CROP PROTECTION PROGRAMME

Non-chemical control of banana nematodes in East Africa

Project R6580 (ZA 0038)

FINAL TECHNICAL REPORT

Start date – End date
1 April 1996 - 15 February 2001

Dr N. R. Maslen

Natural Resources Institute

FINAL TECHNICAL REPORT

'Non-chemical control of banana nematodes in East Africa'

Lead Institution

Natural Resources Institute, University of Greenwich

Dr N R Maslen	IPM Specialist and Project Leader
Mr R I Lamboll	Social Scientist

Collaborating Institutions and Scientists

University of Reading

Dr S R Gowen

Uganda - Kawanda Agricultural Research Institute, Kampala

Dr E. Karamura	Head, National Banana Programme, KARI (1996/97)
Dr W. K. Tushemereirwe	Acting Head, National Banana Programme, KARI (from 1997)
Dr I. N. Kashaija	Nematologist
Dr J. M. Namaganda	Nematologist
Mr F. Bagamba	Socio-economist
S. Mayanja	Technician (Year 1 only)
Ms Gertrude Nabulya	Technician
Margaret Nassiwa	Technician
Agnes Tumushabe	Technician

Uganda - IITA, ESARC, Namulonge (*ad hoc* collaborators)

Dr P Speijer	Nematologist/Agriculturalist
Mr H Talwana	MSc Student and Technical Assistant (Root crops)
Mr J Mudiope	MSc Student and Technical Assistant (Root crops)

Acronyms and abbreviations

Acronym or Abbreviation	**Translation**
BS	Benchmark Site
CBO	Community-Based Organisations
CPP	Crop Protection Programme (DFID, RNRRS)
DFID	Department for International Development
GO	Government Organisation
IPM	Integrated Pest Management
IPPM	Integrated Productivity and Pest Management
NARO	National Agricultural Research Organisation
KARI	Kawanda Agricultural Research Institute
NGO	Non-Government Organisation
TOT's	Trainers of trainers
NRI	Natural Resources Institute
RPF	Resource-Poor Farmers
SCIDA	Saayi Common Interest Development Agency
USEP	Uganda Association for Social Economic Progress
UNFA	Uganda National Farmers' Association
IEDP	Integrated Environmental Defence Project
KRUDEP	Kyampisi Rural Development Project

CONTENTS **PAGE**

Executive Summary

The project **successfully developed and tested a non-chemical banana nematode control strategy** and **trained a range of local stakeholders** in the non-chemical banana control technologies. This was despite (i) being affected by poorly distributed seasonal rainfall, giving exceptionally dry conditions at key crop stages and (ii) by local institutional re-structuring with unplanned and unavoidable staff deployments towards the end of the project.

The main technical achievements (see **Section 4.5**) were:

- A **strategy for non-chemical control** of the main **banana nematodes developed**;
- Bioassays from 30 Kayunga field trial sites showed that 97% of **soil** samples were **clear of banana nematodes after 18 months** and that this gave as good results as longer intervals (23 and 27 months) in these trials;
- Methods for the production, weaning and hardening of pest and nematode-free **tissue-cultured banana plants** were developed;
- **Culture techniques** for mass-production of **banana nematodes** were successfully developed and used in **host status** (screen-house) experiments;
- Application of these techniques revealed that **weeds** are poor or non-hosts of banana nematodes but some **crops** are good hosts and **inter-cropping** groundnuts, beans or maize with bananas **should be avoided**. Root and tuber break crops were poor or non-hosts.
- Break crops may **deplete** important **soil nutrient** of banana. **Cassava**, significantly reduced soil **potassium levels**, while sweet potato did not.

The **sustainability of the strategy**, or length of time before it is necessary to implement another break-crop cycle, could not be determined within the project period. At least four post break-crop years will probably be needed.

Training: About 700 stakeholders were trained or exposed to aspects of the non-chemical technology, including project and non-participating farmers, NGO, CBO and extension service personnel, trainers and NARS staff.

Dissemination outputs: At least 18 publications, including six peer-reviewed publications, 10 internal reports and two further draft papers were produced.

Uptake and promotion pathways: The project identified over 20 target stakeholder organisations, including at least 16 NGO's and CBO's, 3 womens' groups and 7 trainers of trainers (ToT). The emerging success of the project in developing the non-chemical control strategy, encouraged interest in uptake and further development and promotion by the Benchmark Site Programme (see below).This will include integration with other banana pest and crop management methods, a strategy which should ensure broader farmer-interest and uptake.

The findings showed that the technology contributes to improvement in the livelihoods of resource-poor farmers by permitting them the option to grow bananas, their favoured staple, rather than having to tolerate negligible yields, abandoning bananas or cultivating elsewhere in banana nematode-free soil.

Further adaptive evaluation of the control strategy is now recommended. The National Banana Research Programme and partners have initiated a Benchmark Site (outreach) Programme (BSP) and one of the sites is in neighbouring Luwero, which has areas of serious banana yield decline. The most appropriate uptake pathway will be through the BSP and it is understood that this is being planned. Socio-economic findings indicate that promotion of the technology as a

stand-alone strategy is less attractive than being presented as a suite of banana management methods. Such an Integrated Productivity and Pest Management approach will make its use more attractive because it deals with the complex of banana pests and diseases and thereby can minimise demand on farmers' time and the required depth of understanding. The findings, experiences and access to trained farmers and other stakeholders of the current project are available to stakeholders in any new uptake initiative.

To better understand its viability and potential effects on improving yields, the nematode break crop technology should be evaluated for at least 5 (farmers requested 10-15) years in order to determine the maximum nematode-free interval possible before a new break-crop cycle becomes necessary.

1. Background

There is a long tradition of growing bananas in Uganda, which is currently the world's largest producer (c. 9.0m tons per annum in 1996), accounting for approximately 15% of total global yield. However, productivity has been declining for over forty years and yields in the previously more productive Central region are now about one third (6 tons/ha) of that in the Western region (17 tons/ha). This is believed to be due to changes in cultivation practices, socio-economic factors and particularly to the arrival of alien pests and diseases such as the burrowing nematode, *Radopholus similis* and black sigatoka, *Mycosphaerella fijiensis* (Swennen and De Langhe, 1989).

The importance of the nematodes was shown in a study of the relative importance of crop pests in sub-Saharan Africa by Geddes, 1990, in which they ranked highest of all pests and diseases. Nematodes cause root destruction, which decreases a banana plant's stability, particularly when bearing fruit. In consequence, plants readily topple over and the fruit is lost. In such situations, crop losses can exceed 50% in one production cycle. Cooking bananas and plantains are particularly vulnerable (Gowen and Queneherve, 1990). Unfortunately, many farmers cannot distinguish between damage caused by the microscopic nematodes and the much more visible banana weevils (*Cosmopolites sordidus)*. In consequence, much damage caused by nematodes is erroneously attributed to weevils (Gold *et al.*., 1993).

R. similis is not native to Africa and has been introduced on banana plants imported from elsewhere, probably more than 100 years ago. When deprived of its hosts, *R. similis* will survive in soil for about one year, but this will depend on the effectiveness in removing <u>all</u> host plants and on the absence of other hosts, usually weeds, that may support low populations of *R. similis*. *Pratylenchus goodeyi* is known only as a pest of banana in East and Central Africa, Cameroon and Canary Islands. In Uganda, it is more important than *R. similis* at the cooler (higher) elevations (Kashaija *et al.*, 1994). Because its host range is narrow, management by conventional non-chemical methods is feasible.

The concept of planting disease-free bananas in land free of the principal nematode pest (*R. similis*) is not new, as it was first suggested about 35 years ago (see in Gowen & Queneherve, 1990). The objectives are adaptive rather than strategic and basically involve uprooting of all infected banana material from a plot, cultivation of a non-host break-crop for a period which will clear the nematodes, followed by re-cultivation with pest-free banana planting material. The technology for achieving this has become feasible with the increased availability of mass-produced disease-free plants (micro-propagation). The uncertainty of acquiring 100% clean planting-material was hitherto seen as the only serious obstacle preventing the removal of banana nematodes from farmers' fields. In previous work (CRBP Annual Report, 1994), the use of tissue-cultured Cavendish banana plants in re-plantings in Cameroon reduced the need to apply nematicides for the first 2 years of the crop, after which *R. similis* eventually returned, possibly from nearby banana plantations. Preceded by a non-host break-crop, it is likely that such soil might have remained free of these nematodes for much longer.

In Uganda, significant numbers of farmers have replaced bananas with root and tuber crops such as cassava and sweet potato because of the banana decline. These are non-hosts to common banana nematodes. Other than the need to acquire pest-free planting material, the growing of a break-crop for a subsequent return to higher banana yields would not therefore involve a major deviation from these practices. To avoid the risk of trace-populations of nematodes lingering for more than one year, break-crop periods of 18-24 months would probably be necessary.

The important achievements of earlier work relevant to bananas under this project are as follows:

- Nematode surveys showed that *R.. similis* and *P. goodeyi* were the most important (i.e., damaging) species on bananas in Uganda (Kashaija *et al.*, 1994).
- These nematodes will not reproduce on cassava and sweet potato (Namaganda, 1996).
- Preliminary surveys of weed hosts indicate that very few species can support these nematodes but only at low densities (less than 0.5% by number) compared with banana (Namaganda, PhD thesis, 1996).
- Root knot nematodes (*Meloidogyne* spp) are found on cassava throughout Uganda (Coyne and Namaganda, 1994) and care should be taken to grow resistant or tolerant varieties.
- A number of resistant/tolerant varieties of cassava were identified, which could be used in the banana/root crop cultivation systems (Talwana e*t al.*, 1995).

This project builds on these findings but also takes advantage of new developments in producing reliable and low-cost disease-free planting material.

Most farmers still prefer bananas as their main staple food. However, besides the decline towards smaller banana plot sizes and short plantation life, many fear that bananas can no longer be reliably grown as permanent plantations. As a consequence, they abandon banana-growing when signs of declining productivity are observed, as mentioned above. As many farmers believe that chemical fertilisers and pesticides spoil the land, leading to productivity decline, there is a demand for a "natural" method of rehabilitating and sustaining banana production. This is also the view of the GoU and the Uganda National Banana Research Programme. This project was commissioned to address this demand by on-station and farmer-participatory (on-farm) evaluation of this technology in different areas of Uganda.

2. Project Purpose

The project purpose was aimed at improved methods for the management of major root nematode pests of bananas and plantains being developed and promoted.

More specifically, the purpose was to develop and demonstrate a non-chemical method for control of the soil and root nematodes causing yield decline in bananas, which is suitable for use by subsistence and emergent commercial farmers.

3. RESEARCH ACTIVITIES

3.1. Presentation of Activities and Outputs in this report

3.1.1 *Output categories*

This project ran for three years from 1 April 1996 - 31 March 1999, followed by a one-year extension from 1 April 1999 - 31 March 2000. This was one of the early CPP projects and the Outputs to be developed from the Research Activities were framed more broadly than was subsequently required by CPP. There were two output categories given in the 1996-99 log-frame Section 14, which are Outputs 1 and 2, below. Two more outputs were specified in Section 18a of the 1996-99 PMF and Section 4 of the 1999-00 Project Extension form. These are effectively more specific sub-categories of Output 1, i.e., Outputs 1(a) and 1(b).

Outputs

1. Strategy developed
(i) A strategy for the enhancement of banana production through control of nematode pests developed and demonstrated
(ii) Sustainable banana production based on cultural practices without nematicides

2. Local people trained

3.1.2 *Classification of Research Activities*

The numbering sequence of the specific logframe Research Activities in the 1996-99 Project Memorandum Form was not continued through to the 1999-00 Project Extension Form, although core activities were continued to the end of the project, with some new ones were added. For clarity, the activities for the main project (1996-99) and the one year extension (1999-00) are summarised below in Section 3.1.3, and are described in detail in **Section 3.2.** Some additional funding was also made available by CPP for short inputs in 1996/97 and in 1998/.99.

As there are only two broad Output categories (**Section 3.1.1**), the Activities giving rise to these Outputs will be described under four sub-categories in this report, as follows:

1. ***Stakeholder identification and induction, and development of essential project knowledge, techniques and capabilities***.
2. ***On-Farm and On-station technical activities***
3. ***Training and dissemination activities***
4. ***Project assessments and validations***

Categories (i) and (ii) relate to Output 1 (**Section 3.1.1**), category (iii) describes Output 2 and category (iv) relates to both Outputs 1 and 2.

3.1.3 *List of research activities*

3.1.3.1 Stakeholder identification and induction and development of essential project knowledge, techniques and capabilities.

1996-99

Activity 1: Socio-Economic studies undertaken on the willingness of farmers to use tissue-cultured banana plants following a break crop
Activity 2: Techniques for mass-culture of key nematodes established.
Activity 3: Evaluation of methods for transfer of tissue-cultured plants from laboratory to field

3.1.3.2 On-Farm and On-station technical activities

1996-99

Activity 4. Field trials to establish optimum duration for break-crop to control nematode populations.

Activity 5. Examination of host status of common **weeds** for key nematodes.
An extra activity was added to obtain a more balanced understanding: Examination of the host status of common banana system **crops**.

1999-2000 Extension

Activity 1. Quarterly assessment of soil fertility levels with break crops and clean banana sequence

Activity 3. Clean banana plant vigour and quality up to flowering monitored with farmers

3.1.3.3 Training and dissemination activities

1996-99

Activity 7. Train local staff in nematode identification and evaluation of soil populations and root damage

1996-97 Additional funding

Activity 1. Assessment of nematode species profile on 10 yam varieties and extent of damage; dissemination.

Activity 2. Identification of suitable cassava cultivars for use as break crops; dissemination

1999-00 Extension

Activity *6.* Same as Activity (Increased dissemination of control strategy to NARS, extension service and farmers through open days, seminars, workshop, etc).

Activity *7.* At least 100 participating farmers trained in technologies tested and promoted by the project

Activity *8.* At least two technical papers and one socio-economic publication in final draft or submitted

3.1.3.4 Project assessments and validations

1998/99 Additional funding

Activity 3. Additional socio-economic inputs

1999-00 Extension

Activity *4.* Continual socio-economic and technical evaluation to improve farmer dissemination and maximise uptake pathways

Activity *9.* Final socio-economic assessment and validation of banana break crop and complementary technologies by project end

3.2 Description of Research Activities

3.2.1 *Stakeholder identification and induction and development of essential project knowledge, techniques and capabilities*.

Activity 1 (1996-99): Socio-Economic studies undertaken on the willingness of farmers to use tissue-cultured banana plants following a break crop

<u>Introduction</u>

Replanting bananas at regular intervals has not been a common practice in Uganda. In a study on factors affecting uptake and adoption of banana crop protection research in Uganda, it was noted by Lamboll *et al*., 2000 that "The longevity of banana plantations has fallen from about 50 years to only 5-10 in some areas." According to a recent Benchmark Site baseline survey report on Luwero (NBRP, 2000), from interviews with farmers in central areas, yield decline has reduced the life-span for bananas planted in pure stand from 6 to as little as 2 years. As a consequence, significant numbers of farmers have replaced bananas with cassava, sweet potato and other crops. However, for most farmers bananas are still the premier staple and the growing of a break-crop for a subsequent return to higher banana yields would be particularly appropriate and attractive.

The break-crop technology requires removal of the existing infested banana plants and replanting the field with pest free banana planting material after freeing the soil of the root-infecting banana nematodes. Fields are then not planted to bananas for 18 – 24 months. Farmers first needed to be primed on the method of uprooting infested bananas, growing a break crop and then replanting. Their willingness to use this technology, and particularly the use of tissue cultured plants (clean planting material) also needed to be determined.

Based on information from a diagnostic survey carried out earlier by the Uganda National Banana Research Programme (UNBRP), and in accordance with changes in the Banana Programme's priority in establishment of its benchmark sites, two on-farm trial areas, Kayunga in Mukono district (central Uganda) and Kyanamukaka in Masaka district (south western Uganda) were selected as appropriate areas for farmer-participatory activities, in addition to on-station activities at Kawanda Agricultural Research Institute (**Fig. 3.2.1.1**). Nematode occurrence and abundance is different at these two sites. *Radopholus similis* and *Helicotylenchus multicinctus* are more common in Mukono District, while *Pratylenchus goodeyi* is more abundant in Masaka District. These are the three most important banana nematode species in East Africa.

<u>Farmer induction and information gathering activities</u>

On-farm and baseline surveys (**Appendix 1 and 2**) were conducted concurrently as part of this process and the findings are presented and discussed under Outputs in **Section 4**. To encourage farmer support and acquire farm and household information for selection and establishment of trials cum demonstrations, several meetings were conducted between the Banana Programme team and farmers, District Agricultural officers and Local administrators in both areas. The meetings were aimed at:

- introducing the project and its objectives to principal stakeholders
- understanding farmers' attitudes to the technology, and their willingness to participate in the project
- collecting additional information to be used in developing better farmer selection criteria

FIG. 3.2.1.1 Map of Uganda showing the three project activity areas

Field surveys were conducted to determine the most appropriate crop(s) to be used as break-crops and how the technology would fit the cropping system. Using the baseline questionnaire data (farm history, cropping systems, pest and disease status, preferred banana cultivars, etc.) was collected on these farms and initial/pre-planting nematode populations were assessed in the fields of farmers with a positive interest. Baseline information on farmers' 'current' knowledge and practices of pest and banana management was also collected. In addition to a general baseline survey of farms and households in these areas, the interest and willingness of farmers to evaluate the break crop technology and to use tissue cultured banana plants would also be determined.

Activity 2 (1996-99): Techniques for mass-culture of key nematodes established.

<u>Introduction</u>

In order to obtain sufficient nematode inoculum for screen-house pot experiments, it was first necessary to identify host-plants, or host-plant cultivars which would encourage and sustain large soil and root populations of the principal banana nematodes, *Radopholus similis*, *Helicotylinchus multicinctus* or *Pratylenchus goodeyi.*

Mass culture of banana nematodes for alternative host plant experiments

Seedlings were transplanted into 2l plastic buckets filled with sterile soil. The number of seeds or seedlings planted in each bucket was varied according to the size of plant and its root system. Foe example, up to 50 millet seeds were planted, while only one banana plantlet of a local East African Highland cooking type was planted in each bucket.

Two weeks after transplanting, the plants were inoculated with a mixed population of banana nematode species obtained from banana roots. The inoculum for each pot was a suspension consisting of *Radopholus similis*, *Helicotylenchus multicinctus*, *Pratylenchus goodeyi* and *Meloidogyne* sp. in known proportions. Inoculation was done by making several depressions close to the plant roots into which portions of the thoroughly mixed nematode suspension were introduced using a syringe. The plants were watered regularly and any vagrant plants that germinated as a result of wind dispersion were removed as soon as they germinated.

At termination, total soil volume and total root weight were recorded. A sample of 100 ml of soil and 5g of root was taken for nematode extraction. In the case where total root weight was less than 5g, all the available root weight was used for nematode extraction.

Extraction of nematodes from soil was by filtration and from roots by maceration and filtration using a modification of the Baermann Funnel technique (Hooper, 1986). The nematodes were concentrated in 25 ml by concentration and decanting. Two aliquots of 1 ml each were drawn from each sample for identification and counting of the nematodes, which was done under a stereomicroscope. An average count from the two aliquots was recorded and mean soil and root counts were calculated. The reproductive rating R, defined as the ratio of mean nematode count from the plant species to that from banana, the known host of the nematodes was calculated from mean root counts. The host status of the plant relative to banana was determined from the counts and the reproductive rating.

Activity 3 (1996-99): Evaluation of methods for transfer of tissue-cultured plants from laboratory to field

One of the main routes of transmission and infection of banana fields is though infected banana planting material. Availability and use of clean, good quality, planting material in fields cleared of nematodes by break-crops is essential. Otherwise the 1-2 year recourse to break crops is quickly wasted by direct re-infection.

