much rain and that it is common in valleys than hills. Too much rain implies constant down pours, rain in the night when there is no sunshine or wind, cloudy days in wet season (*amachu*) and thick mist *(igiho*) that settles for a long time. Farmers consider AB the same as late Blight (LB) of Irish potatoes because whenever beans are intercropped with Irish potatoes, the diseases occur at the same time. To farmers, foliar symptoms are the same and one crop transmits the disease to the other, "once you see one crop developing patches, the other will automatically begin to develop them as well", they explain.

Other diseases that were not considered important by farmers but were present in their fields are Anthracnose, ALS, BCMV Rust and Southern blight. Southern blight was not very common but was significantly prevalent in localized areas in the highlands of Rubaya Sub-county, Kabale district. Farmers linked this to BRR since the 'easily observable' symptoms were mainly yellowing of leaves. Rust was scattered in different fields and attacked very few plants. In fact, farmers, neither considered rust disease nor a big problem.

Foliar symptoms of anthracnose, ALS and BCMV, all rain diseases, were not related to their corresponding pod symptoms. Farmers did not pay attention to foliar symptoms of anthracnose but were aware of the pod symptoms which they linked to AB that either attacked at an early stage or even a varietal difference enhanced by rain splash. Rain splash was linked to spread simply because all pods showing anthracnose symptoms had soil on them. ALS foliar symptoms were considered as signs of crop senescence while some thought of it as initial symptoms of AB. Its pod symptoms were also related to AB or hailstorm damage. BCMV symptoms were interpreted as effect of too much rain but where it occurred with chlorosis, it was considered to be BRR that attacked a mature crop or simply BRR survivors. When pods were observed for any differences farmers concluded that pods affected by anthracnose would never form seed, those affected by ALS were filled with water and those affected by AB would still yield except the diseased patches. A term *Machechu* was used to describe pod damage literally meaning the sound made when the cooked pods are chewed or raw pods are broken (*Okuchechuka). T*hus the pods affected by `rain diseases' were described as "hardened and easily break on touch, do not get ready when cooked and are not tasty when eaten". According to farmers all pod symptoms led to *Machechu* thus there was no clear difference among the different diseases in relation to pod damage.

3.2.2 Management practices

Farmers' management practices of "rain diseases" are basically aimed at preventing and reducing the rain effect other than actual control. They include planting later in the season when rains have reduced, regulation of planting and staking density, timely weeding and defoliation of leaves whenever plants develop thick canopies. These practices help the crop to remain well spaced and open to light and free air circulation such that the humidity around the crop is reduced thereby avoiding "*gufura*" which enhances disease spread. Defoliation is only effective in thick canopies and when rain is moderate but when rain persists, its effect is not significant. Some farmers defoliate a vigorous crop to open it up rather than controlling disease. Some farmers knew that spraying controls disease having observed it work in sprayed Irish potato/bean intercrops but could not access chemicals. Since the other diseases were linked to AB, farmers consider the control measures to be sufficient for all.

3.2.3 Conclusion

Generally, farmers in Southwest Uganda understand plant health and can tell the differences between healthy and diseased plants. Their understanding of disease is influenced by conditions under which the disease prevails and the effect on the diseased plant. Although they may not know that pathogens cause disease, they precisely know which conditions are likely to cause disastrous effects and try to avoid them. Thus their disease management practices are preventative rather than curative. Farmers' description of disease as 'soil or rain disease' is a testimony to their orientation to environmental conditions. Mostly farmers know and can describe observable symptoms on leaves and pods although the symptoms are not correlated to specific diseases. However, there is a general limitation of linking all diseases to those considered important may be because farmers commonly observe those all the time. Diseases that farmers consider less important are neither well known nor controlled although they may be prevalent in their fields and capable of reducing yield. Farmers also care more about pods (the food) than leaves so can easily recognize pod symptoms (ALS, anthracnose) but not foliar symptoms.

Disease linkages and the confused-symptom identity may result in unrealistic ways of control or refusal to take up the control technologies disseminated. As such, farmers need to be helped to understand the diseases prevalent in their area and their dangers such that they can appreciate the need to control them. Farmers should also be facilitated to know the importance of some activities that are routinely done (particularly those that are useful IPM components) so that they appreciate the cost of doing them thereby enhancing adoption.

C H A P T E R F O U R

4.0 Communication Systems

4.1 Local organizations

Farmers in Kabale and Kisoro traditionally work together in groups. Major groups in which farmers have strong ties are credit groups (*Bikoguze*), farming groups (*Obuhingi*), carrier groups (*engozi/engobyi*), funeral related groups *(Twezikye*) and religious groups (*Ihe rya BikiraMaria*). Sixty six percent of the respondents belonged to funeral related groups, 55% to credit related groups, 45% to carrier groups, 20% to farming groups and a minority to religious groups. Funeral related groups are segregated according to gender. The men's group (*ekyembaho*) is charged with the responsibility of contributing money which is used to purchase timber used to make coffins for dead group members or members of their families. The women's group contributes and prepares food during burials. Credit groups mainly pool money, through membership fees and monthly subscriptions, which they either loan out to members and non-members or contribute to individual members at a time. These credit groups are an important source of income to the locals. Carrier groups also perform duties according to gender. Men transport the sick in locally made carriers to health centers while women follow with drinks and attend to the sick. The farmers' carrier groups are the only effective means of transporting the sick from remote hilly places to health centres. Religious groups visit to encourage and pray for the sick, needy and desolate. Only women are members of this group. Farming groups are the ones directly involved in farming. Members of the same group cultivate for individual members and can be hired by non-members at a cost. The group treasurer keeps the money collected and all group members share dividends at the end of the year. The major advantage about farming groups is that work is done faster thus farmers are likely to be in time for crop production activities. During cultivation farmers exchange views about many issues like new technologies, yield trends, crop diseases, possible solutions market prices, etc. the majority of farming groups are women groups while the minority is mixed.
Funeral and carrier groups are village or hill based and obligatory. The Bataka committee, whose responsibility is to set the regulations and discipline defaulters, administers them. The rest of the groups are optional and an individual chooses which groups to join whether within or outside the village. Membership to these groups is subject to paying membership fees (100-500=) and honouring the monthly subscriptions (500-1000=) and membership is maintained by active participation in the group activities. A committee selected by group members administers the group and key committee positions are Chairperson, Secretary, Treasurer and Defense.

Belonging to local organizations by the majority of farmers imply that farmers recognize the usefulness of working together so it may be easier to work with groups in new technology dissemination. Farming groups, therefore, are a potential network for agricultural technology dissemination that should not be overlooked when designing ways of diffusing technologies into the communities.

4.2 Source of agricultural information

Other than local organizations farmers were asked to list their sources of agricultural information. Major sources listed were group members (34%), friends (29%), observation/experience (21%) relatives (16%) and GoU extension workers (16%) in that order. Other minor sources included neighbors, market places, radio, UNFA, Africare and/or Africare farmers, politicians, newspapers and schools. To confirm these sources, farmers were asked to specify sources they had acquired agricultural information from for the last five years. Twenty nine percent had received information from group members, 22% from friends, 17% form extension worker, 15% from relatives and a minority form neighbours and politicians. This further testifies of the importance of groups as an important network for the dissemination of technologies. It can also be observed that mostly farmer-to-farmer networks are more common than farmer-extension worker, farmer-NGO or farmer-Radio. Thus farmer-to-farmer communication networks form a rich source of agricultural information in the area.