Shortage of clean planting material is a major constraint to expansion and improvement of banana production in Uganda. Suckers consisting of fairly well developed buds are scarce owing to the nature of the plant (i.e., exhibiting low output of buds and slow development (Tezenas du Moncel 1985). Establishment of commercial plantations is also limited by this lack of clean planting material. Tissue culture and decapitation are the current methods for overcoming this problem. Plant tissue culture is the science of growing plant cells, tissues or organs isolated from other plants, on artificial media under artificial growing conditions (George 1993). Two methods are currently used for rapid multiplication of clean banana planting materials: (i) *in vitro* shoot-tip culture technique and (ii) decapitation (a field technique). At Kawanda Agricultural Research Institute (KARI), tissue culture is used for rapid multiplication of disease and pest-free planting material.

Banana cultivars most favoured by farmers in the trial areas were selected for micro-propagation and for subsequent use as re-planting material. The East African Highland cooking banana (*Musa* AAA-EA) cultivars, Nakitembe and Ndibwabalangira were selected, using information on farmer-preferences collected in a previous baseline survey (Bagamba, 1997). The banana plantlets which are produced from the original explants, cannot be planted directly into the field, as they must first be weaned and hardened (acclimatised) in a nursery or screenhouse over a period of 5-8 weeks. The plants are then transferred to a mother garden. The objective of establishing a mother garden was to increase production of clean planting material by rapid field multiplication ready for delivery to participating trial farmers when break crops were removed.

3.2.2 *On-Farm and On-station technical activities*

Activity 4 (1996-99): Field trials to establish optimum duration for break-crop to control nematode populations

Introduction

This activity is concerned with encouraging significant decline, or clearance, of banana nematodes by growing non-host crops in previously infected banana fields for about 18 months. The "break crop duration" is equivalent to "nematode decline" and "longevity of key nematodes", since they all relate to the same indicator, which is no, or low ,nematode numbers in the soil and roots. This activity is therefore the same as Activities 2 and 5 (1999-00).

The concept of planting disease-free bananas in land free of the principal nematode pest (*R. similis*) was first suggested 40 years ago (see review in Gowen & Queneherve, 1990). The basic hypothesis of this work is therefore not novel, the objectives are adaptive rather than strategic and depend upon the grower understanding the reasons for a strategy in which scientific (experimental) confirmation under local conditions is all that is required.

R. similis is not native to Africa and has been introduced on banana plants imported from elsewhere, probably more than 100 years ago. When deprived of its hosts, *R. similis* will survive in soil for about one year but this will depend on the effectiveness in removing all host plants and on the absence of other hosts, usually weeds, that may support a low population of *R. similis*. *Pratylenchus goodeyi* is known only as a pest of banana in East and Central Africa, Cameroon and Canary Islands. In Uganda it is more important than *R. similis* above about 1100 m elevation (Kashaija *et al.*, 1994). Because its host-range is narrow, management by conventional non-chemical methods is feasible. To avoid the risk of low populations of nematodes lingering for more than one year, break-crop periods of 18-24 months may be necessary. However, even if low level nematode populations remain in some patches, it appears that a relatively clear start (low nematode levels) given to a young pest-free plant can be sufficient to maintain crop vigour and yield later.

The use of tissue cultured Cavendish banana plants in re-plantings in Cameroon reduced the need to apply nematicides for the first 2 years of the crop, after which *R. similis* eventually returned, possibly from nearby banana plantations (CRBP Annual Report, 1994). Preceded by a (root) break-crop, it is likely that such soil would remain free of these nematodes for longer. Results obtained by Price (1994) in Cameroon, suggest that a one-year break crop of either cassava or sweet potato gives better control of *R. similis* in plantain than bare fallow. Some preliminary on-station trials in Uganda (Namaganda, 1996) indicated that at least 15 months of break crops was required to reduce banana nematodes to negligible levels. In Uganda, significant numbers of farmers have replaced bananas with root and tuber crops such as cassava and sweet potato because of the banana decline. The growing of a break-crop for a subsequent return to higher banana yields is particularly appropriate and attractive for such farmers.

Cassava and sweet potato are normally grown as short-term crops that can be rotated with other crops, whereas banana is grown as a perennial crop in East Africa, making it unsuitable for crop rotation programmes. The exception is in areas where decline in banana production has necessitated frequent (as often as every 2 years) re-planting of the crop, or where farmers have taken to growing alternative crops such as cassava and sweet potatoes because of unacceptably low yields. Where re-planting has become necessary every 2-3 years, a non-chemical control strategy which can restore reasonable banana yields for even 3-4 years is much more attractive.

Field sites

In the East and Central zone of Uganda, which includes Mukono District, banana production has severely declined, so the technology was perceived to be appropriate there on the above criteria. The South zone, which includes Kyanamukaka (Masaka) is at an intermediate level of decline, so that the technology could be useful in preventing or retarding further decline to levels experienced in many central areas. Accordingly, field trials were established with farmers in Kayunga (Mukono), at Kyanamukaka (Masaka) and on-station at Kawanda Agricultural Research Institute (**Fig. 3.2.1.1)**. The main objectives of these trials were:

- to establish the effectiveness of cassava and sweet potato in the control of banana nematodes under farmer conditions
- assess the effect of some common food and fodder crops on banana nematodes in infested soil
- determine the effective duration for the break-crops to control the key nematode populations.

Method:
On-farm and on-station plantations with average populations above 100 nematodes per gram of root were identified and experimental plots demarcated. The plot dimensions were 18 x 18 metres and each contained 25 banana mats. Banana plants were uprooted and roots and corms removed from the experimental plots to eliminate as far as possible the food sources for the target nematodes. On-farm (Kayunga and Masaka), the plots were planted with either cassava or sweet potato, depending on the participating farmers' choice of break-crop. On-station trials, beans, maize and mucuna (the tropical cover crop, *Macuna pruriens*) were planted in addition to cassava and sweet potato. Most of these are common crops in the banana system and it was deemed important to evaluate their ability to reduce or clear soil of banana nematode populations, or to act as host plants. Even some varieties of break-crops might conceivably sustain small populations of banana nematodes for a few weeks or months, making it difficult to clear all nematodes, or possibly create the need for a much longer break-crop period. At both on-farm and on-station trials, neighbouring plots that were under continuous banana cultivation were used as controls. In on-farm trials, replication was by farm, while on-station the treatments (beans, maize, macuna, cassava, sweet potato and banana) were replicated five times in a complete randomised block design.

In Kayunga, the first planting of cassava took place in October 1996 but the full planting was not completed until May 1997 because there was not enough cassava planting material for all the plots to be planted at once. Planting took place in May 1997 at KARI (on-station) and in October 1997 in Masaka. There were major difficulties in establishing the early Kayunga root crops, because there was insufficient (only 50%) planting material available in 1996 due to dry weather with poor germination in the material that was provided. Full root crop re-planting, including gap-filling, was done in May 1997 and the field (sampling) programme is therefore deemed to commence on this date. Pre-treatment data from nematode-infested soil under bananas was also taken in May 1997. Thereafter, each non-banana crop was re-planted in the same plot during the rainy season following the harvesting of the previous one. The number of times experimental crops were re-planted is therefore not uniform, as the crops have varying maturity/harvesting periods. Likewise, collection of samples (especially roots) for nematode population assessments was not uniform across the crops. The planting and harvesting details for Kawanda, Kayunga and Kyanamukaka are shown in **Tables 3.2.2.1 - 3.2.2.3**. Rainfall data for the years 1997 to 2000 inclusive are shown in **Fig. 3.2.2.2**.

To establish the potential of the break crops to control banana nematodes and the broad duration required, soil and root samples (when available on a particular crop at the time of sampling) were collected from the experimental plots every 3 months. Before bananas were returned to the experimental plots, soil samples were collected from each plot and subjected to a bioassay to check residual levels, if any, of the key banana nematodes in the soil.

<u>Nutrients</u>

As there was a possibility of depletion, or change in composition, of certain soil nutrients by break crops it was decided that this should be investigated simultaneously with the sampling programme, although at longer intervals. In order to assess the positive or negative effects of the root crops (cassava, sweet potato and other potential break crops) on soil nutrients, soil samples were collected from the experimental plots at the beginning of the trial (pre planting of root crops), after one year and after two years of growing the root crops. The soil samples were analysed and the data used to determine changes in soil nutrient levels over time. As soil fertility is probably one of the most poorly defined concepts in soil science (Delvaux, 1995), it was intended that this component of the study should be kept relatively simple. That is, to identify those soil nutrients or components that showed a clear trend to increase or decrease over the two-year period. This could then be taken into account in future to advise growers of the need for additional fertiliser and other requirements.

<u>Crop development</u>

Measurements were also made of re-planted banana crop characteristics such as main crop height and girth and bunch development or yields on sampling visits to the trial sites. These were intended to give a general estimate of crop quality against farmers' own opinions in project questionnaire surveys. However, it was found impracticable to make meaningful quantitative analyses of farmers' plots having different site characteristics and consisting of different cultivars of different ages at different stages in the rotation, and against a variety of difficult-to-measure criteria. The approach was therefore modified to noting farmers' opinions and satisfaction indicators in the socio-economic and technical impact assessments together with a researcher-assessment of participating farmers' understanding and conduct of the trials cum demonstrations towards the end of the project.

Table 3.2.2.1. Planting and harvesting details for On-Station trials (Kawanda)

Date	Crop	Activity	Observation/Comment
May 1997	Beans, Maize, Mucuna, Cassava, Sweet potato	Planted in 5 replicates each . This is the first crop	5 Plots (3replicates of contiguously growing bananas left in as control
September 1997	Maize, Beans and Mucuna	Second (season) crop plated	Germination poor due to erratic rains. They were to be replanted when rains came.
October 1997	Maize, beans and Mucuna	Second (season) crop replanted as the previous one germinated poorly	Plants kept weed free
March 1998 June 1998	Maize, beans Beans	Planted (i.e third crop) Third crop harvested	 Harvested June 1998
March 1998 June 1998	Sweet potato Sweet potato	Second crop planted The crop was harvested	
August 1998	Maize	Third crop harvested	
September 1998	Cassava Mucuna	First crop harvested Second crop harvested	
October 1998	All 5 crops Beans 4th crop, Maize 4th crop Mucuna 3rd crop sweet potato 3rd crop	Planted	Crops kept weed free
November 1998	Cassava 2nd crop	Planted	
January 1999	Beans	Harvested	
March 1999	Maize and sweet potato	Harvested	
April 1999	Beans 5th crop and maize 5th crop	Planted	
July 1999	Beans	Harvested (5th crop)	
August 1999	Maize	Harvested (5th crop)	
October 1999	Mucuna 3rd crop, sweet potato 3rd cassava 2nd crop	Harvested	
November 1999	Bananas	Replanted	Bananas, using clean planting materials (tissue culture and suckers) were returned to the trial plots after removing all other crops. Banana establishment (germination was however disturbed by drought, so all gap-filling was done later in March-May 2000.

Table 3.2.2.2 Planting and harvesting details for On-Farm trials (Kayunga)

Date	Crop	Activity	Observation/Comment
September 1996	Original bananas	Collection of soil and root samples for preliminary assessments (pre-planting) of nematode status	
October 1996		Selected the 1st 22 farmers to participate in the trials	They prepared the land for planting of break crops. Plot size equals 20 x 20 m
October 1996	Cassava (1st crop)	Planted but in half the plot area.	Planting material (cassava cuttings) insufficient to cover full plots of the 22 farmers. No more available until march 1997.
October 1996	Sweet potato	Planted in only 5 plots	Only 5 farmers were interested in planting sweet potato as a break crop
December 1996	Cassava		Poor germination of the cassava planted in October, because some of it was received and planted 4-10 days after delivery of the cutting in the area. Then dry spell set in.
February 1997		Selection of additional farmers to bring the number greater or equal to 30 trials. Collection of soil and root samples for baseline information.	
April 1997	Cassava 1st crop	Planting	All the additional farmers plots were fully planted. The remaining half plot of the original 22 farmers was also planted.
May 1997	Cassava and Sweet potato	Sampling	Only soil samples were collected as crops did not have enough feeder roots to sample
June 1997	Cassava and sweet potato		All trial plots (except for the 2 mentioned below) were well managed. i.e. weed free. Except that of Kazibwe Stephen who was later dropped, and Kabula Garim all in Ntenjeru Parish.

Table continued >

Table 3.2.2 2 (continued)

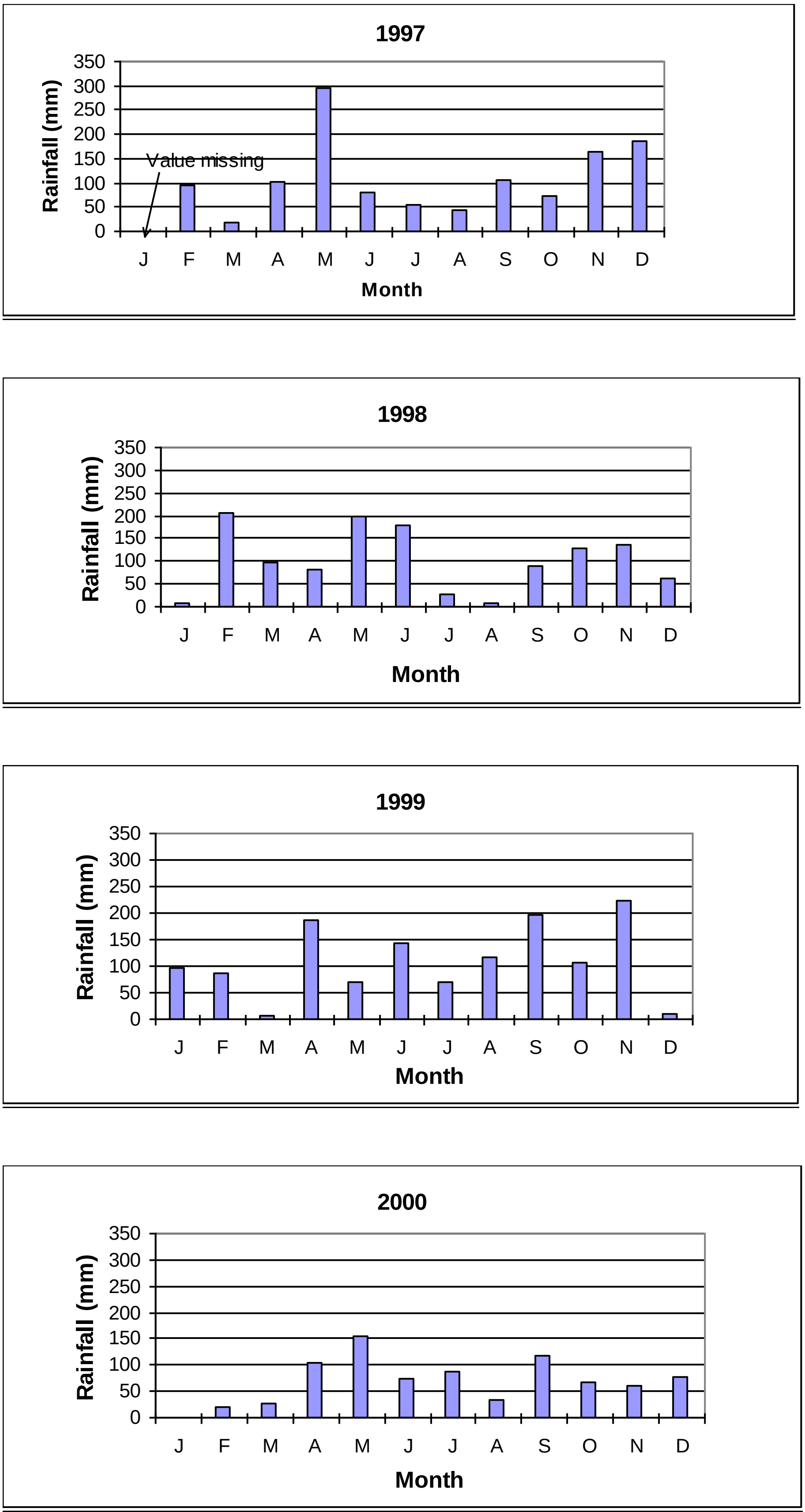
(Kayunga, contd)

Date	Crop	Activity	Observation/Comment
August 1997	Cassava Sweet potato	Sampling	Both soil and roots sample collected from both the earlier and later planted cassava, and sweet potato.
September 1997	Cassava, Sweet potato (planted in October/November 1996)	Harvested	
September/October 1997	Cassava and sweet potato	Planting of the 2nd crop in half the plot that was planted in October 1996	Some farmers removed the old cassava and planted the 2nd crop at once while other removed (harvested) in piece meal and therefore re-planted in piece meal.
October 1998	Cassava and sweet potato	Harvesting of all crop plants.	All crops were harvested and the crops harvested for return replanting of bananas.
November 1998	Banana	Re- planting with clean planting material	All plots were replanted with or returned to bananas. Farmers endeavored to keep the plots weed free and mulched. Compost manure was put in planting holes or later spread around the established plant.

Table 3. 2.2.3 Planting and harvesting details for On-Farm trials in Kyanamukaka (Masaka)

Date	Crop	Activity	Observation/Comment
August 1997		Farmers and plots for the trial selected Collection of baseline samples (soil and banana roots) from selected plots	5 plots at one person's large farm and one plot in an another area but close by (about 15 km apart.)
October 1997	Cassava – 5 plots sweet potato 1 plot	Planted	The 1st crop was planted
April 1998	Sweet potato	Planted 2nd crop	
November 1998	Cassava Sweet potato	Planted 2nd crop Planted 3rd crop	One plot was dropped as the farmer had put in Maize.
September 1999	Banana	Re-planting with clean planting material	All plots were re-planted with bananas

Fig. 3.2.2.2 Rainfall at Kawanda Agricultural Research Institute, Kampala (1997-2000)



Note: Readings for Jan 1997 and Jan 2000 are missing

Activity 5 (1996-99): Examination of host status of common weeds and crops for key nematodes.

Note: An extra activity was added on 'host status of common banana system crops'. Activity 5 is therefore divided into: A. Weeds and B. Crops

A. Host status of weeds

Introduction

The objective of this study was to identify weed species associated with banana stands in Uganda and to establish the host status of the most common ones to the important banana nematodes. Wehunt & Edwards (1968) listed some 38 species of nematodes belonging to 20 genera as possible parasites of weeds. As mentioned above, the most widespread and important banana nematodes are *Radopholus similis* (Cobb) Thorne, *Pratylenchus* spp. and *Helicotylenchus multicinctus* (Cobb) Golden.

Materials and methods

A survey was carried out at Kayunga, Mukono district in order to identify weed species common in banana plots. The study was carried out at 14 farms, all of which were part of the project's on-farm trial s on the management of banana nematodes using breakcrops. The observations were made on non-experimental banana plots since the experimental plots were still under a cassava or sweet potato break-crop. All weed species present in the survey study plot were recorded. Assessment of abundance of a weed species was by visual appraisal. A weed species was regarded as abundant if it occurred in large numbers in several plots, and not abundant if it occurred in very low numbers in the study plots.

Eleven weed species were regarded as common in banana plots, since they were both frequent and abundant. These were: *Galinsoga parviflora*, *Bidens pilosa*, *Commelina benghalensis*, *Ageratum conyzoides*, *Amaranthus* sp., *Senecio disfolius*, *Solanum nigrum*, *Cyperus esculentus*, *Digitaria scalarum*, *Digitaria velutina*, and *Eleusine indica*. Accordingly, they were selected for the host status study. *Crassocephalum crepidioides* and *Tagetes minuta* were neither frequent nor abundant, but they were included in the study because of the cultural importance of the former and the potential importance of the latter as a nematicidal botanical plant. Many farmers do not remove *Crassocephalum crepidioides* from their banana plots because it is believed to be associated with high banana yields. Banana was used as the control.