The information received from the above sources varied widely covering all agricultural areas e.g resistant bean varieties, high yielding crop varieties, timely planting, banana management, crop rotation, row planting, contour band construction, composting, income generation, weather fluctuations (radio only), etc. A track-down of the acquired information was done to find out how and with whom it was shared. Nineteen percent of respondents had shared with relatives and 13% with neighbours. Others were friends and group members. The information was shared while working/cultivating together (16%), visiting (13%) and during meetings (9%). Minimal sharing was also done at church, at home, while travelling and at school (teachers).

It was observed that farmers share agricultural information mainly with their relatives and neighbours. This could be the reasons why the sharing is done while working together or visiting. Diffusion mapping of BRR control technologies was done in Kisoro with six farmers and technology diffusion was followed to secondary dissemination (Appendix ii B). Results obtained showed that the majority of farmers (55%) shared with relatives while 33% shared with friends. Others were group members, neighbors and members of the local council. Results confirm that sharing of agricultural information is mainly through relatives. Thus the main pathways for agricultural information are relatives, friends, group members and neighbours in that order. Sharing among relatives is not limited by physical distance as farmers can share with relatives from far off sub-counties but not immediate neighbours. Many of the friends shared with are located within short physical distances hence distance seems to influence the extent of sharing among friends.

4.3 Sharing of seed

In appraising the communication channels, another study was conducted to find out how farmers shared seed. The majority of farmers (74%) shared seed as beans (68%), sorghum (56%), maize (40%), sweet potatoes vines (29%) and Irish potatoes (16%). An insignificant minority shared sugarcane and peas. Other things shared include foods stuffs (43%), household consumables (42%) and manure (4%). Bean seed was the most shared through gifts (49%)|, exchange (45%), sale (22%) loan (9%) and as payment for labour (2%). Much of the sharing takes place among females (41%) rather than males (5%) or both male and female (23%). Most sharing is among relatives (78%), neighbours (41%) and friends (21%). Relatives mainly share through gifts (46%), neighbours share through exchange (15%) while friends share through both gifts (15%) and exchange (10%). Sale and gifts among neighbours and exchange among relatives are minimal. Mapping of climbing bean technology diffusion done in Bubare Sub-county in Kabale (appendix (ii A) revealed that of the 16 farmers who shared seed, 44% shared with relatives and inform of gifts. Minimal sharing also took place among friends and buyers where there were no particular relationships. Hence seed, like agricultural information, is shared mostly among relatives in form of gifts, neighbours in form of exchange and friends as both gifts and exchange. Seed exchange and diffusion into communities further takes place through informal means such as visiting a newly married woman, visiting a woman that recently gave birth, marriage ceremonies, when a married daughter is acquiring an independent kitchen, entering a new house and casual visits. Since traditionally women attend most of these functions, they share seed this way more than men.

When farmers were asked the best way to be taught a new technology, the majority (53%) wanted to be taught theoretically by addressing gatherings, 30% wanted demonstrations on farmers' fields and 20% preferred demos on selected places such as church, Parish head quarters, etc where they could easily monitor the progress. Those that wanted learning theoretically could relate to other occasions like political gatherings, etc so thought could learn the same way. On acquiring a new variety through purchase, 43% of the respondents wanted the seed given to LCI Chairperson to sell, 30% wanted it given to LC 3 Chairperson to sell while 13% wanted it given to selected farmers at village level. Farmers were further asked as to how they could acquire a new variety free of change. Fifty six percent wanted it given to LCI Chairman to distribute, 32% to LC 3 Chairperson and 14% wanted existing groups to distribute. Others wanted the supplier to do the distribution at village level and if quantities were not enough they preferred selected farmers to multiply first and then give to others. Farmers seemed to have more confidence in the LCI Chairperson more than LC 3 Chairperson due to bad experiences with seed given by government.

Another technology dissemination pathway identified in the study communities were Local leaders (LCs) that could be used particularly in mobilization of farmers. Churches too play a big role in sensitization and mobilization of local farmers.

Rich communication networks exist in S.W Uganda. Farmers are grouped into various local organisations that have different objectives. These groups cut across different wealth categories (Appendix i) and cause people to work together thus the idea of people working together is already developed in the area. Much of the communication takes place among farmers rather than between farmers and institutions or departments. Farmers communicate whenever they come together either as individuals or groups. Female farmers communicate when travelling (to the market, to visit, etc), during meetings, at places of worship, during funerals, during parties, when attending seminars (few) when doing communal work and in market places. In S.W Uganda most women attend markets to sell produce and buy other foodstuffs. Men have networks similar to women's in addition to leisure at bars, during clan meetings and when doing *bulungi bwansi*. Exchange of ideas is continuous regardless of the place as long as there is a group of people. Sharing of agricultural information and technologies is mainly through relatives, friends, group members and neighbours.

4.4 Factors influencing farmers' communication networks and potential to share technologies

It was hypothesized that factors such as education level, age, gender and wealth status influenced farmers' communication networks and their potential to share technologies or information. Farmers that were more wealthy, older, more educated and women were hypothesized to have more networks than their counterparts. The wealthy and more educated were hypothesized to share less than their counterparts while the older and women farmers were hypothesized to share more than the younger and male farmers. Farmers in Kisoro were hypothesized to share more than farmers in Kabale.

Farmers' sharing potential was described by three variables namely shares seed, number of people shared with last year and amount of seed shared last year. A Chi-square test of association was computed to determine whether a systematic relationship existed between farmers sharing potential and each of the hypothesized factors above. Cramers V statistic was used to measure the strength of the relationship.

For all independent variables (education level, age and wealth status of respondents) there were insignificant relationships with low associations in the case of sharing seed. The number of people shared with and the amount of seed shared last year showed moderate and substantial associations respectively for all the three variables (table 19). H_o was thus not rejected for any of the variables. Gender was not included because from frequency summaries (section 4.7.3) it was established that women shared more than men did (41% and 5% respectively). Also from sections 4.7.2, 4.7.3 and appendix iii A and iii B it was observed that communication networks and technology diffusion pathways were almost the same for all farmers regardless of age, education level, wealth and gender. It was therefore not necessary to test this part of the hypothesis.

Table 19: Relationship between farmers' potential to share technologies and respondents' age, education level and wealth status.