Seeds of broad-leaved weeds, with the exception of *Commelina benghalensis*, were germinated in shallow plastic basins filled with sterile soil. Propagules of the three grasses *Digitaria scalarum*, *Digitaria velutina*, and *Eleusine indica*, the sedge species *Cyperus esculentus* and cuttings of *Commelina benghalensis*, were also planted in the shallow basins. Three weeks after planting, the weed seedlings were transplanted into 2l plastic buckets filled with sterile soil. Four weed seedlings were planted in each bucket while only one banana plantlet of a local East African Highland cooking type was planted in each bucket. The potted weeds were arranged in a randomized complete block design with five replicates in a screenhouse.

Two weeks after transplanting, the weeds were inoculated with a mixed population of banana nematode species obtained from banana roots. Inoculation was done by making several depressions close to the plant roots into which portions of the thoroughly mixed nematode suspension were introduced using a syringe. The plants were watered regularly and any foreign weeds that germinated as a result of wind dispersion were removed as soon as they germinated. The short-lived weeds were cut back as soon as they dried and new seedlings planted in the pots without removing the old root systems.

The experiment was run over five months, after which total soil volume and total root weight were recorded. Samples of 100 ml of soil and 5g of root were taken for nematode extraction. Where total root weight was less than 5g, all the available root material was used for nematode extraction.

Extraction of nematodes from soil was by filtration and from roots by maceration and filtration using a modification of the Baermann Funnel technique (Hooper, 1986). The nematodes were concentrated in 25 ml by concentration and decanting. Two aliquots of 1 ml each were drawn from each sample for identification and counting of the nematodes, which was done under a stereomicroscope. An average count from the two aliquots was recorded and mean soil and root counts were calculated.. The reproductive rating R (Tedford & Fortnum, 1988) was calculated from mean root counts. The host status of the weeds relative to banana was determined from the counts and the reproductive rating.

B. Host status of common crops

<u>Introduction</u>

In parallel with the weed study, the objective of this screen-house study was to identify crop species associated with banana stands in Uganda and to establish the host status of the most common ones to banana nematodes.

Crop rotation is one of the approaches to nematode management, especially for annual crops. The success of crop rotation depends on sufficient knowledge of the target nematode pest and its host range. Non-host, or at least poor hostplants, must be used for a period of time to remove or bring about a decline of nematodes to a negligible level. Only cassava and sweet potato have been identified as poor hosts to the important banana nematodes (Namaganda, 1996). However , these crops are not popular in all banana-growing areas with nematode problems. There is need to establish the host status of crops commonly inter-cropped with bananas and/or preferred by farmers to be able to advise them accordingly. A choice of alternative crops is important to suit different banana cultivation systems. This study was conducted to establish the host status of common crops to banana nematodes.

<u>Materials and methods</u>

A survey was conducted in Kayunga and Kyanamukaka sub-counties to identify crops associated with banana cultivation in a banana-based cropping system. A total of sixteen farms was visited. At each farm a team of researchers and a farmer walked through the banana plantation identifying and recording crops (other than banana) present in and around the plantation. Through interviews with farmers, crops usually intercopped with bananas , or grown separately, were recorded.

The seven most common crops were: beans (*Phaseolus vulgaris*), carrot (*Dacus carota*), groundnut (*Arachis hypogaea*), maize (*Zea mays*), millet (*Eleusine coracana*), pineapple (*Ananas comosus*) and tomato (*Lycopersicum esculentum).* Crops such as Cassava (*Manihot esculenta*) and Sweet potato (*Ipomoea batatas*) which are known to be poor hosts of banana nematodes, and the EA highland banana cultivar Nakitembe (which is susceptible to the nematodes) were included as references.

The crops were planted in sterilized soil (soil, sand in a 1:1 ratio) in 5 litre buckets placed in a shadehouse. Tomatoes were pre-germinated and transplanted, while seeds of beans, carrot, groundnut, maize, cuttings of cassava, sweet potato, and suckers of pineapple and tissue-cultured banana were planted directly in the sterilised soil. As growth sizes of the crops and their root systems differ, crop plant densities in the pots were varied in order for those with low root biomass to yield enough total fresh root weight for nematode extraction. After establishment, the plants were inoculated with a mixed population of nematodes obtained from banana fields around KARI. The inoculum was introduced to the plant rhizosphere in each pot, contained 3400 *P. goodeyi*, 350 *H. multicinctus* and 750 *R. similis*. through holes made in soil around the roots with a wooden rod. The holes were then re-filled with additional sterilised soil. Plants were watered regularly during dry spells and were kept weed-free.

At termination of the plants were removed from containers and roots cut off and washed free of soil. Soil and roots were processed in the same way as in the weed study and mean numbers of nematodes in 100ml soil and 5g of roots from the replicates were calculated for comparison of associated nematode densities. The results are discussed in **Section 4**.

Activity 1 (1999-2000): Quarterly assessment of soil fertility levels with break crops and clean banana sequence

Different types of crop may utilise different nutrients from the soil and at different seasonal rates and quantities. Root crops obviously have different nutrient requirements to bananas and it is important to know which nutrients are reduced or depleted and will need replacing for banana re-planting. Of course, a competent grower of any crop must know the general ability of his soil to meet crop requirements and whether supplementary fertilisers are needed. To monitor the possibility that certain nutrients might be depleted by the root crops used as break crops, soil samples were collected from the experimental plots on three occasions over the trials:

(i) at the beginning of the trial (pre planting of root crops),
(ii) after one year
(iii) after two years of growing the root crops.

The soil samples were chemically analysed for the main nutrient levels (P, Ca, K, Mg, Na N), clay, silt and sand content and pH. The data were analysed to determine changes in soil nutrient levels over time. Tables 3.2.2.1-3.2.2.3 show the dates of the trials and crops growing in the plots at each site. The results are discussed in **Section 4**.

Activity 3 (1999-2000): Clean banana plant vigour and quality up to flowering monitored with farmers

This activity was designed to gauge the impact of the technology in terms of farmer perceptions and opinions of the quality of the developing re-planted clean banana plants. The monitoring for this was conducted as part of an Impact Assessment study in the last year of the project (Bagamba, 2000). Manyproject farmers kept notebooks to record crop yields and other aspects of interest, including crop condition (size, quality) and this could help in their discussions with visiting project team members. Technical staff made regular assessments of plant survival (break crop or bananas) on farm visits in order to "gap fill" plants which looked sickly or had died. Detailed systematic field studies of banana vigour and quality at the three sites were not conducted because of the difficulty of comparing different local varieties, including tissue cultured plants within and between sites and at widely different stages (planting dates) between sites. However, farmers' experimental plots were also assessed by researchers and ranked as 'very good', 'good', 'fair', 'poor' and 'very poor', depending on the type of management and performance of the banana plants. As farmer-opinions and practices, rather than scientific data, are the essential determinants for uptake of the technologies, their views were considered most important. Farmers were encouraged to compare the trial plots with their own or nearby conventional plots and their opinions on plant vigour are discussed in **Section 4**.

3.2.3 *Training and dissemination activities*

Activity 7. (1996-99): Train local staff in nematode identification and evaluation of soil populations and root damage

Over the course of the project, four technicians were trained in banana and plant nematode sampling, processing and identification and to conduct the more routine aspects of assessment and recording of field/farmer information and crop/plot maintenance. These were as follows:

Stephen. Mayanja
Gertrude Nabulya
Margaret Nassiwa
Agnes Tumushabe

There were normally two technicians working under the project at any time but as one moved elsewhere, a new candidate was recruited. This level of training, with the need to use basic scientific (sampling and processing) equipment and microscopes, was obviously unsuitable for farmers and was restricted to local (KARI) staff.

Activity 1 (1996-97) *Additional funding*: Assessment of nematode species profile on 10 yam varieties and extent of damage (dissemination).

Introduction

Yams are an important crop in parts of East Africa and are slowly becoming more popular in Uganda and there is government interest in increasing yam production. Nematodes are already known as limiting factors to yam production in various tropical countries, particularly West Africa, yet surprisingly little is known about the nematodes associated with yam in Uganda, or the pathogenicity to yams of nematode taxa occurring in Uganda. Limited surveys were conducted by scientists from Namulonge and Kawanda (e.g., Namaganda *et al.*, 1993; Coyne and Namaganda, 1994; Coyne and Namaganda, 1996), including work as part of a precursor project (DFID Project R5739), to gain some knowledge of the nematode taxa associated with Ugandan root and tuber crops, including yams. However, the main overall effort was directed at cassava and sweet potato, which have been the principal root crop targets of research by the National Root and Tuber Crop Programme. In addition to other pests, this generated useful information on the major nematodes of cassava, their specific pathologies and on varietal resistance to nematodes. It also confirmed that cassava and sweet potato were non-host crops of banana nematodes. This did not seem to be the case with yams, as the nematodes *Scutellonema bradys*, *Meloidogyne* spp. and particularly *Pratylenchus coffeae* are known to be major yam pests. As *P. coffeae* is also a pest of banana, the possibilities of using yams as main or supplementary break crops to cassava and sweet potato appeared unlikely. However, neither the severity of attack on Ugandan yam varieties, nor the susceptibility of different varieties to different nematode taxa was known, although there were indications that the situation might not be as severe, or even the same, as in West Africa. The nature of this would affect the options for deployment of yams in a break-crop cycle for non-chemical control of banana nematodes. There was thus a need to evaluate yam host-plant responses to nematodes in local fields.

Materials and Methods

The trial was established in July 1996 at Sendusu station of the International Institute of Tropical Agriculture (IITA), East and Southern African Regional Centre (ESARC), Uganda to evaluate agronomic performance and host plant response to nematode attack on new IITA hybrids. Sendusu station experiences bimodal rainfall, with the main rains occurring from March to June, while short rains fall between September and December. The site is at an elevation of 1128 m with an annual rainfall of approximately 1050 mm and average temperature of 22 (15-31) ^{o}C with the average minimum and maximum of 15^{o}C and 31^{o}C, respectively. The soil is classified as a dark reddish-brown sandy loam (IITA 1992). The land selected, had been used for mass production of bean seeds for 7 years, followed by a 5 year grass fallow period. Five hundred open-pollinated lines had been produced in the IITA breeding program in Nigeria and were introduced into Uganda as tissue cultured plants. These tissue cultured plantlets were planted in a complete randomized design with a minimum of 25 plants in a row and no replicates. After 6 months the plants were mature and were evaluated for number and quality of tubers produced. Twenty-four yam lines, showing superior agronomic performance, were then selected and used in this study. Ten mature plants of each of the 24 lines were sampled for nematode damage and infestation. Damage was assessed for root knots and cracks and scored using the whole tuber immediately after harvesting. The scoring method for these damage indices was: 0 = no damage, 1 = slight damage, 2 = moderate damage, and 3 = severe damage.

Nematodes were extracted from tubers by randomly cutting five 2 g tuber cores (1cm in diameter and 2 cm deep) using a cork borer. The cores were chopped further into 1 mm pieces and each was placed on a paper tissue supported by a sieve resting in a labelled petri dish. For 7 days, nematodes were extracted from this material. Each day, the filtrate in the petri dish was collected and the dish was refilled with water. The filtrates were kept at 4 oC, and the extracted suspensions for all 7 days were combined. Prior to counting, the volume was reduced to 25 ml. The suspension was agitated thoroughly with air from an aquarium pump. Three subsamples of 2 ml each out of the 25 ml solution were taken, using a micro pipette . The nematodes were counted and identified in a 'Meku' slide under a compound microscope.

Data collected were entered in a Microsoft Excel spreadsheet and translated to Dbase IV. The means of the non-transformed data of damage indices and nematode counts were separated by the Least Squares means procedure of the SAS statistical package (SAS, 1987). The results are summarised in Section 4.

Activity *2* (1996-97) *Additional funding*: Identification of suitable cassava cultivars for use as break crops; dissemination

Introduction

The cassava break-crop used in the trials, and the most popular cassava cultivar over the project duration was undoubtedly SS4, mainly because of its resistance to African Cassava Mosaic Virus (ACMV), but also high yield, good texture and cooking qualities. However, the National Root and Tuber Programme has a continuing programme of evaluation of indigenous and introduced varieties. In particular, it is important to acquire information on crop varietal resistance to pests and diseases for breeding programmes and selection of various physical, chemical or culinary qualities. This will also influence demand by farmers and also permits better prediction of suitability for growing in particular areas, or on-farm purposes, or to decide on an appropriate variety for use in crop and pest management.

This Add-On activity was aimed at contributing to our knowledge of cassava varietal resistance. It is important that cassava yields and resistance to pests are maximised to farmers' benefit. In relation to the break crop technology, it is important that the root and tuber break crops themselves are resistant or tolerant to nematodes, but also that they are do not encourage high populations of nematode taxa like *Meloidogyne* spp., which could be damaging from time to time, if in high populations. This study looked at the susceptibility of cassava cultivars to these nematodes.

Materials and Methods

Stem cuttings of 13 cassava varieties 'Migyera', 'Nase 1', 'Nase 2', 'TMS 60140', 'TMS 30001', 'TMS 4(2)1425', 'TMS 30786', 'Bukalasa 7', 'SS 4', 'SS 7', 'Bao', 'Ebwanateraka' and 'Bukalasa 11', about 10 cm long were planted horizontally in perforated plastic buckets containing about 10 l of steam sterilised sandy loam soil. Soil sterilisation was done in converted oil drums over heat for 24 hours. This was to kill nematodes present in the soil which could have interfered with the experiment. Following sterilisation, the sterilised soil was extracted for nematodes using the modified Baermann funnel technique (Hooper, 1990) to assess the nematode kill, and no live nematodes were found. The perforated buckets with cassava cuttings were placed outdoors, arranged in a randomised complete block design with 25 replications and allowed to establish for 30 days. Five plants per variety were inoculated with 100, 1000, 10000, 100000 *Meloidogyne* eggs/juveniles, respectively and five left uninoculated as a control. Individual cassava plants were inoculated directly by pouring the required number of eggs in water into small holes made in the soil around the base of the plant and an additional 1-2 cm layer of soil added after inoculation.
The inoculum consisted of a mixed population of *M. incognita* and *M. javanica* in approximate ratio of 4:1 (identification by J. Machon of International Institute of Parasitology, St. Albans, UK.) and was extracted from previously inoculated tomatoes by a method of Hussey and Barker (1973). The plants were allowed to grow for another 12 weeks after inoculation. In the twelve week period the root-knot nematodes were expected to have completed at least eight life cycles (Orton-Williams, 1972; Eisenback and Triantaphyllou, 1991).

Before harvest, plant heights were taken. At harvest, the plastic buckets were inverted and emptied in such a way that most roots remained intact. The roots were hand picked from the soil and weighed. Percentage reductions in plant height and fresh root weight due to root-knot nematode infection for every level of *Meloidogyne* spp. inoculum used over the non inoculated plants (control) were calculated. Analysis of variance was carried out over varieties for each respective *Meloidogyne* inoculum level and over levels of inoculum for each variety.

To enable counting of *Meloidogyne* spp. females in roots, a 1 g root sample was taken from each of the inoculated plants, cut into about 2 cm pieces, washed clean and tied in a muslin cloth so as to keep each sample separate. The bundles were placed in a boiling solution of equal volumes of lactic acid (DL-Lactic acid), glycerol and distilled water with 0.01% acid fuchsin stain for about 2-4 minutes and then allowed to cool in the staining solution. The bundles were then placed in a clearing solution consisting of equal volumes of glycerol and distilled water for about 24 hours. The clearing solution removed the stain from plant tissues but not from the nematode tissues and thus when the roots were viewed under a stereo-microscope, the nematodes were easily located (Hunt and Bridge, 1991). Individual root samples were then observed under a stereo-microscope and dissected to expose the nematodes.

The number of females with and without eggmasses and the number of galls per gram of roots were recorded, with coalesced galls counted as one. The females with eggmasses were expressed as a percentage over the total number of females (percentage female fertility). The gall index (GI) and egg index (EI) were scored according to the method of Sasser *et al*. (1984). A resistance index (RI) was calculated using a formula, RI = $SQRT(GI^2 + EI^2)$ and host reaction determined from the RI using a system of Kouamé *et al*. (1995). The percentage female fertility and RI were subjected to analysis of variance in the same way as percentage reduction in plant height and fresh root weight.
The results are discussed in Section 4.3.3.

Activity 6 **(1999-2000): Increased dissemination of control strategy to NARS, extension service and farmers through open days, seminars, workshop, etc.**

Activity 6 (99-00) is a continuation of Activity 8 (1996-99) into the one-year extension phase. The dissemination activities for 1996-2000 are therefore discussed together here.

Activities aimed at dissemination increased as the project progressed because there was a gradual increase in demonstrable practices and crops in trial plots to facilitate more effective and convincing training. There was also a process of conducting a range of training with participating farmers and of proceeding to identify target individuals and institutions who would benefit from the technology and who would be interested in promoting it.

A range of different stakeholder training activities and methods were used by the project for different target groups and purposes. These included monitoring and farm visits, specific topic training (e.g., break crop principles, planting and maintaining tissue-cultured and conventional re-planted bananas) farmer participatory evaluations, research station visits by stakeholders, open day, farmer field days, farmer to farmer training, workshops and training of trainers with NGO and others. Promotion pathways to target institutions and beneficiaries were identified and details are given in Section 4.

Activity *7* (1999-2000): At least 100 participating farmers trained in technologies tested and promoted by the project

Through a range of training methods and topics (see Activity 6 (1999-00) above), the project trained in excess of 100 farmers taking up the break crop method for non-chemical control of nematodes. The level of interest from non-participating farmers was surprisingly high and were keen to take up the break crop and replanting method and an equivalent number of these farmers were therefore also given training and follow up advice.

Activity *8* (1999-2000). At least two technical papers and one socio-economic publication in final draft or submitted

Details are discussed under Outputs (Section4) and a list of project dissemination outputs (publications, reports, information leaflets, seminar presentation, etc) is provided in Section 4.

3.2.4 *Socio-Economic project assessments and validations*

This sub-section contains three socio-economic activities intended to enable output of the main project objectives:

1. Additional S-E input (Activity 3, 1998-99)

2. Periodic socio-economic and technical assessments (Activity 4, 1999-00)
3. Final socio-economic assessment and validation (Activity 9, 1999-00)

[1] contributed to outputs in [2] and [3] and is therefore not discussed further under Outputs in Section 4. However, activities under 2 and 3 contribute to the same series of outputs and are discussed together in Section 4.

Activity 3 (1998/99) ***Additional funding*****: Additional socio-economic inputs**

Introduction

The initial time input estimates for the project were based on the availability of socio-economic staff who had inputs into other local projects (including non-CPP), permitting savings in staff time and local costs. However the assumed inter-project flexibilities and staff availability proved unsustainable a new Social Scientist, Mr Lamboll, was assigned after project commencement. Secondly, the spread of sites, following changes in NARO benchmark areas, and the wider farmer interest we discovered, required additional and broader assessment, demonstration and validation with farmers than originally projected. Thirdly, the original three-year period for completion of the trials *cum* demos was ambitious, but achievable provided there were no major delays. However, there were delays. The project unavoidably started late in Year 1 and had seen a severe dry period in Q1 and heavy rains in Q3 of Year 3. The field activities were therefore retarded somewhat and the weather also adversely affected nematode inoculum development for some key trials and conditions in the field. There was a need for an experienced social scientist to interact with a trainee NARO social scientist and farmers/stakeholders at this important stage of the project.

Inputs

The extra social inputs were essentially to contribute to the activities already described and specifically:

- Understand a range of farmers' perceptions of introduced methods of nematode management-a cross-sectional survey of farmers in the Mukono and Masaka sites through focus group discussions and individual interviews.
- Assess with a range of stakeholders the potential for uptake of the management methods. Help further identify relevant stakeholders (eg participating farmers, non-participating farmers, village representatives, public extensionists, NGOs working in relevant areas) and carry out interviews with key informants.
- Identify next steps, depending on the outcome of 1 and 2 above- the above activities will help to identify the way forward. A key areas to address was likely to be the institutional capacity of the public agricultural services and/ or others to scale out these activities.

Specific output

A report at the end of the project containing: farmers perceptions of management methods; an assessment of the potential for the uptake of the management methods and options for next steps.

Activity 4. (1999-2000): Continual socio-economic and technical evaluation to improve farmer dissemination and maximise uptake pathways

Introduction

There were two project socio-economic studies conducted between April 1996 and May, 1999 in addition to specific smaller assessments (e.g., of farmer practices, opinions or training needs). In addition, a report on assessment of farmer training needs was produced.

(i) a baseline survey conducted in May 1996, with some follow-up in 1997 (Bagamba, 1997)
(ii) Group assessment of farmer training needs in Kayunga (1998)
(iii) a mid-term impact assessment in May 1999 (Bagamba, 1999)

A final socio-economic report and an end of project review of the socio-economic findings and uptake aspects were also produced but is reported against Activity 9 (1999-00), below.

(i) Baseline survey (May 1996)

The baseline survey and accompanying "front end" information-gathering, participant farmer identification and assessment activities were described in the first part of this section (Section 3.1.1) to flow logically with the progression of project activities over four years. The Outputs are described in **Section 4**.

(ii) Group assessment of farmer training needs, Kayunga (December, 1998)

Introduction

Periodic training and problem-solving meetings were held, particularly in 1998-99 when crop developments in the field raised issues of current crop management needs and possible future needs and inputs. This group meeting is one example of such activities intended to address the recommendations of socio-economic surveys on farmer -needs, or expectations of researchers.

During a team visit to Kayunga (October, 1998), when the post-break crop principles and practices were being discussed, several Kayunga project farmers independently requested more information about general and recommended banana management practices, which would help them to achieve higher yields and to make their plantations productive for a longer time. This was also indicated by survey information and presented an opportunity to improve farmers' broader knowledge and to identify and agree on gaps in their knowledge (which were unlikely to be the same for all farmers) to address their individual training needs. This would also help to improve their performance in the trials and would contribute towards the overall aim of the project.

Method

Two different farmer groups from villages in Kayunga project area participated in two separate group meetings. One group was from Ntooke/Bwetwyaba village area, with 6 female and 1 male project farmers (at Mrs Faith Mutyaba's plantation) and the other from Ntenjeru village, with 1 woman and 5 men farmers (at Mary Musisi Nalubwama's kibanja). The approach to carrying out the of farmer training needs assessment was similar with both groups. Farmers and researchers moved as a group to a trial site belonging to one of the members of the group and where there was an adjacent banana plantation. The farmer was then asked to sketch out a map of the plantation showing any variation in the bananas being cultivated. While sketching the map, the farmer was asked to describe the history of the plot. The farmer was then asked for any differences in the state of the bananas on the site over time. S(he) was then asked to account for any differences and the discussion was then opened to other farmers. Looking around the site, examples were identified of differences between healthy and less healthy looking banana plants (e.g. dried leaves, small stems, small bunches) in the plots, and discussion continued. Examples of observed (and labeled) differences in bananas taken at the meeting are shown in **Plates 3.1.4.1 - 3.1.4.5**. The group were then asked the cause of the variations between plants on site and what could be done to address the situation if it was a problem. This allowed researchers to better understand what farmers did and did not know about bananas. A direct question was then put to each farmer asking them for two things about which they would most like to know more with respect to bananas or banana management. The results are presented in Section **4.4.1.1**

(iii) Mid-term impact assessment (May 1999)

The survey was carried out with Kayunga farmers participating in the Break Crop Project to assess its impact on farmers' knowledge of, and practices for, control of banana nematodes. This was concerned with changes in the quantity and types of bananas planted by the farmers, methods of land-opening, planting, treatment of planting material, soil management, mulching and fertiliser/compost, pest recognition and control practices, sources of information for pest control methods, knowledge of the project break-crop technology and purpose, and farmers' perceptions and opinions of the beneficial, neutral or adverse effects of the technology or project activities on their crops. The questionnaire used for post-baseline impact assessments is shown in **Appendix 3** and the findings are discussed in **Section 4.4.1.1**.

Plate 3.1.4.1 Banana problems identified by Kayunga farmers: Banana suckers not good

Plate 3.1.4.2 Banana problems identified by Kayunga farmers: Small bunches

Plate 3.1.4.3 Banana problems identified: (a) Small stems and (b) High mat

(a)

(b)

Plate 3.1.4.4. Banana problems identified by Kayunga farmers: Black scars

Plate 3.1.4.5 Banana problems identified by Kayunga farmers: Yellow leaves

Plate 3.1.4.6   Banana problems identified by Kayunga farmers: Rotting stem

Activity 9. (1999-2000): Final socio-economic assessment and validation of banana break crop and complementary technologies by project end

Two socio economic evaluations were produced for the end of the project:

(i) End of project impact assessment (Bagamba, 2000)
(ii) Final report on socio-economic and uptake aspects of the project (Lamboll, 2000).

(i) End of project impact assessment (March 2000)

This study was conducted to evaluate improvement in farmers' knowledge and effectiveness of the break crop technology, especially after having monitored the re-planted banana plants for over a year. Participatory evaluation techniques were used to assess both the effectiveness of the non-chemical control of banana nematodes using break crops and the impact made on participating and non-participating farmers. Two groups of nine project participating farmers, one from Ntooke and the other from Ntenjeru, was involved in the appraisal of the project, together with 9 non-participating farmers to compare their perception of the break crop technology and the impact made by knowledge spill-over. In all the interviews, farmers were encouraged to contribute freely to the discussion.

The study compared the expectations of the participant groups at the meetings and their experiences of the break crop project: the benefits, negative aspects, constraints and observed differences between experimental and traditional plots. Farmers' experimental plots were also assessed by the researchers and ranked as very good, good, fair, poor and very poor depending on the type of management and performance of their banana crops. The impact of the project was assessed in terms of farmer awareness and application of the new banana production techniques, including the role of tissue-culture planting material, compost making, mulching and the importance of break-crops and conventional clean planting material in the non-chemical control of banana pests. Any constraints that might limit the adoption of the break-crop technology were also noted by the survey team. The findings are discussed in **Section 4**.

(ii) Final report on socio-economic and uptake aspects of the project

This report (Lamboll, 2000) endeavours to draw together the overall socio-economic impressions and uptake aspects of the project. The objectives were to:

(1) Report on farmers' perceptions of introduced methods of nematode management;
(2) Assess the potential for uptake of the management methods;
(3) Suggest possible ways forward, depending on the outcome of 1 and 2 above.

The main findings are discussed in **Section 4.4.2**.

4. Outputs

4.1 *Stakeholder identification and induction and development of essential project knowledge, techniques and capabilities*.

4.1.1: Socio-Economic studies undertaken on the willingness of farmers to use tissue-cultured banana plants following a break crop

Introduction

A succession of field visits was made by the Banana Programme team in the second half of 1996 to Mukono district and to Masaka. Meetings were held with District Agricultural Officers and local administrators. Information was gathered through group and individual discussions with farmers. Concurrently, information was gathered for the baseline survey. Data on farmer and site characteristics for the Kayunga sites was collected using standard questionnaires on the basic socio-economic (**Appendix 1 and 2**) and general On Farm Trials Baseline information (**Appendix 3**). The questionnaire baseline data (farm history, cropping systems, pest and disease status, preferred banana cultivars etc.) was collected on these farms and initial/pre-planting nematode populations assessed. Additionally, information was gathered on farmers' 'current' practices and knowledge about the various banana production constraints. NRI researchers, Dr R Lamboll and Dr S Gowen (project leader until early 1997) participated in the early farmer and site-selection process on two visits in August and October 1996. Site and farm/farmer selection criteria used in this process are shown in **Appendix 4** .

(a) Selection of interested Farmers

Although the farmers selected to participate in the trials expressed willingness to use tissue cultured bananas, it soon became clear that this willingness could not be tested immediately. The willingness of farmers to use tissue-cultured banana plants was likely to be tested some 15-18 months down-stream from the point at which they agreed to evaluate the technology (to participate in the project trials, take out their infected bananas and use break crops, followed by re-planting of tissue-cultured bananas) in order to overcome their yield decline. However, the willingness of farmers to use such plants would be tested empirically, by their continued participation in the project until the time for re-planting using micro-propagated material. The performance of the latter would be the real test of the sustainability of this part of the technology. However, even if they did not use tissue-cultured plants, it was likely that they would accrue some benefit from the nematode-clearing effect of non-host break crops on their conventional banana planting material.

Initially, 22 farmers interested in participating in the trials cum demonstrations were identified. A number of interested and otherwise qualifying farmers were excluded by the selection criteria (**Appendix 4**) at this stage, e.g., their fields had to be in decline and to contain a high density (> 100 nematodes per gram of root) of banana nematodes and conform to certain site characteristics demanded by the criteria. There was a high level of farmer interest in the simple technology being offered and they commenced plot preparation (clearing bananas and planting root crops) very quickly. It was clear that the capacity of the project to monitor trials effectively was finite, as regular nematode and nutrient sampling and other required assessments were time-intensive. It was agreed with socio-economist, Dr Lamboll, that a target of 30-40 trial farmers would suffice as the main cohort of closely participating farmers. Eventually, the number of Kayunga farmers was increased to 34 in early 1997 and one large farmer (six plots) in Masaka. Of the 34 farmers growing break-crops, 30 opted for cassava and only four for sweet potato. The expected drop-out rate for natural reasons, such as changes in circumstances (e.g., financial, infirmity, bereavement, loss of interest in the trials) was 1-2 farmers per year. The final tally in March 2000 was 28 farmers remaining, which attestified to farmers' overall satisfaction with the technology. After the first year, more farmers removed un-productive bananas and took up growing break crops and participated more informally, obtaining information and support from the project, or from project farmers, but without the regular sampling of their fields by the team.

(b) Baseline survey

The initial survey was highly relevant to the project activities, as it helped to identify farmer information needs and constraints which could be addressed. The findings of the baseline survey (Bagamba, 1997) showed the continuing importance of banana, with 70% of total land committed to them. The average household grew 3.4 acres of bananas. Farmers in the medium wealth group had more land allocated to bananas (4 acres) compared to high wealth (3.3 acres) and low wealth (2.3 acres) farmers. This shows that farmers in the middle socio-economic strata will probably have more interest in crop production and are likely to commit more resources to technologies that could improve banana productivity.

In terms of food security, bananas were most preferred, ranked first by 51.5% of the farmers and this was attributed to its being harvested throughout the year. Cassava was ranked second despite the fact that it is not widely grown. The reason for cassava preference was that it stayed in the soil for a long time without rotting. Sweet potatoes were ranked third and yams fourth. Matooke (East African highland cooking bananas – AAA group) were the most preferred food crop in terms of taste by 93% of the respondents. Cassava production was limited by cassava mosaic virus, which had almost wiped out the crop. Access to cassava planting material resistant to mosaic virus was very limited. Availability of good planting material was probably a major motivation for farmers to participate in this project but in itself, this is not a defect, since a liking for cassava due to poor banana yields is perfectly logical and practical. Cassava planting material was supplied free to farmers.

Farmers were asked to rank the matooke cultivars in terms of preference to help in future selection of banana planting material to supply to farmers. Ndibwabalangira, Nakitembe, Ntikka, Siira and Mayovu were the main cultivars cited.

Changes in banana productivity. All respondents reported change in banana productivity with 93% of the farmers claiming to have experienced a decline in production. On average, bunch weight reduced from 15kg to 6kg over the years. The numbers of bunches harvested per month in a bumper period shrunk from 140 bunches to 29 bunches (Table 4.1.1). Farmers in the top socio-economic strata experienced the greatest decline in banana productivity with bunch-sizes falling from 20kg to 6kg. Farmers in the middle strata experienced serious decline in banana production, with bunch sizes falling by about 10kg (Table 4.1.1) and the number of bunches reducing from 165 to 35 per month, but this was still better than farmers in the top and bottom strata.

Table 4.1.1 Changes in banana productivity

Productivity characteristics	Top	Middle	Bottom	Overall
Average age of current banana plot (years)	1.2	15.8	3.2	11.9
Minimum age of banana plot (years)	0.7	1.0	1.0	0.7
Average bunch weight (kg) before decline	20.0	15.8	9.8	14.7
Monthly harvested bunches before change				
Bumper period	50.0	165.3	47.3	140.0
Scarcity	-	28.4	-	28.0
Current bunch weight (kg)	6.0	5.5	7.4	5.9
Current bunches harvested per month				
Bumper period	10.0	35.1	14.8	28.6
Scarcity	4.0	5.8	5.3	5.5

Factors attributed to the decline in order of decreasing importance included pest buildup, drought, poor soil fertility and poor management practices (Table 4.1.2). Pests associated with the decline included the banana weevil (reported by 79% of the farmers), ants ('Kaasa') (71%) and to a lesser extent earthworms ('Obusiringanyi') (7%) (Table 3). Few farmers (7%) differentiated toppling from weevil damage implying that farmers are less aware of the nematode problem.

Table 4.1.2 Causes of banana production decline

Reasons for Production decline	Proportion of farmers (%) Top	Middle	Bottom	Overall
Decline in soil fertility	33.3	50.0	0.0	39.3
Drought	66.7	45.0	40.0	46.4
Poor management	33.3	25.0	20.0	15.0
Pest buildup	66.7	65.0	40.0	63.0
Kind of pests				
Weevil	33.3	85.0	80.0	78.6
Ants	66.7	70.0	80.0	71.4
Earthworms	0.0	10.0	0.0	7.1
Toppling	66.7	10.0	0.0	7.1

Planting material: Most planting material was secured from own plantations and pest control measures were minimal. 97% of the farmers planted maiden suckers, which by the time of planting would have had pest accumulation (weevil and nematodes), encouraging pest buildup and dispersal.

Few farmers employed practices that could improve soil fertility and moisture management. Despite the fact that weeding was done frequently (6 times annually), this was done using a hoe which could lead to root damage.

Pest management: Pest management in the field was minimal with 32% of the farmers not carrying out any pest management. Other farmers reported using a variety of methods to control the pests but on a less intensive scale. The majority of farmers were not satisfied with the methods they used to control their pests. Only 18% rated the methods used as moderately effective and 18% rated the effectiveness as low. 11% rated the methods used as ineffective**.**

Pest management information: Limited access to information was a major constraint to pest management. 11% of the respondents reported lack of access to information, 11% received information from the extension service and only 4% receive information from the radio. A higher proportion of farmers (25%) got information from fellow farmers.

Cassava plots: The first cassava in the Kayunga sites was planted in November 1996. Harvesting began in July 1997 without consent from researchers. Food shortage was one of the reasons that persuaded them to harvest the cassava early. Most farmers in the area usually have less food for household consumption. Most farmers complained that the cassava (variety SS4) was bitter. Below 12 months, the cyanide content is still high but farmers could not wait for this to reduce. The 8 month period between planting and harvesting was also still too short to have an effect on the nematode population, which necessitated a second cassava planting.

Most of the farmers had inter-planted the cassava with other crops, especially beans, maize and groundnuts, without consent from the researchers. Beans and maize are known hosts to Pratylenchus goodeyi. Farmers claimed to have been advised by the extension agent residing in the area, who had been involved in the project in the early stages, to go ahead with inter-cropping. Inter-cropping cassava with other crops is a tradition in the area to enable farmers to produce food in a period when cassava is not yet ready.

Findings: The main finding from the baseline survey Bagamba (1997) (Appendix 5) was that:

1. There was a need to improve the farmers' knowledge-base on pest control and soil-improvement as a way of improving banana productivity, which would also encourage farmers to adopt the break crop technology.
2. Nematode control was seen as necessary but, packaged and presented as a stand-alone (single-pest) control strategy, was probably not the most effective way to improve banana productivity in the area. The project should therefore aim for a more encompassing presentation when promoting the break crop technology, taking into account cultural, agronomic, biological, social and economic aspects.

4.1.2: Techniques for mass-culture of key nematodes established.

Successful i*n-vivo* screen-house mass-culture methods were developed for the important banana nematodes. The methods were described in **Section 3.2.1**. This work developed concurrently with similar screen-house work, investigating the banana nematode host status of (a) common weeds and (b) common crops found in the banana cropping system.

Findings: Susceptible banana plants were used initially to culture the nematodes (*R. similis, P. goodeyi and H. multicinctus*), until better hosts were found. Other than bananas the best host plant(s) for mass production of *R. similis* was found to be groundnut; for *P. goodeyi* beans and maize and for *H. multicinctus,* beans.

4.1.3: Evaluation of methods for transfer of tissue-cultured plants from laboratory to field

At KARI, specialist staff had completed training in tissue-culture laboratories in S. Africa by early 1997. Methods for production of tissue-cultured banana plants, weaning and hardening-off were verified and later documented by Namanya *et al.* (1999**)**. This is shown in **Appendix 6**.

Meristem and shoot tip culture is a routine method used in rapid multiplication of bananas that are true to type. Adventitious buds induced from shoot tips on a modified MS media are repeatedly dissected to increase the number of buds. Rooted plants, after acclimatization in the nursery for 1-2 weeks, are potted in plastic pots for 1.5-2 months and supplied to farmers for field planting. *In vitro micropropagated* plants are disease free, more vigorous in growth, have higher rates of survival and a uniform growth compared to suckers. **Decapitation** is a technique in which the apical meristem is destroyed to suppress apical dominance and stimulate sucker development. This produces 8-12 suckers (depending on cultivar) 3-4 months earlier than normal regeneration of 10-12 months. Ongoing work is aimed at improving plant quality and increased production of planting materials to meet the farmers' needs. KARI has been able to provide clean planting material for 22 mother gardens in seven districts of Uganda (Masaka -1, Kamuli -1, Rakai-1, Kibale -3, Mpigi -4, Luwero-11, Mbarara-1). Materials have been provided for Individual farmers, Non Governmental Organisations and Research scientists' experiments (both on farm and on station).

Field handling, planting and management of tissue cultured plants: The main methods of transferring plants to the field were assessed and ways of avoiding plant losses were developed (Kashaija and Namaganda, 1999) and these are outlined in a guide leaflet in **Appendix 7**. Subsequently, a more detailed report was produced on **Production and handling of banana planting material** by Namaganda, 2000 (see **Appendix 8)**. Tissue cultured banana plants are normally kept in the nursery for a period of 2 -4 months before field planting. This prepares them for direct sunshine under field conditions. By this time, the plants are 20 –30 cm tall with at least 3-5 broad leaves. These are then ideal for field planting.

The advantages of tissue cultured banana plants are that they:

- will establish quickly
- grow more vigorously and taller,
- produce bigger and heavier bunches,
- have a shorter and more uniform production period.

In general the superior performance of micro-propagated bananas is due to the fact that they already posses an active root and shoot system at the time of planting.

4.2 *On-Farm and On-station technical activities*

4.2.1 Field trials to establish the optimum duration for break-crops to control nematode populations

Nematode densities in soil and roots of bananas and break crops were monitored at three sites (Kawanda, Kayunga and Masaka) as described in **Section 3.2.2.**

4.2.1.1 Kawanda

In addition to the continuous banana, cassava and sweet potato break-crops planted at on-farm sites, these on-station trials also included macuna, maize and beans (see **Section 3.2.2**). This trial shows the decline in banana nematodes under break-crops, or root and soil nematode population changes under the other three crops, against those under continuous banana plots between October 1997 and August 1999 (**Appendix 9A**).