Variable	X^2	Df	Asymp Sig. (2-sided)	Cramers V
Age				
Shares bean seed	3.068	3	0.381	0.202
No of people shared with last year	16.718	15	0.336	0.435
Amount of seed shared	41.786	45	0.609	0.556
Education level				
Shares bean seed	2.392	2	0.302	0.179
No of people shared with last year	8.147	10	0.614	0.375
Amount of seed shared last year	32.083	30	0.364	0.597
Wealth status				
Shares bean seed	4.950	2	0.084	0.257
No of people shared with last year	11.556	10	0.316	0.446
Amount of seed shared last year	23.987	30	0.773	0.516

From the results**,** respondents' age, education level and wealth status were not significantly related ($P>0.05$) to sharing, particularly with respect to number of people shared with and amounts of seed shared. Other factors such as quantities available, relationship with receiver, etc could be determinants of the willingness of farmers to share bean seed and how much to share. A comparison was made between Kisoro and Kabale districts to establish which farmers shared seed most. Results were obtained as shown in Table 20 below:

Table 20: A comparison of Kabale and Kisoro farmers' potential to share technologies.

Variable	X^2	Df	Asymp Sig (2 sided)	Cramers V
Shares bean seed	15.032	1	0.000	0.448
No of people shared with last year	8.600	5	0.126	0.545
Amount of seed shared last year	18.108	15	0.257	0.634

Results show a significant relationship ($P<0.05$) with moderate association only in the case of sharing seed. H_o was thus rejected for this case. The number of people shared with and the amounts they shared show insignificant relationships with substantial associations. Hence, farmers in Kisoro share bean seed more than those in Kabale possibly because they harvest bigger quantities than those in Kabale. However, the number of people they share with and the amounts given are not significantly different from those in Kabale. Possibly this could be due to the fact that essentially small amounts are given out in both places.

4.5 Implication

- Farmer-to-farmer communication networks (relatives, friends, groups and neighbours) present viable and rich technology dissemination pathways. They should be considered as important channels through which technologies can diffuse into the communities.
- Women are a potential asset as adopters of new technologies and a suitable diffusion pathway since they share more than men. Strategies designed to increase adoption must target women.
- There is need to solve the close-relation problem in order to realize unbiased technology flow in the communities.
- Farmers prefer to learn through field demonstration and meetings. These could be adopted as some of the farmers' training methods during technology dissemination.
- Farmers' access to seed technologies, either through purchase or as donations, is best through farmers' groups, LC1 (village administrative unit) and LC3 (Sub-county administrative unit).

LIST OF APPENDICES

Appendix i

Wealth Category List: Muhende village, Kafunjo Parish, Kabale district

Wealth indicators	Very rich (1)	Moderately rich (2)	Poor (3)	Very poor (4)
Amount of land owned	**-10 acres (7-10 plots)**	**-5 acres (12-15 plots)**	**2-3 acres (15-20 plots)**	**<1 acre (3 plots)**
Type of labour used	**-Permanent and casual hire**	**-Family and casual hire**	**-Family labour**	**-Sell labour**
Source of income & other resources	**-15-20 local cattle -20-30 goats/sheep -motor vehicle -commercial buildings in town & villages**	**-2-5 local cattle -10-15 sheep and goats**	**-1-3 local cattle -3-5 goats and sheep -sell labour**	**-No animals -Sell labour**
House construction materials	**-Mud and wattle plastered walls -Cemented floors -Iron sheets**	**-Mud & wattle plastered walls -Cemented floors I-ron sheets**	**-Mud & wattle walls -Earthen floors -Iron sheets or grass**	**-Mud and wattle -Earthen floors -Grass thatch**
Education level (a) Parents (b) Children	**-Secondary to Diploma -Primary to University**	**-Primary – S.4 -Primary – S.6**	**-Primary leavers -U.P.E**	**-Illiterate -U.P.E.**
Food availability	**-Enough food**	**-Not enough**	**-Not enough**	**-Never enough -Sell labour to get food**
Access to health services	**-Attend big hospitals**	**-Attend sub-dispensaries**	**-Attend sub-dispensaries**	**-No access to health services**

Wealth Category List – Nyarutojo village, Kafunjo Parish, Kabale District

Wealth indicators	Very rich (1)	Moderately rich (2)	Poor (3)	Very poor (4)
Amount of land owned	**-5$^+$ acres (8-10 plots)**	**-3-4 acres (12-15 plots)**	**-2 acres (10-15 plots)**	**-1 acre (1-2 plots)**
Type of labour used	**-Casual hire**	**-Casual hire -Family labour**	**-Family labour**	**-Sell labour**
Source of income & other resources	**Agro-produce -5 local cattle -10 goats**	**-Agro-produce 2-4 local cattle**	**-Agro-produce -sell of labour**	**-No income**
House construction materials	**-Mud and wattle plastered walls -Earthen floors**	**-Mud & wattle plastered walls (silt plaster) -Earthen floors**	**-Mud & wattle walls -Earthen floors -Iron sheets or grass**	**-Mud walls -Grass thatch**
Education level (a) Parents (b) Children	**-0' Level -Day primary & secondary schools**	**-'0' level drop outs (S.3)**	**-Primary level -Primary leavers**	**-Illiterate U.P.E.**
Food availability	**-Enough local food stuffs**	**-Food not enough**	**-Sell labour to get food**	**-Exchange labour for food**
Access to health services	**-Attend big hospitals & dispensaries**	**-Attend dispensaries**	**-Attend sub dispensaries**	**-No health services**

Wealth Category List – Kanyando & Kirwa villages, Karambi Parish, Kisoro district

Wealth indicators	Very rich (1) *(Umukire)*	Mod. rich (2) *(Umukire uringanire)*	Poor (3) *(Umuchene)*	Very poor (4) *(Umutindi)*
Amount of land owned	**-10+ acres (4-6 plots)**	**-3-10 acres (5-8 plots)**	**-1-2 acres (2-6 plots)**	**-A plot or no land**
Income and other resources	**-Enough money -May have a vehicle -May have cattle (30), poultry and goats**	**-5 heads of cattle -15 goats & sheep -salary earner (average 80,000)**	**-Works for others (average 30,000-40,000) per month**	**-No specific income -Money enough to pay tax and buy food -No animals**
House construction materials	**Permanent -Brick painted walls -Cemented floors, glass windows**	**Semi-permanent -Iron roofed -Mud & wattle walls -Cemented or earthen floors**	**-Mud & wattle walls -Iron sheets or banana fibre roof**	**-Hut (grass walls) -Mud & wattle walls + grass thatch**
Type of labour used	**-Employs permanent labour**	**-Hires casual labour**	**-Sell labour**	**-Sell labour -Works for food**
Children's education	**-Go to good schools**	**-Majority of children in schools -Few may not**	**-Children belong to U.P.E**	**-May go to school (strictly U.P.E) or may not**

Appendix ii: Technology Diffusion Maps

A. Climbing Bean Technology – Kabale

KEY

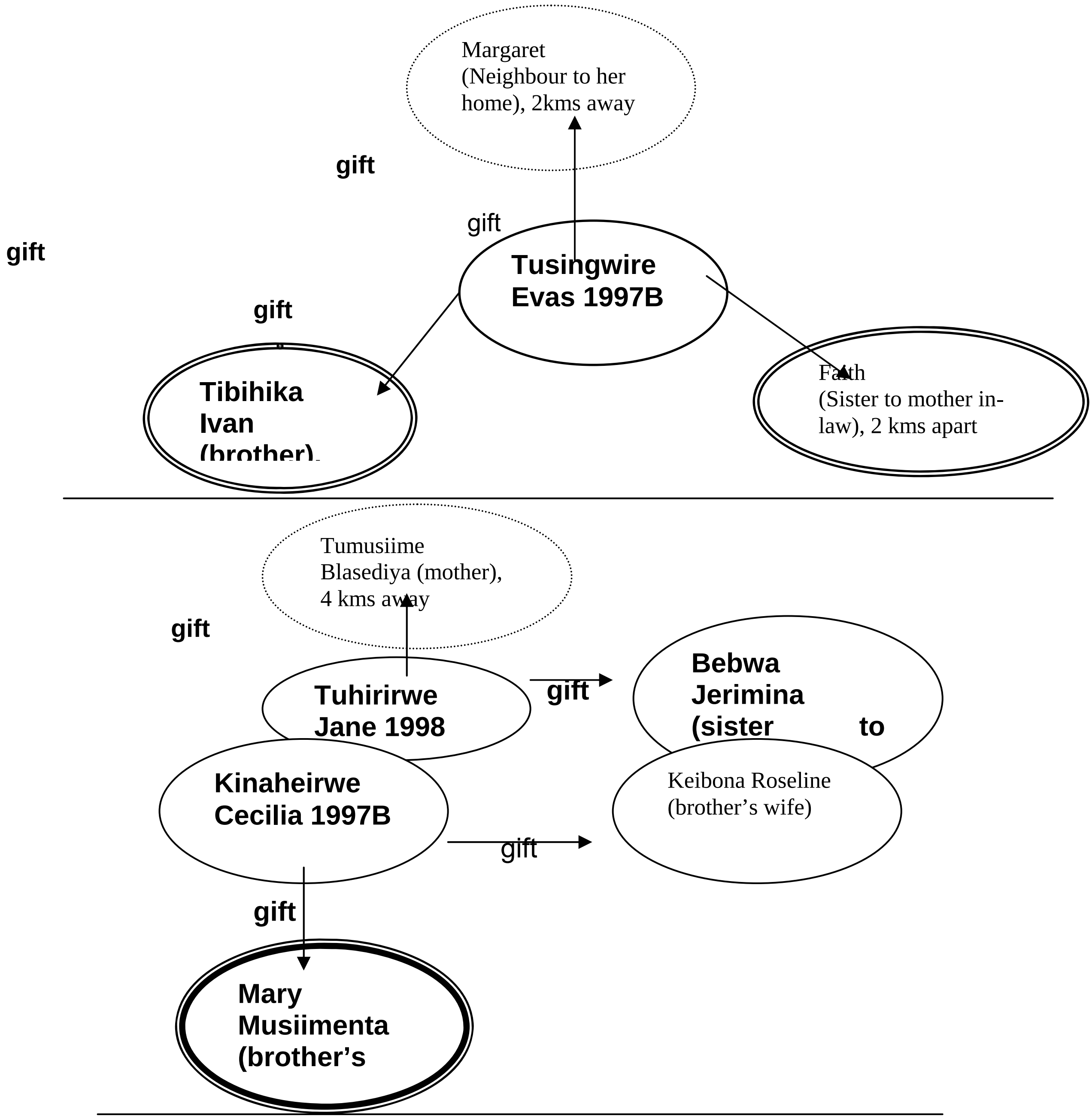
--------- **Different parish**

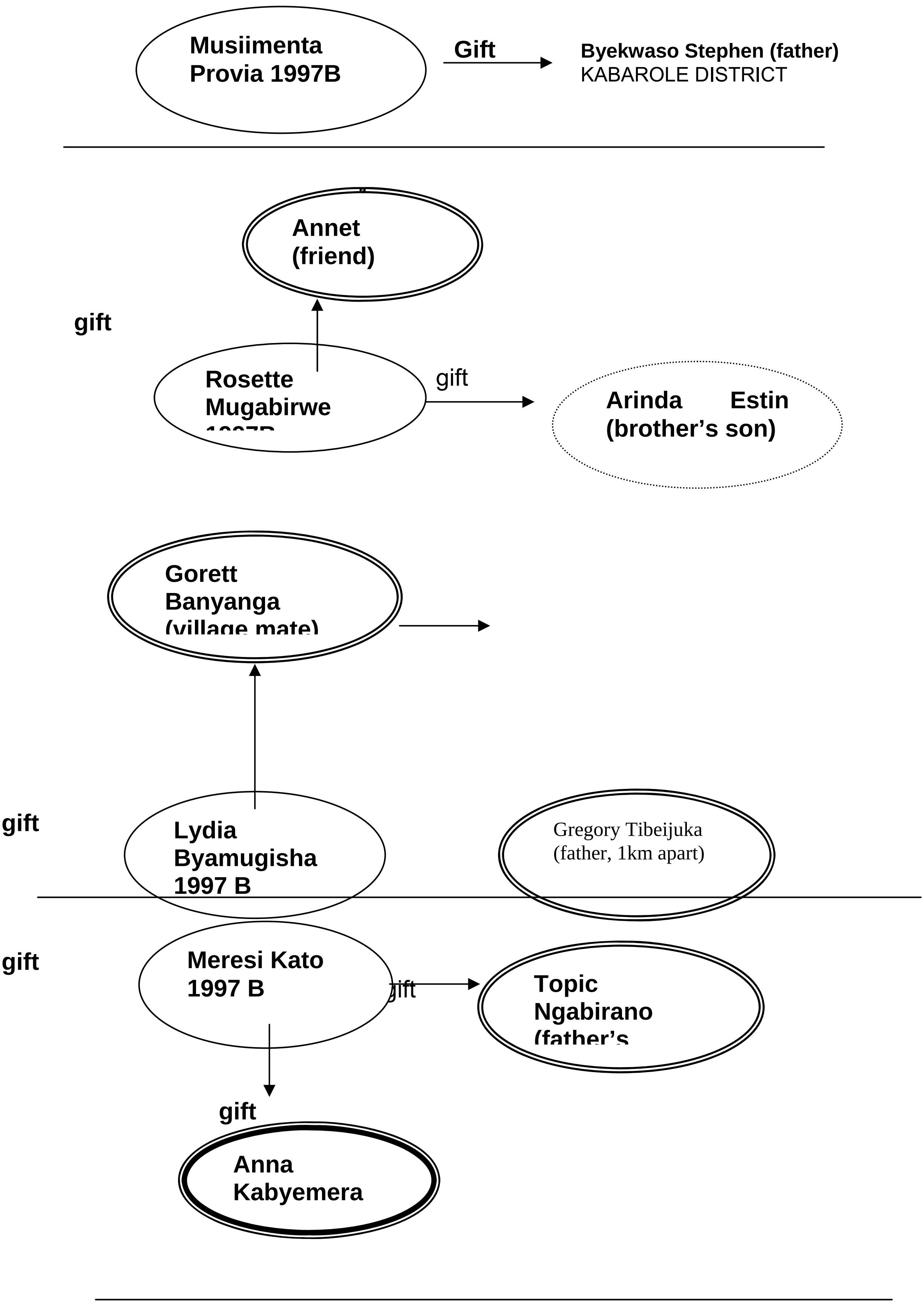
Neighbouring village

Different sub-county

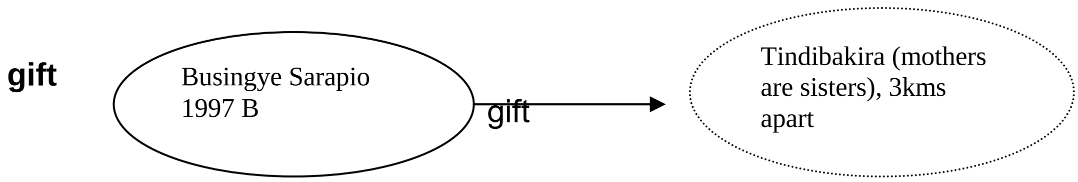
Same village

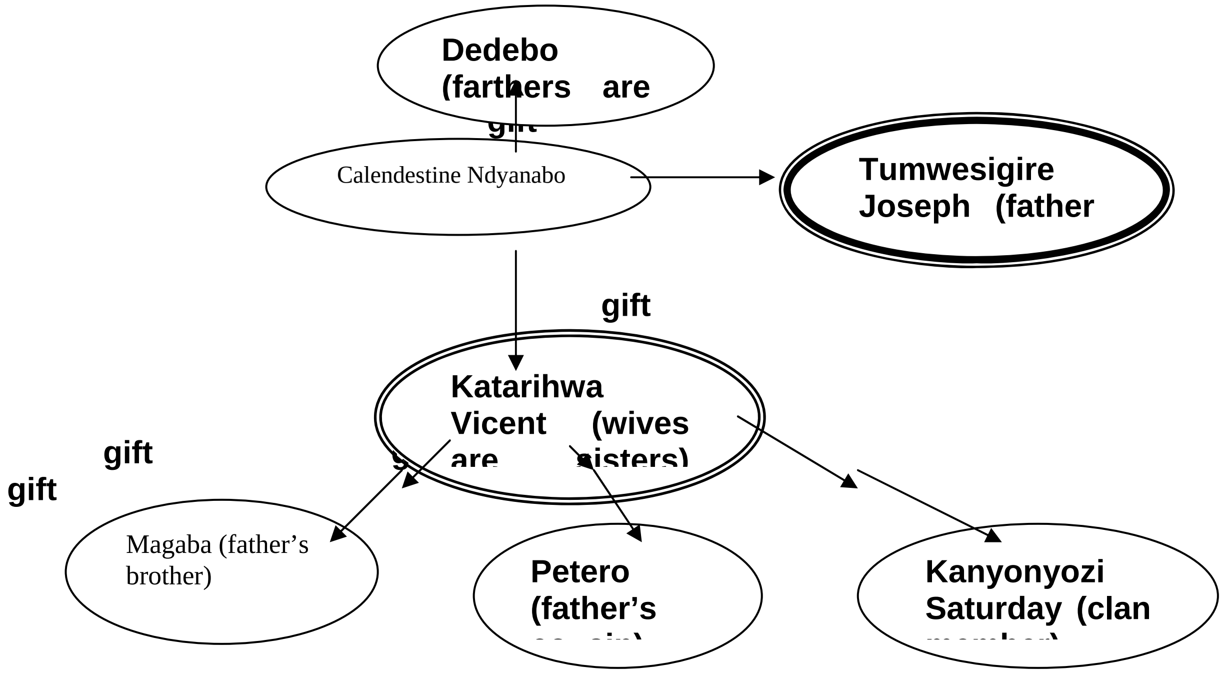
Secondary dissemination

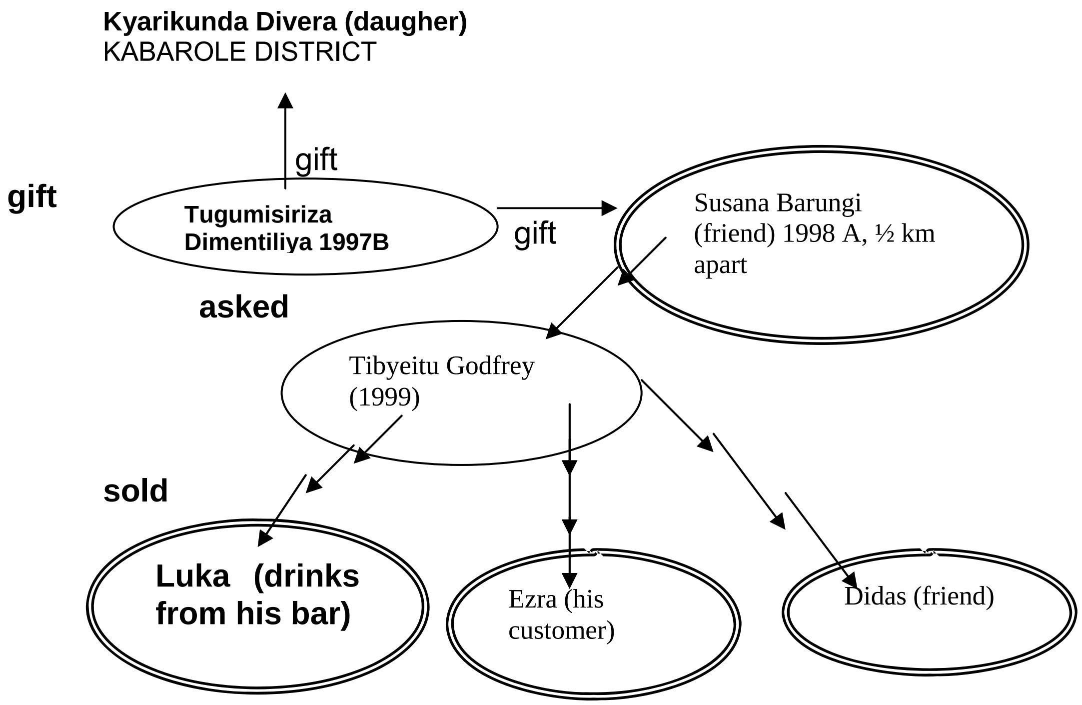




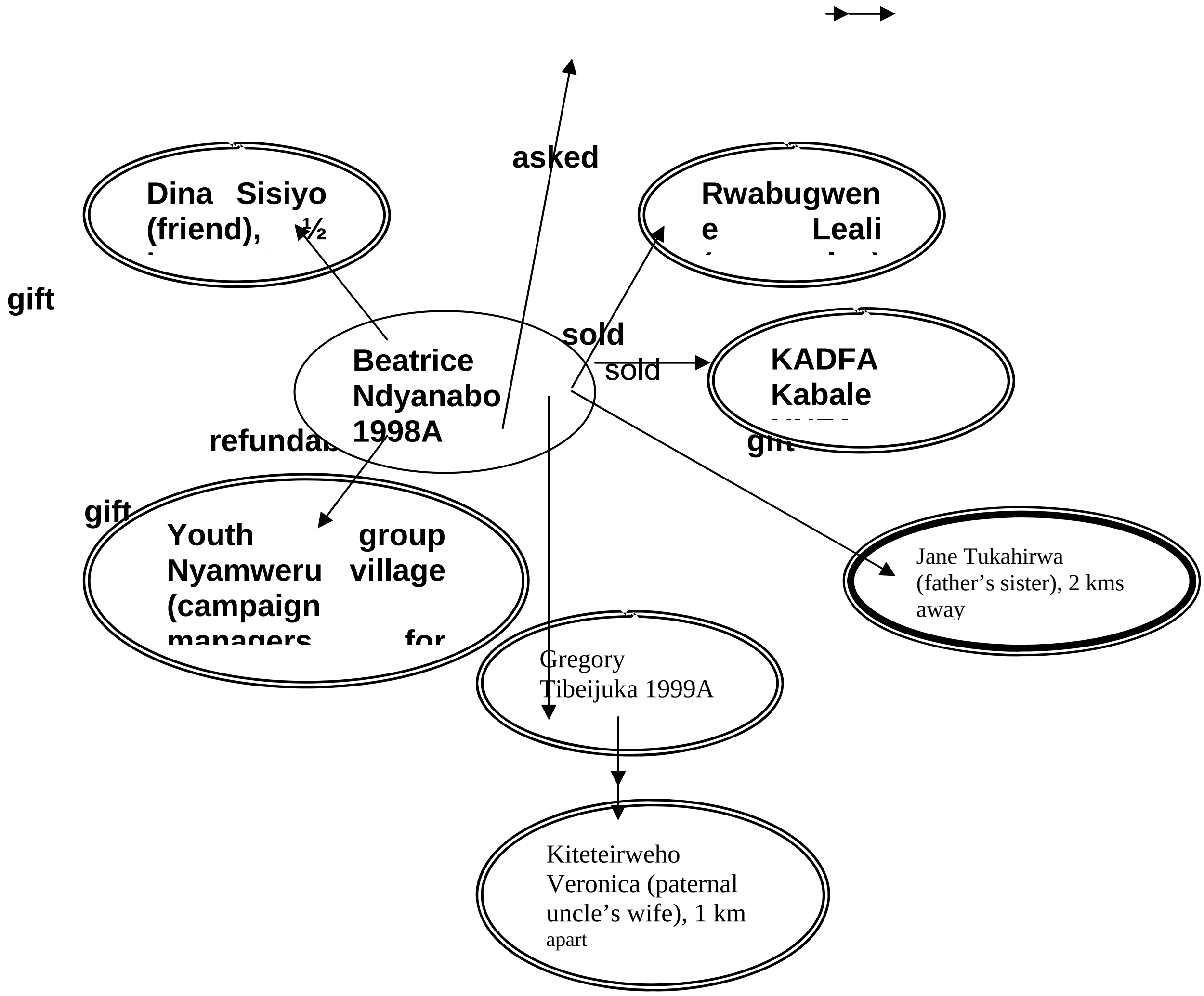