<u>Seasonal nematode population changes (Kawanda)</u>

P. goodeyi was found in soil and roots of all crops, except bean roots, and these declined to an undetectable level in all crops by August 1999. *R. similis* was more numerous than *P. goodeyi* and declined to very low numbers in soil of macuna, beans and cassava (average 10 per 1000g soil) by August 1999 (**Appendix 9A**). *H. multicinctus* numbers were high in banana and macuna soil and roots. In the other crops, numbers were high in the soil under beans and sweet potato (120-130 per sample) and low or absent in other soil and root samples, particularly beans, cassava and maize. *Meloidogyne* spp. increased over the season in soil and roots under beans and cassava, compared with banana and the other crops (see Relative Abundance, below).

Screen-house bioassays from potted bananas grown in soil collected from the trial plots following non-banana crops showed that, although 15% of banana samples (N=20) contained populations of *R. similis,* no *P. goodeyi* or *R. similis* remained to re-infect the break-crops (cassava and sweet potato) or beans (**Table 4.2.1.1**). However, 6% of macuna samples were found still to contain low populations of *R. similis*, although they were not detected in field soil samples except in August 1999. *H. multicinctus* was found in 40% of banana samples and at lower levels in maize (10%), beans (5%) and sweet potato (5%). *Meloidogyne* spp. were found in 20% of cassava samples and in macuna (6%), maize (5%) and beans (5%).

Table 4.2.1.1 Screen-house bioassays: field-trial soil samples containing nematodes after break crop cycle

	Total reps	Mean no. of Nematodes per 100g roots				No. replicates containing nematodes (Max. 5 pots, 4 reps per pot)				% of replicates with nematodes			
KAWANDA	N=	PG	HM	RS	ML	PG	HM	RS	ML	PG	HM	RS	ML
BANANA	20	0	9000	4500	0	0	8	3	0	0	40	15	0
MUCUNA	17	0	0	500	500	0	0	1	1	0	0	6	6
MAIZE	20	0	1000	0	15500	0	2	0	1	0	10	0	5
BEANS	19	0	500	0	500	0	1	0	1	0	5	0	5
CASSAVA	20	0	0	0	5000	0	0	0	4	0	0	0	20
SWEET POTATO	19	0	1000	0	0	0	1	0	0	0	5	0	0
MASAKA													
BANANA	-	-	-	-	-	-	-	-	-	-	-	-	-
CASSAVA	12	0	0	0	0	0	0	0	0	0	0	0	0
SWEET POTATO	4	0	0	0	11500	0	0	0	0	0	0	0	0
KAYUNGA													
BANANA	-	-	-	-	-	-	-	-	-	-	-	-	-
CASSAVA	104	500	18000	1000	29000	1	7	2	8	1.0	6.7	1.9	7.7
SWEET POTATO	11	0	0	0	0	0	0	0	0	0	0	0	0

PG = *Pratylenchus goodeyi* , HM = *Helicotylenchus multicinctus* , RS = *Radopholus similis* , ML = *Meloidogyne* spp.
- = No sample

<u>Relative abundance of nematodes (Kawanda)</u>

The relative abundance of nematodes under crops in the Kawanda trials is shown in **Table 4.2.1.2** and **Appendix 10A**. *H. multicinctus* was most abundant on banana and macuna, sweet potato and maize. *P. goodeyi* was abundant on maize and banana, but was much less plentiful at Kawanda than at the two other trial plot areas. *R. similis* was abundant on bananas, but occurred in insignificant numbers in soil of macuna, beans and cassava. *Meloidogyne* spp. were more numerous on cassava and beans than other crops.

Table 4.2.1.2 Relative abundance of nematode species in banana and other crops (Kawanda)

KAWANDA		**H. multicinctus**	**P. goodeyi**	**R. similis**	*Meloidogyne* spp
Banana	Soil	**	*	**	*-
	Roots	***	**	***	*
Cassava	Soil	*	*	-	**
	Roots	*	*	*-	**
S. potato	Soil	**	*	*-	-
	Roots	**	*-	*-	-
Macuna	Soil	**	*	-	*-
	Roots	**	*	*-	-
Maize	Soil	**	**	*-	*-
	Roots	**	**	*-	*-
Beans	Soil	**	*	*	**
	Roots	*-	*	*	**

*Mean nematode density per 100g fresh roots
- = absent, *- = only in single sample, low numbers <25, * = 1 - 100, ** = 101 - 1000, *** = 1001 - 10,000

4.2.1.2 Kayunga

A pre-break crop assessment of nematode numbers in soil and roots of nematode-infected banana was made in May, 1997, prior to removing them and planting the cassava and sweet potato break crops. These crops were planted, harvested as they matured and re-planted, as summarised **in Table 3.2.2.2**. All the plots were eventually re-planted with bananas in November 1998 (after 18 months), mainly with the farmer-preferred cvs. Nakitembe and Ndibwabalangira. The soil was sampled for nematodes and nutrients from May, 1997 until March, 2000. Processed electronic data for three (quarterly) sampling dates between May 1999 and May 2000, along with equivalent sample data (Nov 1999 - Mar 2000) for Kawanda, were lost due to a computer hard disk failure at KARI. These could not be re-entered from raw field data and analysed in time for this report. However, this does not prejudice the main findings of the study with respect to nematode abundance and decline under break-crops.

<u>Seasonal nematode population changes (Kayunga)</u>

Populations of the main banana nematodes, *P. goodeyi* and *R. similis* declined to negligible levels under break crops between October 1997 and May 1999 (Appendix 9B).

The numbers of *P. goodeyi* were relatively low from break-crop planting in April 1997 to banana re-planting in November 1998 through to final (root) sampling in March 2000 . *P. goodeyi* also occurred in low numbers (<20 per sample) in soil and roots associated with cassava and, in sweet potato, only on one sampling date in each case. No *P. goodeyi* were found in roots of break crops, or in re-planted banana from October 1998 onwards. The other narrow host-range nematode, *R. similis*, was found on several dates in banana soil samples and, on most sampling occasions, in roots of the continuous banana control plots. However, with the exception of two single-sample occurrences (2-8 nematodes per sample, and representing under 1% of total samples), none were found in roots and soil of cassava or sweet potato after May 1998 until the final sampling under re-planted banana in March 2000, when negligible numbers (4 nematodes per 100g root) were found in 1 sample. Conversely, the mean *H. multicinctus* numbers fluctuated but were generally around ten-times higher in bananas than in cassava and sweet potato (rarely exceeding 100 nematodes per 1000g soil or 100g roots). *Meloidogyne* spp. were more common on cassava (15-25% of samples) than banana or sweet potato (5-8% of samples). The visual appearance and production of cassava did not seem to be significantly affected by root-knot nematode population levels, which averaged 930 (180-3590) nematodes per 100g of roots (Appendix 9B).

Screen-house bioassays from potted bananas grown in soil collected from the trial plots following break crops before re-planting, showed that sweet potato soil contained no infective nematodes. However, 1% of replicate soil samples from under cassava contained *P. goodeyi* and 1.9% of samples contained *R. similis*. In addition, 6.7% of cassava samples contained *H. multicinctus* and 7.7% contained *Meloidogyne* spp.

Relative abundance of nematodes (Kayunga)

At least one earlier diagnostic survey by the NBRP showed that *R. similis* and *H. multicinctus* were generally more abundant in Kayunga, while *P. goodeyi* were more numerous in Masaka. This is generally supported by soil and root nematode densities shown in **Tables 4.2.1.3 and 4.2.1.4**.

Table 4.2.1.3 Relative abundance of nematode species in banana and other crops (Kayunga)

KAYUNGA		**H. multicinctus**	**P. goodeyi**	**R. similis**	*Meloidogyne* spp
Banana	Soil	***	*	**	*
	Roots	***	**	**	**
Cassava	Soil	*	**	*-	**
	Roots	**	-	**	***
S. potato	Soil	**	**	*-	*
	Roots	**	-	-	**

*Mean nematode density per 100g fresh roots
- = absent, *- = only in single sample, low numbers <25, * = 1 - 100, ** = 101 - 1000, *** = 1001 - 10,000

P. goodeyi was found in moderate numbers (**) in banana roots and low numbers (*) in soil. It occurred in moderate numbers in cassava and sweet potato soil, but was absent from their roots. *R. similis* occurred in moderate numbers on banana and on roots of cassava. However, the cassava populations declined to nothing after March 1998, 16 months before re-planting with banana in September 1999. *H. multicinctus* was abundant in banana roots and soil and moderately abundant in cassava roots and sweet potato roots and soil (**Appendix 10B**). *Meloidogyne* spp. was abundant in cassava roots and moderately abundant in roots of banana and sweet potato and soil of cassava.

4.2.1.3 Masaka

Seasonal nematode population changes (Masaka)

P. goodeyi , *R. similis* and *H. multicinctus* were abundant in roots and soil of continuous banana, often occurring in 50-97% of root samples on different sampling dates. *Meloidogyne* spp. occurred only in occasional low numbers. However, the break-crops were only lightly affected.

P. goodeyi and *R. similis* were cleared from roots of cassava and sweet potato by May 1999, although small numbers of *P. goodeyi* (10% of samples) remained in cassava soil. (**Appendix 9C**) . *H. multicinctus* and *Meloidogyne* spp. declined to undetectable levels in cassava and sweet potato soil and roots by May, 1999, although *Meloidogyne* spp., anyway, occurred in very low numbers at this site. Final samples (roots only) taken from continuous banana and break crop plots in March 2000, six months after re-planting with banana, disclosed no *P. goodeyi* or *R. similis* in the "break crop" banana plants, but high numbers of *P. goodeyi* (2000 per 100g root) in the continuous banana plots.

Screen-house bioassays from potted bananas grown in soil collected from the trial plots following break crops, showed that no infective banana nematodes remained in soil from the four cassava break crop plots to re-infect potted banana plants in the screen-house. However, all four replicate samples from the sweet potato plots contained *Meloidogyne* spp.

Relative abundance of nematodes (Masaka)

H. multicinctus, *P. goodeyi* and *R. similis* were abundant in roots of continuously grown (control) bananas in the Masaka trials. *R. similis* occurred in low numbers, while *H. multicinctus* and *P. goodeyi* occurred in moderate numbers in banana soil. All four species occurred in intermittently and in low numbers in cassava soil, but only *P. goodeyi* was found in cassava roots, and then on only one occasion (Jan 1998) in negligible numbers (**Table 4.2.1.4 and Appendix 10C**). In sweet potato soil, *H. multicinctus* and *Meloidogyne* spp. were found in low numbers, but each on one occasion only . In sweet potato roots, both were found in moderate numbers, but only one or two occasions in the early part of the trials.

Table 4.2.1.4 Relative abundance of nematode species in banana and other crops (Masaka)

	H. multicinctus	**P. goodeyi**	**R. similis**	*Meloidogyne* spp

MASAKA					
Banana	Soil	**	**	*	*-
	Roots	***	***	***	*-
Cassava	Soil	*	*	*	*-
	Roots	-	*-	-	-
S. potato	Soil	*-	-	-	*
	Roots	**	-	-	**

*Mean nematode density per 100g fresh roots
- = absent, *- = only in single sample, low numbers <25, * = 1 - 100, ** = 101 - 1000, *** = 1001 - 10,000

4.2.1.4 General findings from field trials

Nematode decline and break-crop duration

Most banana nematodes (*P. goodeyi* and *R. similis*) were cleared, or declined to very low numbers under break-crops. *H. multicinctus* has a much broader host-range and numbers generally did not decline in crops that were able to maintain them in high numbers at the beginning of the trials. Some crops, like macuna, were better hosts to *H. multicinctus* than others (cassava, . *Meloidogyne* spp. were widespread and were not reduced by break-crops. *Meloidogyne* was not observed to be a serious problem with the SS4 variety of cassava or with banana. However, it might become a complication with cassava, if the selected or preferred break-crop variety is not resistant or tolerant to nematodes. This was foreseen and some cassava varieties were evaluated with IITA and the National Programme in this study (Talwana *et al.* 1997a and b). Further work with new varieties continually being released will be needed.

H. multicinctus and *R. similis* were more abundant at Kayunga, while *P. goodeyi* was more abundant at Masaka. *P. goodeyi* and *R. similis* were found in soil and roots of cassava and sweet potato, but they were in low numbers and it appears from other studies that they would not reproduce on these break crops. Maize was a good host to *H. multicinctus* and *P. goodeyi* , macuna was a good host to *H. multicinctus* and beans were a moderately good host to *Meloidogyn*e spp.

Work done by Namaganda (1996) and Namaganda *et al.* (1998) concluded that a period of at least 15 months of break-crop cultivation was required to reduce banana nematodes to negligible levels. In the present study, the optimum period required under break-crops to clear the narrow-host banana nematodes, *R. similis* and *P. goodeyi* could not reliably be determined in the time available, despite a one-year extension. This was largely due to prolonged periods of extremely dry weather at key times in the growing cycles. In extreme dry conditions, certain activities are detrimental to plant development and production and e.g., sampling and planting/transplanting cannot be attempted without risk of crop damage or loss. This meant that some activities had to be deferred until there was rainfall, causing delays in re-planting (bananas) and in the sampling and assessment programme. At the time of the last field and sampling assessment in March 2000, only a few plants on a small number of farms had harvestable bunches, so that only a tentative impression could be obtained, and this was done in the final socio-economic assessment (Bagamba, 2000).

The sites all had different periods under break-crops, as follows:

Kayunga 18 months
Masaka 23 months

Kawanda 27 months

There was no direct relationship between length of break-crop and (time taken for) nematode clearance or decline to negligible numbers. Agro-ecological and other site characteristics, and also effectiveness in clearing original banana material from the soil and prevention of re-infection, or contamination with new host-plants probably influenced the effective break-crop interval, as reflected by banana nematode decline.

Kayunga: The narrow host-range banana nematodes, *R. similis* and *P. goodeyi* , both appeared to be cleared from most farmers' plots within 18 months. Some farmers did not manage their plots quite as effectively as others and it was no surprise that a small number of bioassay samples from under cassava were found with a trace number of these nematodes (1% of samples contained small numbers of *R. similis* and 1.9% *P. goodeyi*) in two farmers' cassava break-crop plots out of ten sampled (Ssajabi and Nalwanga plots, respectively).

Masaka: *R. similis* and *P. goodeyi* were cleared from **roots** of break-crops within 23 months but very low numbers of *P. goodeyi* were still found in 10% of **soil** samples from cassava break-crops. However, occurrence of these nematodes in break-crop soil is relatively unimportant compared with roots and this was confirmed by a complete absence of these nematodes in subsequent bioassay samples from bananas grown in this soil.

Kawanda: *P. goodeyi* were cleared from all non-banana crops within the 27 months period , whereas *R. similis* was cleared only from sweet potato and maize and declining to negligible numbers in cassava, macuna and beans (**Appendix 9A and 10A**). However, they were not found in screen-house bioassay samples of bananas grown in field soil from cassava, sweet potato break-crops or beans (**Table 4.2.1.1**).

It is concluded that most plots can be cleared of the main banana nematodes in 18 months, or populations reduced to insignificant numbers, using root and tuber break-crops, or non-host crops. *H. multicinctus* is not strongly affected (reduced) by cassava, sweet potato and some other crops, as it has a wider host-range than *P. goodeyi* and *R. similis*. However, it is generally a less damaging banana pest than these, even though it is often found in denser populations under banana and damage may occasionally become locally severe.

Crop and yield quality

Because of poor seasonal rainfall, it was not possible to assess and demonstrate yield benefits in the ratoon crops (i.e., second and subsequent crops) in which bunch sizes are typically larger than the first crop. Also, because of the dry periods and generally lower annual rainfall over the project term (**Fig. 3.2.2.2**), it is unlikely that sufficient yield gains would have been demonstrable, even with a 6-12 month project extension, to have been any more convincing to most farmers than the qualities and improvements which were observed. Within the constraints of the time available, generally favourable farmer opinions on the plant vigour and fruit yield and quality were obtained and are discussed in **Sections 4.4.1, 4.4.2** and **4.5.**

4.2.2 Examination of host status of common weeds and crops for key nematodes.

4.2.2.1 Host status of weeds

In Uganda, the plant parasitic nematodes *R.similis, P.goodeyi* and *H.multicinctus,* have been identified among the major factors responsible for decline in banana production (Gold *et al.*, 1993; Kashaija *et al.*, 1994). Banana establishments are normally associated with a wide range of weeds, both broad-leaved and grasses, some of which may be alternative hosts of banana nematodes. The objectives of this study was to identify weed species associated with banana establishments in Uganda and to determine the host status of the most common ones to the important banana nematodes.

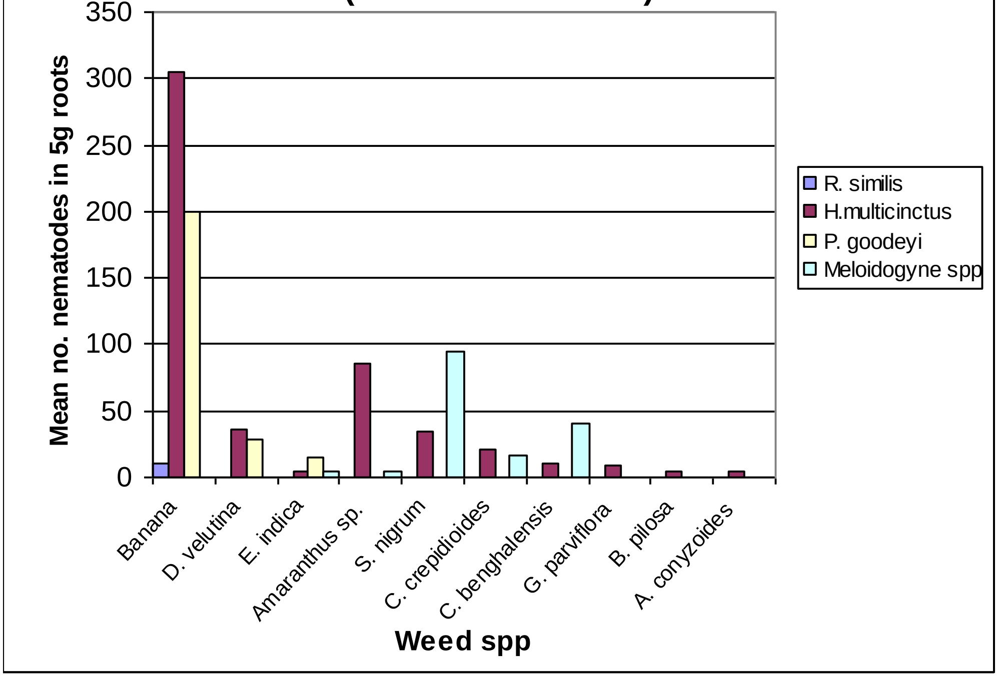


Fig. 4.2.2.1 Mean nematode numbers in 5g roots (Banana and Weeds)

The host status of 13 common weed species to banana nematodes was studied in screenhouse experiments. Banana nematodes were recovered from soil and roots of both banana and nine weed species but nematode population densities indicate that these weed species are poor hosts of banana nematodes (**Fig. 4.2.2.1**). *H. multicinctus* was the only nematode species recovered from soil and occurred on banana and only six weed species at population densities much lower than that of banana. From roots, *R.similis* was recovered from banana only, while *H. multicinctus* was present on banana and nine weed species and *P.goodeyi* was present on banana and only two weed species, *Digitaria velutina* and *Eleusine indica*, at a very low count compared to banana. No nematodes were recovered from *Tagetes minuta*, *Cyperus esculentus*, *Senecio disfolius* and *Digitaria scalarum*, indicating that these four weed species are non-hosts of banana nematodes.