Musiimenta
Provia 1997B
Gift
Byekwaso Stephen (father)
KABAROLE DISTRICT
Annet
(friend)
gift
Rosette
Mugabirwe
gift
Arinda Estin
(brother's son)
Gorett
Banyanga
(village mate)
gift
Lydia
Byamugisha
1997 B
Gregory Tibeijuka
(father, 1km apart)
gift
Meresi Kato
1997 B
Topic
Ngabirano
(father's
gift
Anna
Kabyemera


gift
Busingye Sarapio
1997 B
gift
Tindibakira (mothers are sisters), 3kms apart


Dedebo (farthers are
Calendestine Ndyanabo
Tumwesigire Joseph (father
gift
Katarihwa Vicent (wives are sisters)
gift
gift
Magaba (father's brother)
Petero (father's
Kanyonyozi Saturday (clan

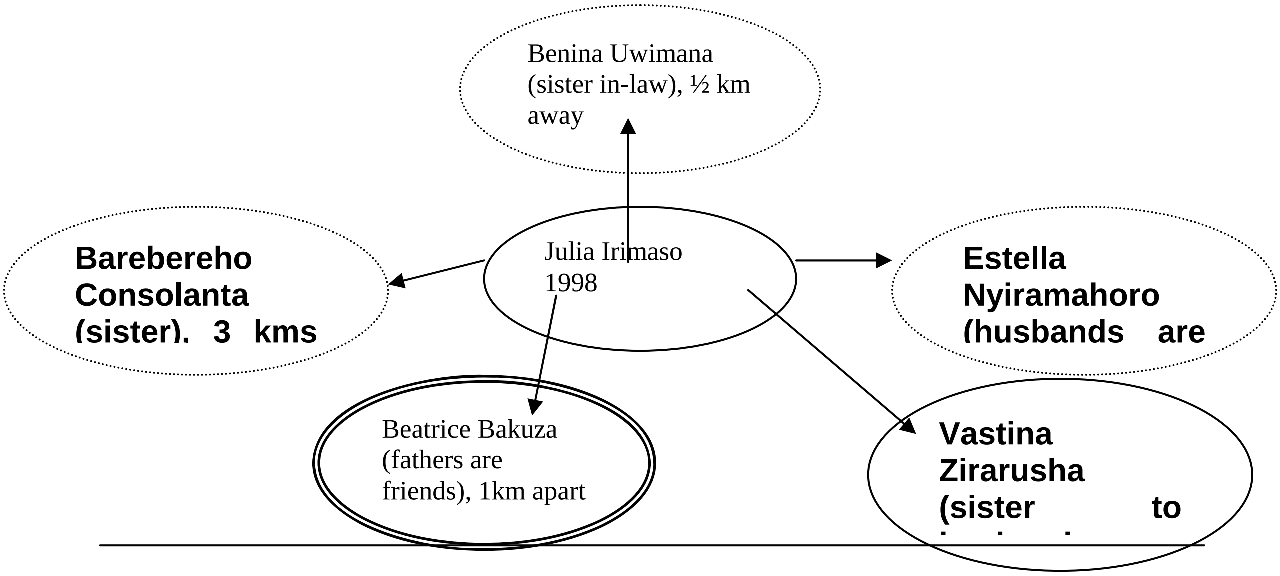

Kyarikunda Divera (daugher)
KABAROLE DISTRICT
gift
gift
Tugumisiriza Dimentiliya 1997B
gift
Susana Barungi (friend) 1998 A, ½ km apart
asked
Tibyeitu Godfrey (1999)
sold
Luka (drinks from his bar)
Ezra (his customer)
Didas (friend)

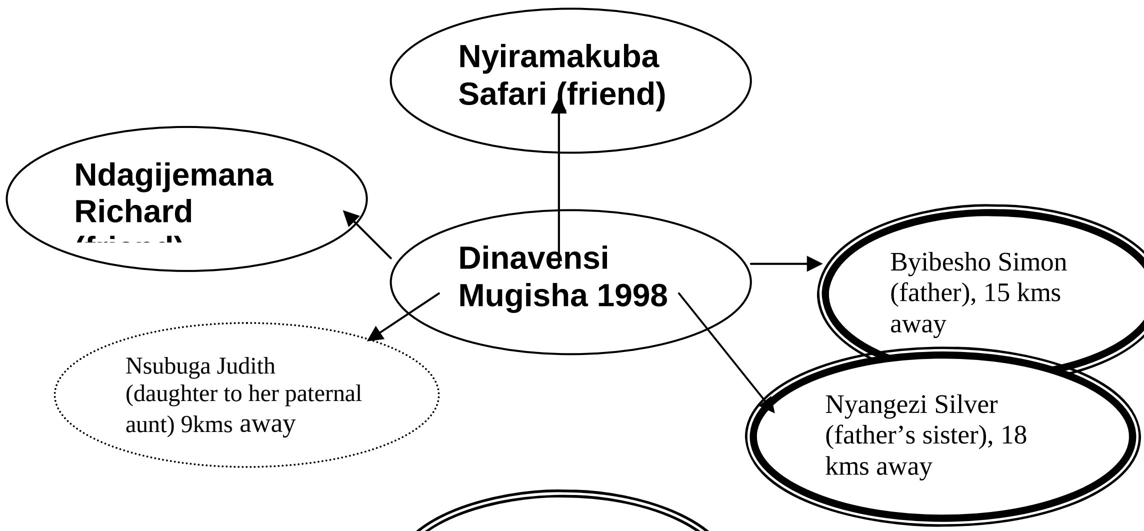

Karegyesa Patrick (brother), 2kms apart
Bagashasha Federesi 1998B
Rwangoya Eric (brother),

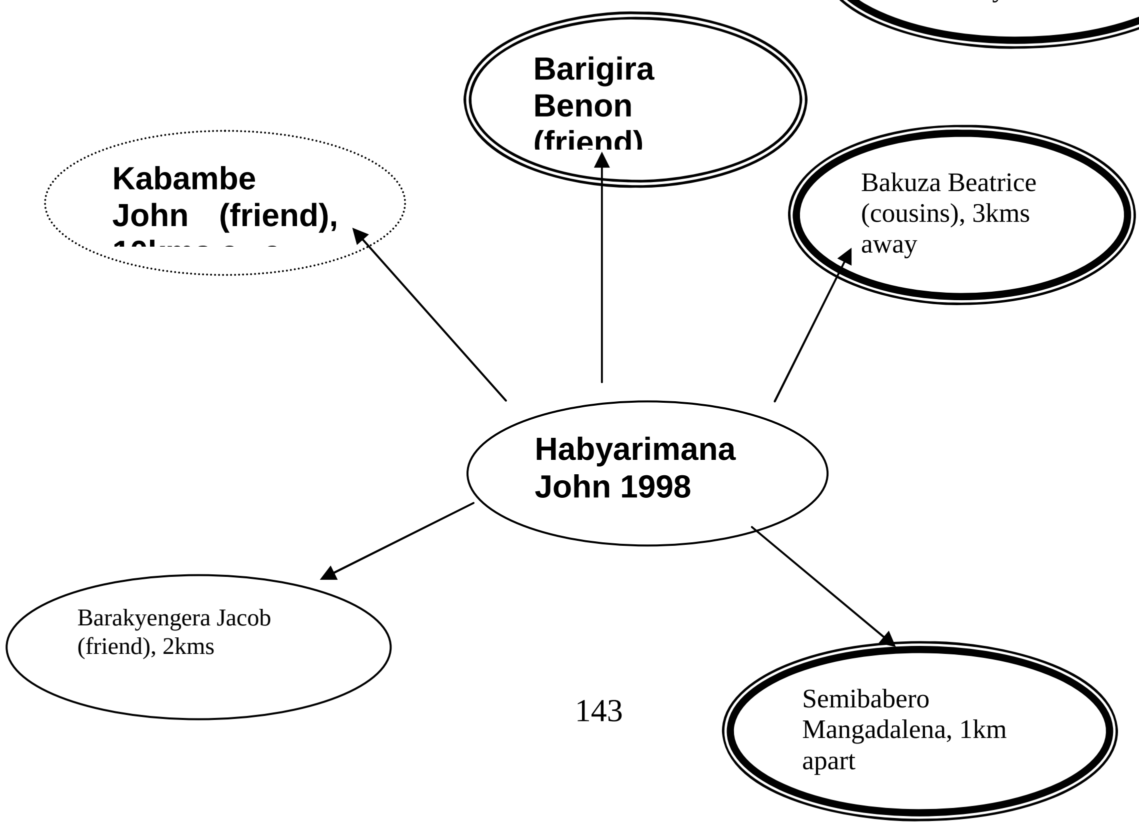


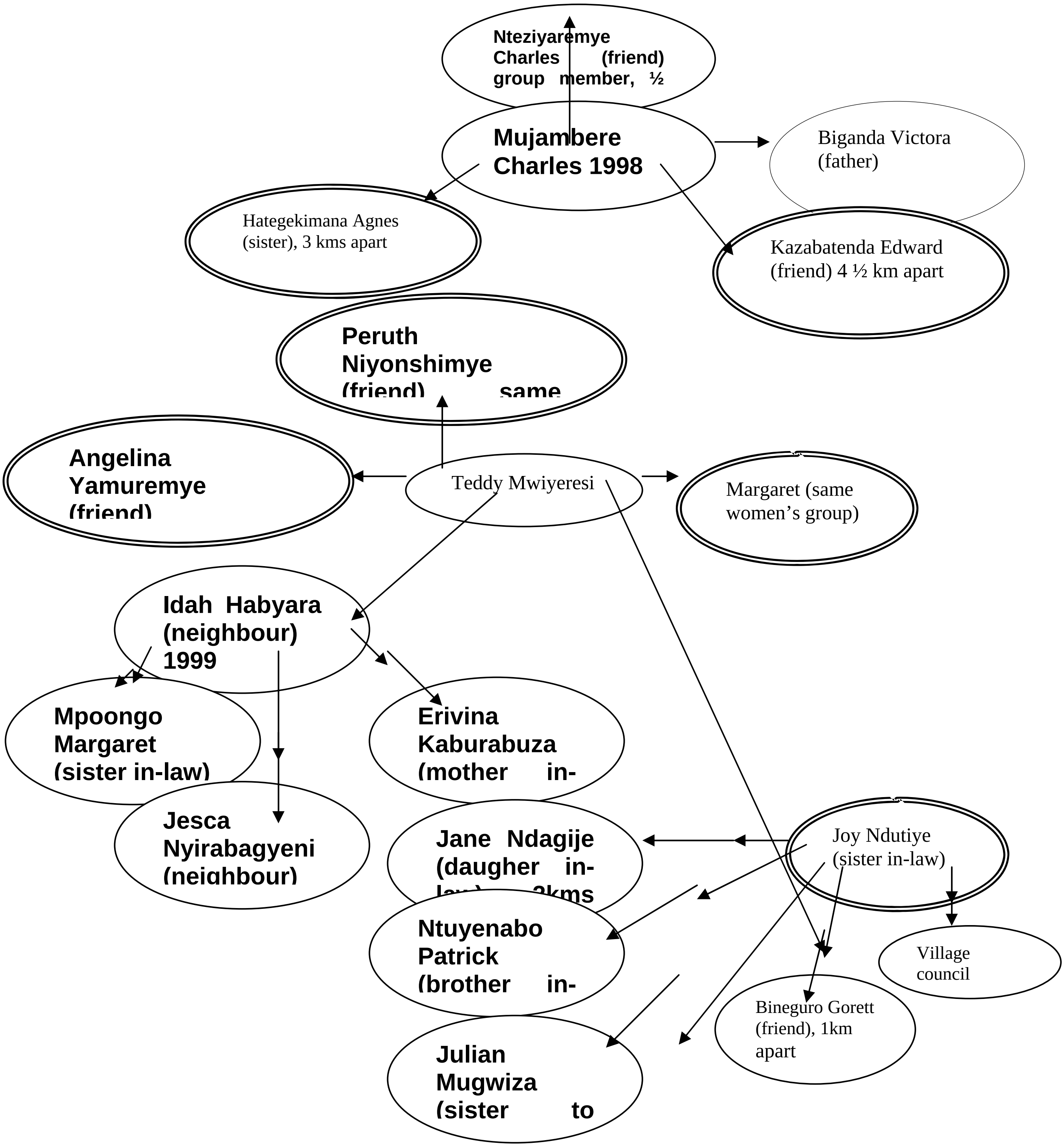
asked
Dina Sisiyo (friend), ½
Rwabugwene Leali
gift
sold
Beatrice Ndyanabo 1998A
sold
KADFA Kabale
refundab
gift
gift
Youth group Nyamweru village (campaign managers for
Jane Tukahirwa (father's sister), 2 kms away
Gregory Tibeijuka 1999A
Kiteteirweho Veronica (paternal uncle's wife), 1 km apart