The weed species in this study were either non-hosts or poor hosts of the major banana nematodes. However, the poor hosts are potential reservoirs of these nematodes that may result in nematode population build-up in banana plots. Results of Hannon, 1963 (Blake, 1969) suggest that *R. similis* might survive in soil for longer than 14 months unless special precautions are taken to remove susceptible hosts, including weed species.

These experiments are not conclusive, as nematode population levels in the inoculum were relatively low and the different nematode taxa were present at different population starting levels.

However, the results were similar to those found by other researchers. Most reports do suggest a limited host range for the major banana nematodes.

4.2.2.2 Host status of common crops

From the two sites surveyed (Kayunga in Mukono and Kyanamukaka in Masaka district), 37 crops common to the banana cropping systems were identified. They included fruit trees and other perennial crops, and annual crops, including vegetables. The following ten were selected for host-status assessment: beans/*Phaseolus vulgaris*, carrot/*Daucus carota*, cassava/*Manihot esculenta*, ground nuts/*Arachis hypogaea*, maize/*Zea mays*, millet/*Eleusine coracana*, pineapple/*Ananas comosus*, sweet potato/*Ipomea batatas*, tomato/*Lycopersicon esculentum*, and the control, banana/*Musa sapientum*). Overall, five plant-parasitic nematode species were found in root and soil samples collected from the ten crops. These were *Helicotylenchus multicinctus*, *Pratylenchus goodeyi*, *Radopholus similis*, *Meloidogyne* spp and *Rotylenchulus* spp. The latter species was found only in one millet root sample and was therefore not included in the analysis. Similarly, results of nematodes from soil samples are not presented as the numbers recovered were too small for meaningful analysis.

The results showed that pineapple and carrot were either immune or non-host to the major banana nematodes (*Radopholus similis*, *Pratylenchus goodeyi* and *Helicotylenchus multicinctus*) in Uganda. None of the three nematodes was found in either roots or soil of these two crops. Similary, no *R. similis* were found in either roots or soil of beans, cassava, sweet potato or tomato crops.

H. multicinctus had a significantly higher population density in beans than in all the other crops. The density of *P. goodeyi* was similar in banana, beans and maize but higher than in the other crops. *R.. similis* density was much higher in ground nuts than in banana which in turn had a significantly higher density than millet. The density of *R. similis* in banana was similar to that in maize. A higher population density of *Meloidogyne* spp. was found in carrots followed by tomato.

Discussion

Five genera of plant parasitic nematodes, *R. similis*, *P. goodeyi*, *H. multicinctus*, *Meloidogyne* spp and *Rotylenchulus* sp., were found associated with 10 different crops that were examined for host suitability/status to banana nematodes. Of these, *R. similis*, *P. goodeyi* and *H. multicinctus*, are known to be the major nematode pests of bananas in Uganda (Kashaija, 1994; Speijer *et al.*, 1994). *Meloidogyne* spp, though reported as an important banana nematode in Taiwan (Gowen and Queneherve, 1990), does not appear to be a serious pest of bananas in Uganda.

The crops evaluated varied in their host status to the different nematode species. Banana was infested by the four known banana nematode species. Only *Meloidogyne* was found on carrot and no nematodes were found on pineapple. *Rotylenchulus* sp. was only found in millet. Beans, maize and groundnuts were as attractive to *P. goodeyi* as banana. Beans also supported a higher population density of *H. multicinctus* than banana but were not infested by *R. similis*. Namaganda *et al.* (1996) found that beans and maize were good hosts of *P. goodeyi* but banana was observed to be a better host than either in that study.

Although *R. similis* is known to have a narrow host range, its status in most other crops grown in Uganda is poorly known. This study indicates that groundnut is a good host to *R. similis*. However, it is possible that being very susceptible, the banana roots were damaged by the nematodes leading to their suppressed multiplication because *R. similis* can be very sensitive to food quality (Kashaija, 1996).

Of the six crops infested by *Meloidogyne*, significantly higher densities occurred in carrot and tomato. The status of carrots to root-knot nematodes in Uganda is not well understood but tomatoes are known to be very susceptible.

Beans are good hosts of *P. goodeyi* and *H. multicinctus* and a non-host of *R. similis*. Maize is a good host of *P. goodeyi* but a poor host of *H. multicinctus* and *R. similis*. Groundnuts are better hosts of *R. similis* and poor hosts of *P. goodeyi* and *H. multicinctus*. On the other hand, the results indicate that pineapple is a non-host of all the four nematodes and carrot is not a host to the three key banana nematodes. According to Bafokuzara (1982), however, pineapple was associated with some (unspecified) species of the genera *Helicotylenchus*, *Rotylenchulus*, and *Meloidogyne*, and with *Pratylenchus brachyurus*, which is not a pest of banana.

Intercropping other crops is common practice in Uganda and East Africa banana-growing areas. This is mainly a result of shortage of land. Our results suggest that beans, maize and ground nuts should not be intercropped with banana as they are equally good or better hosts of the important banana parasitic nematodes, and will therefore easily lead to increased populations of these nematodes under banana. Cassava, millet, sweet potato and tomato are shown to be poor hosts. Although the reproductive factor was not measured, the results implied that multiplication in these crops was very low. If intercropping can not be avoided these crops could be used. Such crops should however not be intercropped for a long period as the banana nematode population may gradually build up. The same crops could instead be used in rotational banana-cropping to reduce banana nematodes in heavily infested fields to a level below the damage threshold. The study has shown two crops (pineapple and carrot) that are non-hosts to the three banana nematodes. The former is already commonly used as an intercrop in some parts of Uganda (e.g. Mukono). The two crops could therefore be recommended for use as the best intercrops or rotational crops in the banana cropping system, subject to other agronomic and social factors.

4.2.3 Quarterly assessment of soil fertility levels with break crops and clean banana sequence

Soil samples were collected from the trial sites for soil nutrient analysis on three occasions (Pre-treatment, 12 months and 24 months after break crop planting) between May 1997 and May 1999. The most important banana nutrients are potassium (K) and nitrogen (N). The on-station and on-farm results were not in total harmony, as on-farm results indicated no consistent effects of cassava and sweet potato on the levels of nutrients in soil, unlike on-station levels. This was thought to be due to the considerable soil variation within and between farmers' plots in Kayunga, which have different histories and may be separated by a distance of more than one Km. For this reason, the on-station nutrient levels only were analysed to provide an indication whether commonly grown alternative crops, particularly break-crops, had any significant depleting effects on nutrients required by banana plants in a (break-) crop sequence.

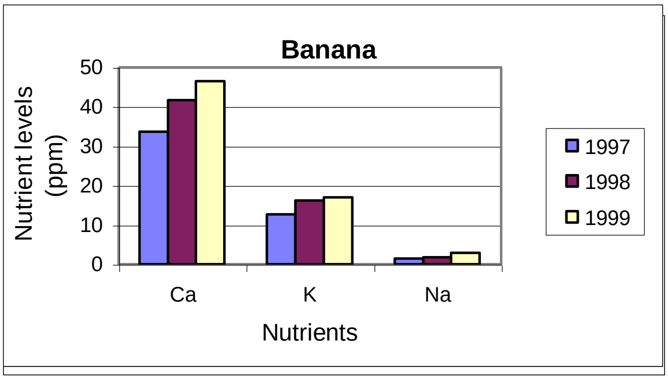
The on-station results showed that maize and cassava depletes soil of potassium and calcium (Ca), falling year by year, compared with banana (**Fig. 4.2.3.1**). The level of potassium fell by 63.5% after one year and by 76.3% after two years of continuous cultivation of cassava in a field previously under banana. The average levels of potassium in the cassava plots after two years were reduced by 69% compared with continuous banana plots. Macuna and beans also reduced potassium (by 41-56%) and calcium levels (by 22-52%) over 2 years. In year one, potassium levels under sweet potato fell by 46.6% and calcium levels by 19.5%, but did not fall further in year two

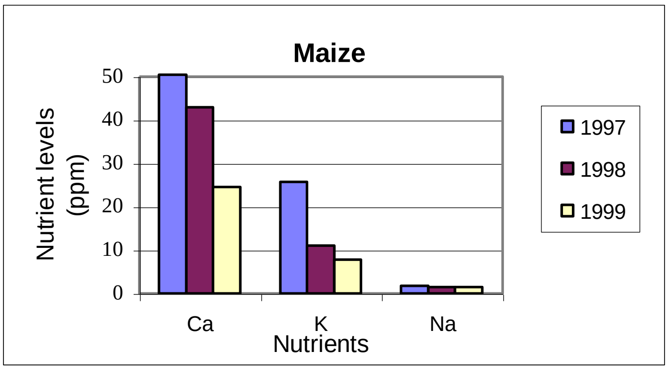
Discussion

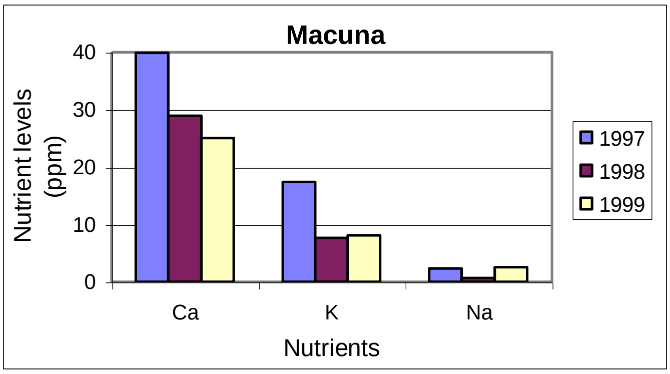
The main findings from the soil nutrient studies are that cassava and maize tend to deplete the soil of potassium and calcium (**Fig. 4.2.3.1**). Potassium is the most important nutrient for banana plant development, and therefore to the grower, who must take steps to correct any nutrient deficit when bananas are re-planted. Potassium is essential for flower initiation, to obtain maximum fruit, hand and bunch numbers and fruit size. Low potassium is known to restrict the transfer of nitrogen, phosphorus, calcium, magnesium, sodium, manganese, copper and zinc across the xylem and it also reduces dry matter production, especially to bunches (Lahav, 1995). Low potassium supply tends to produce thin fruit and fragile bunches. This is why potassium is so important in banana-culture and growers need to be aware of the nutrient-depleting characteristics of any break-crops or inter-crops to optimise their production prospects.

.

Fig. 4.2.3.1 On-Station Trials: Soil nutrient changes (1997-1999)







4.2.4 Clean banana plant vigour and quality up to flowering monitored with farmers

The background was discussed in **Section 3.2.2**. As manpower and resources were limited and quantitative assessments were likely to be confounded by wide temporal, varietal and between-site variability, this aspect was monitored through socio-economic and researcher surveys with farmers.

A majority of farmers felt that the experimental plot banana plants looked at least as good as conventional bananas and 50% said that the former actually looked healthier (Bagamba, 1999). Farmers noted repeatedly that newly planted suckers, particularly pared ones, established poorly if there was drought or insufficient rain, whereas tissue-cultured plants generally recovered easily and looked healthier (Bagamba, 2000). In farmer group assessments, yields were considered to have become much more acceptable after application of the technology by the Ntenjeru group. Some farmers of this and the Ntooke group appreciated better the crop vigour and quality differences between the field trial and traditional plots (Bagamba, 2000). However, as noted elsewhere, banana varieties were chosen by farmers on the basis of their familiarity and security, rather than higher yield. Many local varieties are not grown for high yield. For example, variety Ndyabalangira has tolerance to local conditions, early-maturing characteristics and good taste and texture, but typically has average bunches, whereas one or two varieties such as Mpologoma were said by some farmers to show good quality and vigour and to yield significantly larger bunches (**Section 4.4.2.1**).

The quality and vigour of the tissue-cultured banana plants was also assessed by researchers, who rated the farmers on management and crop performance (**Section 4.4.2.1** and **Table 4.4.2.2**). The high scores for performance attest to the crop quality, although this was also due to overall management methods used, as well as the use of clean (tissue-cultured) planting material. Having tried and accepted the principle of growing tissue-cultured plants, various farmers expressed a preference for growing higher-yielding varieties for home consumption and for market. In considering future promotion and wider uptake, higher yield is an important crop quality and can contribute to improving the livelihoods of poor farmers. This is clearly an area for further evaluation and development in a future adaptive project.

4.3 *Training and dissemination activities*

4.3.1 Train local staff in nematode identification and evaluation of soil populations and root damage

As described in **Section 3.2.3**, four technicians were trained, acquiring specific knowledge and skills for the nematode break crop field and laboratory research over the course of the project. They conducted the routine soil and root sampling, extraction and processing for nematode assessments, preparation for nutrient analysis, collecting and recording field and laboratory information for the project and accompanying research staff on field visits. Two technicians also assisted periodically with preparation of tissue cultured plants.

4.3.2 Assessment of nematode species profile on 10 yam varieties and extent of damage; dissemination.

As described in **Section 3.2.3**, a trial was established at Sendusu, which is 40 km north of Kampala in Uganda, to assess the host plant response to natural nematode infestation of yam lines. Of particular interest was the possibility of infestation by nematodes which also attack bananas.

Five genera of nematodes were found parasitic on yams in this study: *Meloidogyne* spp., *Pratylenchus* spp., *Scutellonema* sp., *Rotylenchulus* sp., and *Helicotylenchu*s sp. (**Table 4.3.2.1**). *Meloidogyne* spp. were the dominant species, with densities ranging from 0 to 23,017 nematodes per 100g of tuber material. *Pratylenchus* spp. (a mixture dominated by *P. pratensis* and few *P. coffeae* (identified by Dr. J. Bridge, CABI) were the second most abundant, with between 0 and 291 nematodes per 100g of tuber material. *Helicotylenchus dihystera*., *Rotylenchulus* spp., and *Scutellonema brachyurus* (identified by Dr. J. Bridge, CABI) were observed in low densities (**Table 4.3.2.1**).

Line TDR 87/00559 OP 38 supported the highest population of *Meloidogyne* spp. of 23,017 larvae per 100g tuber material. The line TDR 87/00559 OP (34) followed with a density of 12,436 *Meloidogyne* larvae per 100g tuber material. No nematodes were observed on tubers of the lines TDR 87/00571 OP (71) and TDR 91/00121 OP (22), with only the line TDR 91/00658 OP (30) not being significantly different ($P < 0.05$) from these two lines.. A good correlation was observed between the tuber galling index and the number of *Meloidogyne* spp. larvae in tubers, with $r = 0.74$ ($P < 0.0001$, $R2 = 0.55$). *Pratylenchus* spp. densities were generally low (less than 292 per 100 g of tuber material) however, significant differences in densities were observed between the cultivars There was no correlation between the *Pratylenchus* spp. density and the tuber gall index or the numbers of *Meloidogyne* spp. larvae.

Discussion: The nematode species identified in this study have been reported previously as parasitic on yams by Jatala and Bridge (1990). *Scutellonema* spp. and *Pratylenchus* spp. have been reported to severely infest yams (Bridge 1978; IITA, 1985; IITA 1995). Contrary to this, the current results show scant occurrence of these nematode species under natural infestation in Uganda. Since the trial was set on land formerly under fallow, it is likely that there were few or no previous alternative hosts for these nematode species. Also, tissue culture planting material was used, which was free of nematodes. The dissemination of *Scutellonema* spp. in fields is mainly through planting of infested seed tubers or yam setts from the previous season (Bridge 1988; Wilson *et al.* 1988). *Meloidogyne* spp. were common, probably because these nematodes have a wide host range (Jatala & Bridge, 1990), which can maintain high populations in the field. Though not considered serious pests, *Helicotylenchus* spp. and *Rotylenchulus* spp. have also been reported to attack yams (Bridge 1988; Jatala & Bridge 1990) and were observed in this study.

Table 4.3.2.1. Comparison of nematode densities/ 100 g fresh tuber weight of different yam cultivars, July 1997.

Cultivar	Line	*Meloidogyne* spp.	*Pratylenchus* spp.	*Helicotylenchus* sp.	*Scutellonema* sp.
TDR 87/00559	OP (38)	23,017 a	0 c	63 b	0 b
TDR 87/00559	OP (34)	12,436 ab	0 c	21 b	0 b
TDR 89/01892	OP (15)	9,540 bc	83 b	83 b	42 a
TDR 91/00047	OP (27)	5,833 cd	291 a	0 b	0 b
TDR 91/00807	OP (72)	4,021 d	125 b	0 b	0 b
TDR 89/01892	OP (19)	3,229 d	0 c	0 b	0 b
TDR 87/00571	OP (68)	2,708 d	167 b	0 b	0 b
TDR 91/00047	OP (87)	2,604 d	104 b	0 b	0 b
TDR 89/01892	OP (14)	2,583 d	42 b	0 b	0 b
TDR 91/00658	OP (34)	2,354 d	167 b	0 b	0 b
TDR 87/00559	OP (35)	1,125 de	125 b	63 b	0 b
TDR 91/00121	OP (17)	1,000 de	83 b	0 b	0 b
TDR 87/00571	OP (74)	979 e	146 b	0 b	21 ab
TDR 89/01537	OP (78)	937 e	0 c	0 b	0 b

TDR 89/01537	OP (60)	750 e	42 b	854 a	0 b
TDR 91/00658	OP (44)	667 e	83 b	208 b	0 b
TDR 91/00047	OP (93)	500 e	21 b	0 b	21 ab
TDR 91/00807	OP (50)	417 e	0 c	0 b	0 b
TDR 91/00807	OP (46)	146 e	0 c	0 b	0 b
TDR 91/00121	OP (23)	104 e	0 c	0 b	0 b
TDR 89/01537	OP (51)	83 e	0 c	21 b	0 b
TDR 91/00658	OP (30)	75 ef	0 c	0 b	0 b
TDR 91/00121	OP (22)	0 f	0 c	0 b	0 b
TDR 87/00571	OP (71)	0 f	0 c	0 b	0 b

Within columns, means with the same letter do not differ significantly at $P < 0.05$ using Ls means PDF. Means computed from 10 plants per line. Mean nematodes/100 g

Line TDR 87/00559 OP 38 was severely affected by *Meloidogyne* spp., whereas lines TDR 87/00571 OP (71) and TDR 91/00121 OP (22) did not support any nematode species. This suggests a high variation in host plant response to root knot nematodes and may suggest that lines with sources of nematode resistance may be present in the Ugandan material. However, confirmation through controlled experiments of these sources of root knot nematode resistance is required.

It is of particular interest in relation to culturing yams in a banana cropping system , that the *Pratylenchus* population consisted of low numbers of *P. pratensis* and fewer banana parasites like *P. coffeae*. It was also interesting that the *Scutellonema* species was *S. brachyurus* and not *S. bradys* which is so damaging on yam in West Africa (Adesiyan *et al.*, 1975; IITA, 1985; IITA 1995). If consistently found not to be associated with large populations of nematodes of banana such as *P. coffeae* in Uganda, yams may be much more compatible with bananas than in West Africa.

Dissemination:
MUDIOPE, J, SPEIJER, P.R., MASLEN, N.R. AND ADIPALA, E. (1998). Evaluation of yam host plant response to nematodes in Uganda. African Plant Protection **4** (2): 119-122

4.3.3 Identification of suitable cassava cultivars for use as break crops (dissemination)

4.3.3.1 Evaluation of cassava for reaction to root-knot nematodes (*Meloidogyne* spp.) in Uganda

Introduction

Root-knot nematodes (*Meloidogyne* spp.) are, among others, limiting biotic factors to cassava production in Sub-tropical and Tropical areas of the world. There are several reports of the variability of cassava variety response to *Meloidogyne* spp. infection. However, the minimum population of *Meloidogyne* spp. that will cause a significant measurable loss in cassava production is not known. This study evaluated the reaction of 13 cassava varieties derived from promising germplasm in the collection of the Root and Tuber Crops Programme of Namulonge Agricultural and Animal Production Research Institute, Uganda to root-knot nematodes and estimated the threshold of root-knot nematode damage on cassava in pot trials.