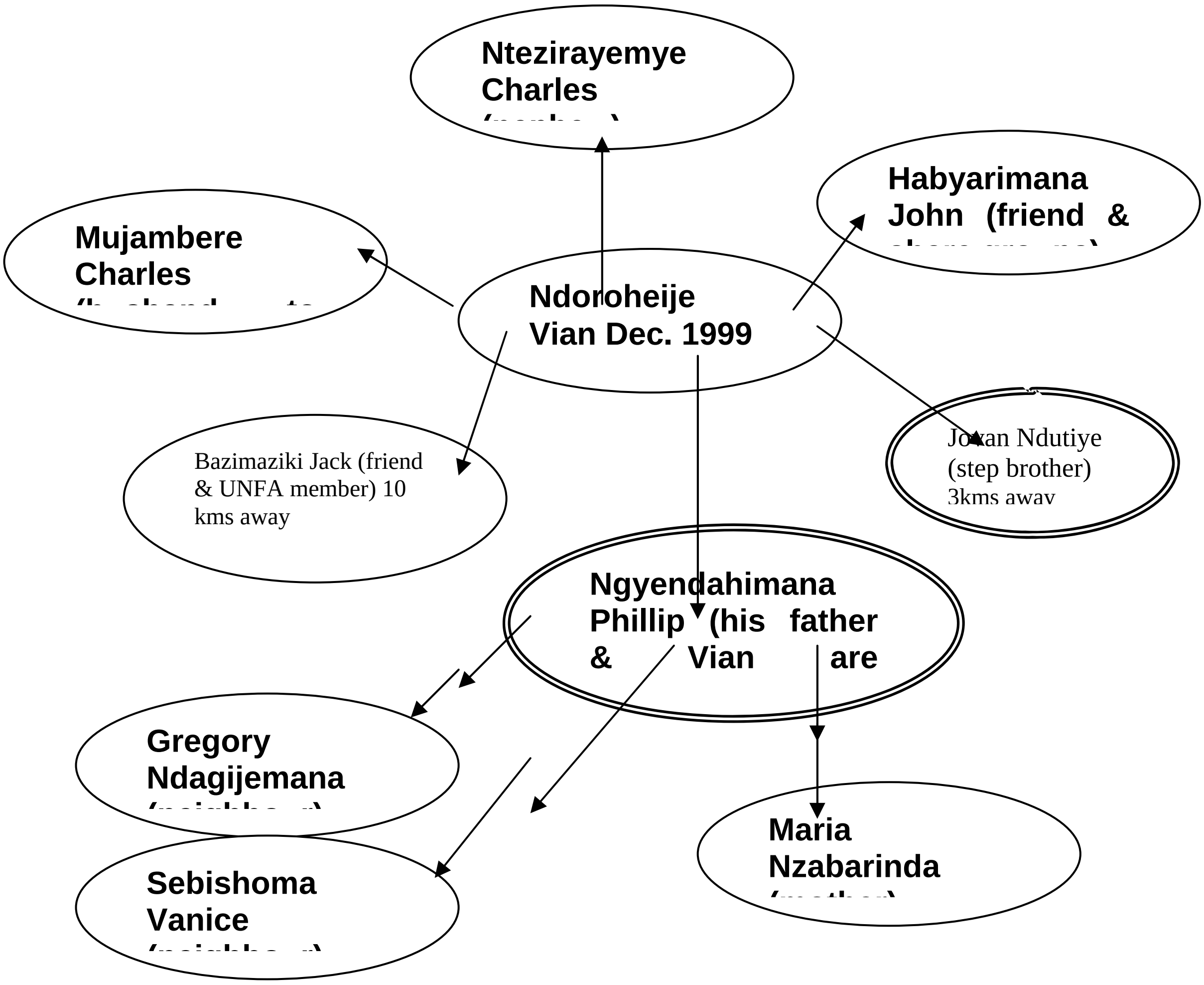
Appendix ii: B –Bean Root Rot Control technology – Kisoro








Nteziyaremye Charles (friend) group member, ½
Mujambere Charles 1998
Biganda Victora (father)
Hategekimana Agnes (sister), 3 kms apart
Kazabatenda Edward (friend) 4 ½ km apart
Peruth Niyonshimye (friend) same
Angelina Yamuremye (friend)
Teddy Mwiyeresi
Margaret (same women's group)
Idah Habyara (neighbour) 1999
Mpoongo Margaret (sister in-law)
Erivina Kaburabuza (mother in-
Jesca Nyirabagyeni (neighbour)
Jane Ndagije (daugher in-
Joy Ndutiye (sister in-law)
Ntuyenabo Patrick (brother in-
Village council
Bineguro Gorett (friend), 1km apart
Julian Mugwiza (sister to


Ntezirayemye Charles
Habyarimana John (friend &
Mujambere Charles
Ndoroheije Vian Dec. 1999
Bazimaziki Jack (friend & UNFA member) 10 kms away
Jovan Ndutiye (step brother) 3kms away
Ngyendahimana Phillip (his father & Vian are
Gregory Ndagijemana
Maria Nzabarinda
Sebishoma Vanice