Host reaction categories indicate that all the varieties tested are susceptible to *Meloidogyne* spp. even at a low initial population of 100 eggs per plant, although to varying severity.

Root-knot nematode infection caused considerable reductions in plant height and fresh root weight of cassava, four months after inoculation. Varieties 'Nase 1', 'TMS 60140', 'Bukalasa 7 and 'Bukalasa 11' seem to be more damaged by nematode infection since they had significantly higher percentage reductions in fresh root weight while 'Nase 2', 'TMS 30001' and 'SS 4' had significantly higher percentage reductions in plant height. The varieties 'Nase 1', 'TMS 60140', 'Bukalasa 7' and

‘Bukalasa 11’ have a relatively sparse root system while ‘Nase 2’, ‘SS 4’ and ‘TMS 30001’ have short plants (personal observation). This may have contributed to the significant reductions in fresh root weight and plant height, respectively. In contrast, ‘Nase 1’ and ‘TMS 60140’ had significantly lower percentage female fertility and were rated moderately susceptible to root-knot nematodes as compared to the other varieties. Therefore, it appears the reduction in fresh root weight in these varieties may be a result of hypersensitive reaction rather than nematode damage. Reductions in plant root and shoot growth of cassava due to infection with root-knot nematodes were observed by Gapasin (1980) and Caveness (1982) and of other plants (Taylor and Sasser, 1978).

They attributed the reduction in plant growth to the infected roots being shorter than the non-infected, having fewer branched roots and fewer root hairs (Taylor and Sasser, 1978; Caveness, 1982), impaired translocation of water and mineral nutrients (Gapasin, 1980) and physiological changes in plants when giant cells and galls are formed (Dropkin, 1972). The extent to which these reductions translate into production loss and the economic implications in field conditions need investigation. Besides, such reductions may not be noticed *in situ* field situations because they can be caused by mineral deficiencies, moisture stress/excess, poor soils or other pests and pathogens. The reduction in plant heights and probably plant top weights may provide inferior planting material for the following season.

The least initial *Meloidogyne* spp. population that caused a significant measurable reduction in plant height and fresh root weight was 1,000 eggs per plant. This is a damage threshold in pots where the rhizosphere may be limiting. It is, therefore, necessary to find how the loss reported in this study translates into production loss in *in situ* field situations and the nematode population that can cause this loss. There was variability in the reaction of the different cassava varieties to root-knot nematode infection, signifying that identifying and using resistant/tolerant cassava varieties may give a viable alternative of controlling root-knot nematodes on this crop.

Dissemination:

TALWANA, H. L., SPEIJER, P., ADIPALA, E. and MASLEN, N. R. (1996). 'Evaluation of cassava for reaction to root-knot nematodes (*Meloidogyne* spp.) in Uganda.' *African Journal of Plant Protection*, **6**:125-134

4.3.3.2 Effect of pre-plant population densities of root-knot nematodes (*Meloidogyne* spp.) on establishment of cassava cuttings.

Summary

The effect of pre-plant populations of root-knot nematodes (*Meloidogyne* spp.) on establishment of cassava (*Manihot esculenta* Crantz) was determined by planting cuttings of five widely grown varieties in Uganda: ‘Nase 1’, ‘Nase 2’, ‘Ebwanateraka’, ‘Bao’ and ‘Bukalasa 11’ in soil highly infested with root-knot nematodes. The nematode effect on cassava plant emergence, height, fresh tops and fresh root weight was determined 12 weeks after planting. Percentage plant emergence was significantly (P = 0.05) lower in plants grown in infested soil as compared to the control plants, although the differences in loss of plants were not significant (P > 0.05) between varieties, suggesting that all varieties were equally affected.

Nematode infection reduced the percentage plant emergence from 100% observed in the non-infested pots to less than 50% for ‘Nase 1’ and ‘Bukalasa 11’ in the infested pots. The varieties ‘Nase 2’, ‘Ebwanateraka’ and ‘Bao’ therefore showed the highest emergence of the varieties tested. Plant height, plant tops and root weights were significant (P < 0.01) reduced in infected plants as compared to control plants of each variety suggesting that root-knot nematodes have a significant effect on cassava production. Significant negative correlation coefficients were observed between number of

female root-knot nematodes that developed in 1 g of roots and fresh plant top and root weight and plant height.

This, coupled with the high coefficients of variation (CV) in infected plants, shows that root-knot nematodes can severely affect the establishment of cassava cuttings and has subsequent negative effect on production.

Dissemination:

Talwana, H L, Speijer, P, Adipala, E and Maslen, N R (1997). 'Effect of pre-plant population densities of root-knot nematodes (*Meloidogyne* spp.) on establishment of cassava cuttings.' *Proceedings of the All Africa Crop Science Congress,* Pretoria, S. Africa, 13-17 January, 1997. 128pp

4.3.4 Increased dissemination of control strategy to NARS, extension service and farmers through open days, seminars, workshop, etc).

4.3.4.1 *Dissemination methods:* As the project developed and field trials were well in progress, there was more tangible evidence to demonstrate the value of using break crops (and later return to bananas) and the variety of demonstrations and interactions increased. These effectively fed into approaches and efforts for wider dissemination. This sub-section 4.3.4 overlaps with subsection 4.3.5 in the progression and variety of training activities that led to the outputs. It is therefore useful to consider the different training, dissemination and promotion activities, with examples, which contributed to both.

1. Monitoring and farm visits

   Every three months since July, 1997 with participating farmers at Kayunga and Masaka.

2. Training in specific aspects of technology

• Break crop principles/practice	45 farmers	July - Sept, 1998
• Removal of infested banana	c. 40 farmers	"
• Land prepn/break crop cycle	c. 40 farmers	"

Conducted in stages with groups (village farmer field schools and parish level seminars) and individuals.

3. Evaluation/training visits

   (a) Obtain farmers' perceptions on the technology, field trials/demonstrations and project as a whole. Various others, but 50 farmers in Kayunga (Sept and Dec, 98) and 56 in Masaka (Sept 98 -Feb 99) participating and non-participating farmers, with Two LC's, researchers and technicians.

   (b) Farmer-participatory evaluation, Noke (= Ntooke) Primary School (17 + 5 participating and non-participating farmers) and Ntenjeru HQ (11+3 farmers). August, 1998.

4. Training visits by farmers

   To strengthen farmers' knowledge in banana management, particularly with tissue cultured material.. On-station facilities and activities and station field visits. Several groups visited KARI research station, with the first group of 6+2 women participating/non-participating farmers from Kayunga visiting for a day in January, 1999.

5. Farmer field days

   These increased when bananas were re-planted with clean planting material/tissue cultured plants, as more practical advice and discussion was requested. Farmers from Masaka and Kayunga, but also involved visits by trainers associated with FOSEM local NGO.

6. Seminar and field visit

43 participating and 5 non-participating farmers from Kayunga attended a seminar and field visit at KARI and exposed to a range of banana management practices. A follow-up visit was made to re-inforce understanding and uptake of the practices.

7. Farmer to farmer training
As mentioned above, participant farmers played a role in influencing non-participating farmers One third of participating farmers interviewed in the mid-term survey, expressed a wish to help transfer the technology to other farmers.

8 (a). Training trainers and dissemination
- Through meetings with Kayunga farmers, District and Sub-County Agricultural officers and Mr Ben Okoot of the NGO, FOSEM, members of farmers' groups were identified to work with interested project participating farmers to disseminate the technology more widely.
- A training of trainers workshop was held at Lweza Conference Centre on 15 December, 1999. The programme is shown in **Appendix 11**. The workshop was used to provide training for farmers' representatives, Sub-county extension workers, FOSEM officers, and others. FOSEM have at least 7 trainers of trainers (TOT's) in Kayunga/Nazigo District who were earlier invited to a farmers field day at KARI in order to learn how to train trainers in the break crop technologies and banana management methods. Under the new GoU de-centralisation system, an extension worker has been located at Kayunga Sub-County headquarters and it was hoped to get him involved in technology dissemination with this group.

9. Dissemination through the NARS
Dissemination of banana management and control technologies was conducted for NARO and other NARS staff. For example, the principles of banana nematode control and preliminary findings of field activities were presented (Namaganda, Kashaija and Namanya, 1998) at the NARO Centenary Conference, attended by Ugandan NARS staff.
In addition, various internal guides were produced and or presented at internal seminars (see **Sections 4.1.2** and **4.1.3**)

10. Other technology promotion pathways which were utilised included (i) The Buganda government's agricultural sector, which effectively mobilises farmers for meetings and training, including those biased to improvement of banana production, (ii) Agricultural shows and (iii) leaflets and presentations (see project publications in **Section 6**). KARI and project staff attended such meetings to demonstrate and discuss banana management technologies with visiting stakeholders.

4.3.4.2 *Uptake and promotion pathways:* As the project evolved, the differing perceptions of stakeholders towards break crop - banana technology started to emerge. These findings helped to clarify and identify the target groups and beneficiaries. Target institutions, NGO's and individuals identified through interactions with FOSEM (an NGO involved with provision of improved seed and seed technology training for farmers) include:

A. NGO's /CBO's with whom FOSEM (OFPEP) collaborates in Mukono District

Church of Uganda
Integrated Environmental Defence Project (IEDP)
Kyampisi Rural development Project (KRUDEP), Kyampisi S-c
Mirembe Self Help Project, Kayunga Sub-county
MUDDA
Saayi Common Interest Development Agency (SCIDA), Ntenjeru S-c.
Talent Calls Club, Goma and Kyampisi Sub- County

Uganda Association for Social Economic Progress (USEP)
Uganda National Farmers' Association
World Vision, Kasawo ADP, in Kasawao Sub-county
World Vision, in Ssi Sub-County
World Vision, Numuganga Sub-County
Young Womens' Christian Association
Feed the Children

B. In Kayunga Sub-County
FOSEM works directly with these.
Kisawo-Kibira Women's Group (Mrs Betty & Mrs Margaret Kibuka)
Twekembe Women's Group (Mrs D Musoke and Mrs D Kijambu)
Leero Nenkya Women's Group (Mrs D Musoke , Mrs Zaam Nkonge)

C. In particular TOT's in Kayunga/Nazigo include:

Mrs D Musoke in Nsota, Kayunga
Mrs D Kijjambu in Nsota, Kayunga
Mrs Betty Kawooya in Kayunga
Mr Robert Kyemba in Nazigo
Mrs G. Kaddu in Nazigo
Mrs Matovu in Nazigo
Mrs Merabu Musisi in Nazigo

Some of these stakeholders, particularly the latter, have visited KARI and Kayunga project farmers' demonstration trials.

The Mukono District AEP Seasonal Review 2nd Rains 1997 and Action Plan 1st Rains 1998 lists some of the above organisations (UNFA, USEP, MUDDA, World Vision, Feed the Children, Mirembe self-help, YWCA and Church of Uganda) as stakeholders in agricultural service support in Mukono District (Lamboll, 2000). Some stakeholder organisations were particularly interested in part of the technology concerned with tissue cultured banana plants. Even without any collateral interest in break crop pest control, this is an important step forward in reducing the transmission of soil pests by making available clean planting material. The district extension service had established demonstration plots, with District funds, using tissue cultured planting material from both Kawanda and Makerere University Farm (Kabanyoro). As noted by Lamboll (2000), this appears to show a clear commitment towards banana production in Mukono.

4.3.5 At least 100 participating and non-participating farmers trained in technologies tested and promoted by the project

Through one-day seminars conducted at KARI and in the project sites, 114 farmers have received training on the break crop and other banana management technologies.. Of these 80 were from Kayunga and neighbouring Nazigo, the latter having been persuaded by the performance of the demonstration plots of the core participating farmers in Kayunga. 34 were from Kyanamukaka and Kisseka Sub-counties in Masaka.

4.3.6 At least two technical papers and one socio-economic publication in final draft or submitted

The project team has published six scientific papers, which are shown in **Section 6**. Two further papers on weed and crop host-plant status assessments are in final draft form and the findings are described in **Section 4.2.2**.

4.4 *Project assessments and validations*

4.4.1 Socio-economic and technical evaluations to improve farmer dissemination and maximise uptake pathways

4.4.1.1 Baseline survey

The baseline survey helped the project team to focus and make site selection and planning decisions for the "front-end" of the project, in addition to providing qualitative and quantitative base criteria against which to measure farmer uptake and project impact in later surveys. The baseline survey findings were presented in **Section 4.1.1** in relation to project initiation activities and are therefore not repeated here.

4.4.1.2 Group assessment of farmer training needs (December, 1998)

Two different farmer groups from villages in Kayunga project area participated in two separate group meetings. The participants and the approach to carrying out the farmer training-needs assessment was described in **Section 3.2.4**. The site (banana) problems identified by farmers in their terms, together with their expressed training needs were as shown below. The following observations may clarify some of the terms used in the table.

Observations and comments

- *Kaasa* (black ants) are found throughout the plot and are thought by at the last some farmers to be detrimental;
- *Mutuba* (Ficus) trees are traditionally found alongside bananas and are considered to be beneficial by farmers. Faith asked if she could plant *Mutuba* trees in the experimental plot.
- Coffee husks were applied to the plot by the former owner and once by the present owner. There is some concern that the husks have a detrimental effect on banana roots (and indeed, there is a possibility that it can pass on coffee-wilt disease).
- Drying of roots – even on fresh plots roots become dry. This condition is known as z*ibugo* and the cause is not known by the farmers present.
- Manure – one farmer has applied animal manure, but has subsequently sold the cow. Hopes to continue with compost.

Ntooke/Bwetwyaba farmers' perceptions of the variations throughout the plantation, characteristics of the bananas, possible causes and possible means of addressing the problem are summarised in the following table.

Table 4.4.1.1 Ntooke/Bwetwyaba farmers' perceptions of the variations throughout the plot, characteristics of the bananas, possible causes and possible means of addressing the problem

Time of planting	Yields	Observations	Cause/reason
Bananas planted before 1986	Yields have declined, but still producing 1	Relatively bigger bunches	Deeper soils. Trees providing shade

	bunch/stool/year		and nutrients from fallen leaves
Bananas planted in or after 1986	Yields have declined, but still producing 1 bunch/stool/year	Relatively bigger bunches	Deeper soils. Trees providing shade and nutrients from fallen leaves
Bananas planted in or after 1986 in central part of plot	Very small bunches and fingers	Rel. small bunches Small stems; Dry leaves; Roots on surface- easily blown over by wind	Shallow, stony soils. ? Thought to be caused by a disease Banana is a surface feeder and the soils are very shallow
Experimental plot planted in 1998	Plants a few weeks old		

Aspects of banana growing about which farmers would like to know more:

Kibugo: How to identify a plantation attacked by nematodes without root sampling or use of a microscope.
Is it OK to remove the male flower?
How many leaves should be left on the banana plant?
Removal of pseudostem sheaths
How to select clean suckers for planting
Weed control

Faith: How to maintain relatively good production after 3 years.
To understand the nematode problem

Jane: Planting hole size
How to kill *Kaasa* – they bite!

Mrs Kaggwa: Mulching – distance from corm
De-suckering – number of suckers to leave on a mat

Kazei Sssajabi: Kaasa and weevil control

Proscovia: How to control pests – Kaasa, nematodes and weevils
Mulching – how to do it

Ntenjeru Group

The kibanja was sketched by Mary as five main plots, four of which have bananas. The banana plots were labelled A, B, C and D on the sketch map and they were described as follows:

A) Bananas planted near the house in 1990. Her planting material came from this *kibanja* and her own plantation near Kayunga. Bunch size has been gradually reducing. There has been toppling/uprooting; drying of leaves and suckers are not good. Kaasa sometimes observed and sometimes tunnels in the corm. Bananas were removed in 1997 for the experiment. Cassava has been planted twice and tissue cultured planting material has been planted in the second cassava crop.

B) Bananas planted in 1993. Planting material from bananas in this kibanja. Previously Lantana-type scrub, with a few AB banana types growing there. Started with bunches approx 25 kg (selling for Ush 4,000). Bunch weight and size started falling from 1997 (only c. 10kg). Tunnels were found in corms; uprooting occurred; kaasa observed; stem reducing in size; many dry sheaths; high mat.

C) This plot was grown to coffee with scattered bananas when the *kibanja* was acquired in 1990. Bananas toppled on their own. She cleared all bananas and started re-planting in 1995, continuing up to 1997. Planting was staggered because of fear of toppling (food security strategy). Bunches originally more or less the same size as plot B.

D) In 1990 Mary was selling Kayinja leaves for cooking. Kayinja had been planted by the previous owner in 1971. However, the plot was in a poor condition: few leaves; small stems; very small bunches. It was improved through: weeding; pruning and leaving sufficient (i.e., harvesting fewer) leaves; leaving enough suckers. Now yields fluctuate but are considered much more acceptable. Problems observed: yellowing of leaves and rotting of stem. No toppling.

Table 4.4.1.2 Summary of Ntenjeru farmers' observations, causes and what can be done

Observation	**Cause**	**What can be done?**
1) Uprooting/toppling	*Biwuka* (Pests?) Roots get disease Weevils Nematodes Olunyu (soil infertility)	Ask for or about chemical pesticides Remove plants and fallow: rest soil kill *Biwuka*
2) Drying of leaves	*Biwuka* destroyed underground part of plant Olunyu	Edgala (medicine) – for weevils Thiodan SG (heard on radio); botanicals /natural (eg ash, cow urine) Fertilizer – compost, kraal manure, coffee husks, banana peels. Clean planting material
3) Suckers not good*	Nutrients are not being replenished **Biwuka**	Replenish nutrients Pruning of suckers Treating *Biwuka* (as above)
4) Small bunches*	Assorted *Biwuka* attacking underground part of plant Soil fertility decline Drought?	As above Grasses used for mulching (grass had been planted in at least one plot for pasture) Soil erosion control
5) Small stems*	Soil infertility **Biwuka** Overcrowding of suckers on mat Too many weeds	As above + Leave enough suckers(3): one with bunch; one medium and one small. Weeding and general management
6) Many dry sheaths	Failure to remove sheaths Dry weather	Remove sheaths regularly

Biwuka		
7) High mat*	Age of plant Soil washed away	Remove old plants As above
8) Black scars/tunnels*	Weevils (*Kayovu*)	Trapping and killing Edgala (chemicals) Remove corm Splitting pseudostem to deny breeding ground
9) Yellow leaves*	*Biwuka* (not Kayovu) Excess fertilizer Disease – not v. common	Uproot mat
10) Rotting stem*	***Associated with yellow leaves. Starts with leaves and moves to stem*** Same cause as yellow leaves	Uproot mat

*Photographs were taken of each of the above observations and are shown in Plates 3.1.4.1 - 3.1.4.5.

Aspects of banana about which the Ntenjeru Group would like to know more

Henry:	Improving bunch size Prolonging plantation life
Mary:	Freeing plantation of biwuka
Simon:	Kayovu Fertilization
Sebagereke:	Kayovu Weed control
Mwanje:	Maintenance of the new bananas from KARI
Solomon:	Weed control Prevention and eradication of biwuka

The training needs were recorded and addressed in subsequent farmer-researcher meetings, both on specific and *ad hoc* visits by the team, field days and farmer visits to Kawanda. See Section 4.3 on training and dissemination activities.

4.4.1.3 Intermediate socio-economic impact assessment

The objectives were summarised in Section 3.1.4, Activity 4.

This survey (Bagamba, 1999) (see **Appendix 12**), was carried out two years after the baseline study (Bagamba, 1997) to assess the impact of the project on farmers' banana nematode control knowledge and practices. Only farmers participating in the Break Crop Project were interviewed, with the following outcome.

The majority of project farmers planted new bananas in plots other than break crop plots. On average, each farmer had planted 37 banana mats since 1997. Methods of land opening changed with 13.6% of the farmers still practising the slash and burn method as compared to 42.9% reported using the same practice in the baseline data. Those that slash and let rot reduced from 35.7% to 9.1% reflecting a decline in opening fallow land (bushy areas) for banana plantation establishment. Most of the farmers (93.8%) obtained planting material from their plantations compared with 84.6% reported in the baseline report.

The proportion of farmers that did not treat planting material dropped from 46.4% to 36.4% (Table 4.4.1.3). Number of farmers using pesticide treatment for their banana planting material dropped from 14.3% to 4.5% opting for paring (9.1%) and removing damaged part (9.1%).

Table 4.4.1.3 Methods of treating banana planting material before planting

Treatment method	% farmers 1997	% farmers 1999
None	46.4	36.4
Pesticide	14.3	4.5
Ash	7.1	-
Cut off damaged part	-	9.1
Reduce root mass	32.1	22.7
Paring	-	9.1

Most farmers improved management of their soil fertility with 31.8% of the farmers reporting using compost compared to 7.1% in 1997 (Table 2). Knowledge on composting was received from the Break Crop Project staff, as farmers were encouraged to make compost for the experimental plots. Use of animal manure and coffee husks remained limited due to limited availability of materials. There was a slight decline in the proportion of farmers who mulch from 35.7% to 31.8% (**Table 4.4.1.4**). Again access to mulch (other than crop residues) is very limited.

Table 4.4.1.4. Soil fertility and moisture management practices

Practice	% farmers 1997	% farmers 1999
Manuring	35.7	50.0
Manure type		
Animal manure	7.1	9.1
Coffee husks	14.3	9.1
Compost	7.1	31.8
Mulching	35.7	31.8
Mulch types		
Elephant grass	3.6	4.5
Banana residue	35.7	13.6
Other crop residues	7.1	18.2

Most farmers (91%) recognized the importance of weevils as pests of bananas, a rise from 78.6% (Table 4.4.1.5). Proportion of farmers recognizing Kaasa's importance as a pest for bananas increased from 71.4 to 86.4%, and awareness of nematodes from 0% to 40.9%.

However, proportion of farmers taking earthworms to be a problem to bananas increased from 7.1% to 31.8%.

Table 4.4.1.5. Knowledge of pests associated with bananas

Pest	% farmers 1997	1999
Weevil	78.6	90.9
Nematodes	0.0	40.9
Kaasa	71.4	86.4
Earthworms	7.1	31.8

Knowledge of nematode control remained scanty among the project participants (13.6% of the respondents). Only 4.5% knew break crop principles, 4.5% the importance of clean material and 4.5% corm removal. These farmers reported to have received this information from the project staff (scientists). When asked about the purpose of the break crop project, 13.6% mentioned soil improvement, promoting cassava (45.5%) and pest control (31.8%).

Most farmers so far appreciated the overall break crop benefits (see **Section 4.4.2.1**) with 50% saying that bananas in the experimental plot were healthier and 31.8% were of the view that the technology be transferred to a wider community. Several volunteered to assist with this process, given some support by the project or local collaborators.

4.4.2 Final socio-economic assessment and validation of banana break crop and complementary technologies by project end

There are two end of project reports in this section: The end of project impact assessment by Bagamba (2000) and the "Report on socio-economic and uptake aspects of the project" by Lamboll (2000).

4.4.2.1 End of project impact assessment (Bagamba, 2000)

Introduction

The Non-Chemical Control of Banana Nematodes Project commenced in 1996 with the aim of controlling banana nematodes by cleaning fields of nematodes through planting non-host crops, mainly cassava and sweet potatoes (break crops). The project started with 34 participants but 28 farmers continued to the end. They began by uprooting and clearing devastated banana plantations and then planted either cassava or sweet potato. Most farmers planted cassava (25), two planted both cassava and sweet potato and only one farmer planted sweet potato alone. Each participant planted two crop cycles of cassava and/or sweet potato in the experimental plot (maximum of two years) to increase the possibility that the fields would be cleared of nematodes. Bananas were then returned to the plots cleared of nematodes using tissue cultured plantlets and corm pared suckers from mother gardens at Kawanda. Re-planting was done in November 1998. Most farmers (over 55%) had harvested their bananas at least once by March, 2000. During the course of the project, participating farmers were trained in most banana production techniques including pest control and soil fertility improvement practices. The group came to Kawanda Research Station to acquire hands-on experience of the methods and technologies used at the research station. Three of the participants were selected to attend a course organised by the Banana Programme at Kawanda in December 1999, so as to go back and teach other farmers (both participating and non-participating farmers).

This socio-economic impact study was conducted in March 2000 to evaluate improvement in farmers' knowledge and effectiveness of the break crop technology, especially after having monitored the [re-planted] banana plants for over a year.

Methodology

Participatory evaluation techniques were used to assess both the effectiveness of the non-chemical control of banana nematodes using break crops and the impact made on farmers knowledge, practices and perceptions (participating and non-participating). Two groups, one from Ntooke and another from Ntenjeru, of farmers participating in the project each group comprising of nine participants were involved in the appraisal of the project (Table 4.4.2.1). One group interview was also conducted with 9 non-participating farmers to evaluate their perception of the break crop technology and the impact made relating to knowledge spill over. In all the interviews, farmers were encouraged to contribute freely to the discussion.

Table 4.4.2.1 Participants of the non-chemical control of banana nematodes technology evaluation meetings in Kayunga, March 2000

Participating farmers		Non-participating farmers
Ntooke group	Ntenjeru group	
1. Lameck Kibugo	1. A.K. Ziwa Zirimala	1. Hareem Lutwama
2. C. Nyanzi	2. Senkatuka	2. Sylivia Kirabira
3. Faith Mutyaba	3. Edward Semakula	3. Katale (Mrs)
4. Regis Tamale	4. Nathanail Ssebagereka	4. Jackson Sekajjugo
5. Deborah Zabasajja	5. Joanita Kasoomba	5. Betty Kyeyune
6. Sarah Kibugo	6. Simon Sengendo	6. Jane Frances Baibirye
7. Namwandu Damulira	7. Martin Senkatuka	7. William Enyonu
8. Sam Kagwa	8. Haliima Mohamood	8. Mukasa
9. Proscovia Ssajjabi	9. Karim Gabula	9. Bernard Mutyaba

Positive aspects

All farmers concurred that they improved their knowledge of banana production and especially on the following aspects:
(i) Mulching to improve soil moisture retention and fertility
(ii) Leaf and sheath removal (only dry leaves and sheath removed)
(iii) Plant spacing of 3 m between mats
(iv) Constructing contour bands to control soil erosion
(v) Reducing plant population by leaving the mother, daughter and grand daughter plants on the mats
(vi) Trapping weevils to control the weevil population
(vi) Removal of leaves infested with black Sigatoka
(vii) Use of break crops to control banana nematodes and
(viii) Use of compost manure to improve soil fertility and plant vigour

Negative aspects

Some farmers complained that suckers removed from the experimental plot took a long time to establish. However, one of the participants said it depended on where they were planted. The suckers she planted where she had removed sweet potatoes established well. She attributed the problem of these farmers' poor establishment of the suckers experienced by these farmers to fields that could be infested with pests. This was confirmed by one of the complainants who admitted to having planted his suckers in an existing coffee plantation.

Insufficient rain or drought was also given as a major limiting factor for establishment of newly planted suckers, especially for pared suckers. Tissue culture plants were reported to recover easily from drought shock.

One farmer attributed small sized banana bunches to the type of the cultivar that was given to the farmers. Other farmers concurred that the cultivar Ndyabalangira generally produces small bunches. They had preferred it to other cultivars during the baseline study because it is tolerant to the environment in the area and produces very good food. It is also early maturing. They argued that, at that time, their main problem was food security and the three attributes of Ndyabalangira i.e. tolerance to the area constraints, producing good food and early maturing were appealing. But now that production for market is taken seriously, they would prefer a cultivar that produces big bunches which are appealing to buyers. One, Mrs Tamale reported that she received Mpologoma cultivar in her planting material, which performed very well. “The bunch was very big and I got two meals out of one bunch unlike other cultivars where I have to combine 2 to 3 bunches for one meal,” said Mrs Tamale.

Researchers' assessments of experimental plots

Farmers’ experimental plots were assessed by the researchers and ranked as "very good, good, fair, poor or very poor," depending on the quality of management and performance of the banana plants. The scoring system was based on prescribed criteria (see Bagamba, 2000). The results are summarised in Table 4.4.2.2.

Table 4.4.2.2. Scientists' assessment of performance of farmers' experimental plots

Rating	No of Farmers Management rating	% Farmers Management rating	No of Farmers Performance rating	% Farmers Performance rating
Very good	5	20	3	16
Good	10	40	11	42
Fair	5	20	8	26
Poor	4	16	2	12
Very poor	1	4	1	4
Totals	25	100	25	100

The results of researchers' assessments of plot-management and performance indicates a good level of uptake of banana management principles, including application of the break crop technology. **Table 4.4.2.2** shows that around 60% of farmers were rated as very good or Good and an average of 84 (80-88)% of farmers scored fair/good/very good for management and performance.

Conclusions

The consultations made with both participating and non-participating farmers revealed that there was impact made by the project, especially through increasing farmers' awareness of new banana production techniques (tissue culture planting material, compost making, mulching and non-chemical control of pests). The baseline study had revealed farmers' unawareness of the nematode problem. The subsequent assessment studies also showed that farmers took a long time to internalise the nematode problem, mainly because nematodes are not visible. However, this study shows that most of the participating farmers (>70%) now do understand the main problem after a series of training sessions.

The study also reveals some constraints that might limit adoption of the break crop technology. The constraints include:

(i) Apparent unwillingness by farmers to abandon the practice of intercropping cassava and legumes (beans and ground nuts)
(ii) Unwillingness to uproot all banana mats/plants during the period of the break crop in the hope of getting at least a small harvest. Bananas are the most preferred food and some farmers are hesitant to uproot the crop as long as they have a prospect of some output
(iii) The management required for the new banana crop is relatively labour-intensive and some farmers fail to cope with this demand
(iv) Most of the required soil amendments (e.g. mulch, manure and compost) are less available, limiting the productivity of bananas
(v) The area receives intermittent rains and in most cases not, thereby affecting the productivity of the banana crop. Farmers fail to realise the benefits of the break crop technology since bunch sizes remain small under drought conditions.

Despite the constraints, farmers appreciated the differences between the trial plots and traditional banana plots, especially the high suckering rate and plant vigour in the trial plots. Dissemination of the technology will require vigorous training sessions especially for the farmers to first internalise the nematode problem.

4.4.2.2 Final report on socio-economic and uptake aspects of the project

Introduction

The objectives for this output were summarised in **Section 3.1.4**, **Activity 9**.

This report (Lamboll,2000) followed the final socio-economic report by Bagamba (2000), discussed above. It reviewed the overall project characterisation of farmers and households in the study areas (farmers' opinions on causes of banana decline, their perceptions of the nematode management trials, their expectations of the research and of the training received, and expectations of success), the potential for uptake of the banana nematode management methods (evidence for uptake, organisations to facilitate uptake, and uptake beyond Mukono district), ending on perceptions of the 'the way forward' (i) within the project area, (ii) in the Central Zone of Uganda and (iii) in other banana-growing areas of Uganda.

Many of the main issues in this report have been presented and discussed above (Bagamba, 2000) (see **Appendix 13**) but some of the main extracts from Lamboll, 2000 (**Appendix 14**) are reproduced below and the highlighted points are discussed in **Section 4.4.2.3**:

<u>Farmer perceptions of causes of banana decline</u>*:*

In the baseline survey, pests associated with the decline include weevil (reported by 79% of the farmers), *Kaasa* (ants) (71%) and to a lesser extent earthworms (7%) .**Very few farmers differentiated toppling from weevil damage (7%) implying that farmers are less aware of the nematode problem.**
Some conclusions may be drawn from the above findings (which coincide with other studies). Farmers are operating in a complex system in which they are very knowledgeable about some aspects (eg variation in yields, incidence of very visible organisms eg weevils and *Kaasa)*, but not others (eg nematodes, diseases). **In particular, farmers are generally not associating decline in bananas with nematodes. Even after two years contact with the project staff, nematodes don't emerge as an issue in discussions with farmers. This has clear implications with respect to uptake.**

The cassava appears to have been a major success. Cassava production was limited by ACMV, which had almost wiped out the crop, and access to resistant planting material was very limited. **Availability of free [cassava] planting material appears to have been a major motivation for farmers to participate in this project.**

In the later impact study when all participating farmers were **asked about the purpose of the project –14% understood it to be concerned with soil improvement, 46% promoting cassava and 32% pest control** (Bagamba 1999). This follows 'sensitization about the objectives' at the beginning of the project, further training in the second quarter of 1998 which involved 'individual farmer contacts, farmer field schools at village level and seminars at parish level (Maslen1998) and researcher visits over a period of over two years. **The majority of farmers perceived the aims of the project differently from researchers involved.**

<u>Farmer expectations of research/ training</u>

A wide range of topics was identified ranging from the general to the very specific. **The articulation of demand for improved methods for nematode control may be interpreted as a success in terms of raising farmer awareness of nematodes, but raises questions as to whether farmers were convinced about the break crop approach.** It is also clear that farmers are grappling with a large number of management issues, of which nematodes is only one. **This has implications for the likelihood of achieving uptake** (see Lamboll (2000), **Section 3**).

<u>Farmer expectations of success</u>

Participating farmers were asked how they would judge whether or not the trials have been a success. The indicators identified revolve around yields and sustainability of the banana crop (**Table 4.4.2.3**).

Table 4.4.2.3 Participating farmers' indicators of success for the trials

Village	Indicators of success
Ntooke village	1. Vigour of the growing plant 2. Yield of the 2nd harvest
Bwetwyaba village	1. Cassava already a success-not affected by the disease (ACMV), good yield and planting material now available. 2. Waiting to see bunches 3. When they start enjoying the bunches 4. If bunches are better than those currently available. 5. If plants sustain yields for longer ie, 10-15 years. 6. Like to see at least the first and if possible the second ratoon

Implications for monitoring and evaluation

The above indicators suggest that monitoring should continue until at least the second harvest (first ratoon). This suggests an evaluation with farmers in the second half of the year 2000. On a less intensive basis it would be worthwhile monitoring the performance of the bananas over a longer time period (10-15 years) to assess whether they meet farmer expectations.

Potential for uptake of the management methods

Farmer motivation for being involved in the project: Cassava production in Mukono was limited by ACMV, which had almost wiped out the crop. Access to resistant planting material was very limited. **The provision of free planting material was a major motivation for farmers to participate in this project.**

Access to clean banana planting material – the banana planting material was delivered at no cost to participating farmers. **Approximately one third (92 out of 275) of the plants sampled in March 1999 had not survived. Uptake will be dependent on farmers access to clean planting material at an acceptable cost and an acceptable survival rate.**

Farmers perceptions of nematodes and other causes of banana decline - although the proportion of participating farmers being aware of nematodes rose from zero in 1997 to 41% in 1999, **very few of the participating farmers reported that they were aware of methods for controlling nematodes (14%)** (Bagamba 1999).. This corresponds with farmers response when asked about the purpose of the breakcrop project –14% understood it to be concerned with soil improvement, 46% promoting cassava and 32% pest control (Bagamba 1999). **Is there sufficient institutional capacity to provide farmers with the appropriate knowledge? To what extent can this 'technology' be applied without the knowledge?**

Appropriateness for poorer farmers- the baseline survey suggests that it is the middle wealth group farmers who are most willing to invest in banana production. Unfortunately, the impact survey in 1999 didn't differentiate between farmers in different wealth groups. **Is this approach appropriate for poorer farmers?**

Evidence of existing uptake in Mukono district

The district extension service has already established demonstration plots using tissue cultured planting material. The co-ordinator is Doreen Kataama, who originally helped to select sites for this project, but wasn't involved again until the 1998 RRA. The demonstrations have been established using district funds, which would appear to show a clear commitment towards banana production in Mukono. The details are shown in the Table below:

Table 4.4.2.4 Mukono district Government demonstrations of tissue-cultured bananas

Location	When established	Material	Source and price
Sub-county HQ Kaworo sub-county, Buikwe county	Original 50 plants planted in October 1997. Subsequent planting has taken number up to 100 plants	Cooking types-Kibuzi, Mbwazirume, Nyeriu. Fhia 3 and 17. Km 5.	Kabanyoro (Makerere university farm) - Ush 500/ plant
Sub-county HQ Goma sub-county Mukono county	Planted 50 plants in April 1998	Cooking types Fhia 3	Kabanyoro Ush 500/ plant
Sub-county HQ Kyampisi sub-county, Mukono county	Planted c.50 plants in October 1998	Cooking types	Kawanda ARI - Ush 1,000/ plant
10 farmers in Ntanzi parish Ntenjeru sub-county Mukono county	Each farmer received c.50 plants in April 1998	Cooking type	Kabanyoro Ush 500/ plant

Uptake beyond Mukono district

Beyond Mukono district, **the Luwero and other benchmark sites are likely uptake pathways** and findings from the CPP uptake study provide ideas for achieving uptake in banana growing areas in general (see Lamboll, 2000, Section 4).

The Way Forward

The project

In the development of the revised project action plan (December 1998) a number of approaches were discussed and agreed with a view to further developing approaches to technology uptake. These included:

1) **Farmers to be provided with feedback from researchers** – although farmers felt information had been collected from their banana plots they had received little feedback on the findings. **This was subsequently addressed** through activities such as informal and arranged meetings on researcher-visits and field days at the trial sites.

2) Increased interaction between farmers, researchers and extensionists: **there appeared to have been less than intended interaction between researchers, farmers and**

extensionists. For example, research technicians had often carried out nematode sampling without any contact with the farmer. The district extension office had been involved at the beginning of the project, but there had been much reduced contact, due in part to staff changes, availability and interests . Activities to address this included farmer visits to KARI, farmer meetings and at the appropriate stage, workshops in Kayunga.

3) **Farmers priorities for training-linked to 2 above was the identified need to prioritise farmer training needs.** This provides a means of assessing **farmer perceptions of nematodes and other factors influencing bananas**, which in turn gives an indication of how uptake may be facilitated.

Central Zone

The UNBRP and other partners are developing a Benchmark Site (Outreach) Programme which has the aim of incorporating and accelerating the movement of promising and tested technologies along uptake pathways for promotion. In Central Uganda a Benchmark Site (BS) is being established in Bamunanika sub-county, Iganga district, which is adjacent to Mukono district. The CPP is facilitating the development of this BS through the Integrated Management of Plant Diseases project and the Management Strategies for Banana Streak Virus project.

In July 2000 a planning meeting (NBRP 2000) for the Luwero BS was held at Kawanda ARI with researchers from NARO, ICIPE, IITA, CABI, University of Reading and NRI participating. During this meeting the diversity and complexity of the population, culture and farming systems in Luwero was emphasised, as was the need for an'Integrated Productivity and Pest management' (IPPM) approach.

There is clearly potential for Luwero Benchmark Site to be an uptake pathway for the outputs of the non-chemical nematode control project. However, **although the recently completed baseline survey (covering 117 respondents in six parishes) reported *kaasa* and weevils as important pests, none of the farmers described symptoms resulting from nematode damage.** A linked biological baseline survey is to take place and this should reveal the incidence of nematodes in the locality. **If they are a significant pest but, as is frequently reported, farmers are unaware of existence, the experiences of the non-chemical nematode control project suggest cost-effective approaches need to be developed which will allow farmers to understand the nature of the pest such that they are able to make informed decisions about how to control nematodes.**

Other challenges to successful uptake which emerged from the Luwero baseline survey (NBRP 2000) are:

- Complex intercropping in banana plots**- can the breakcrop/ clean planting material adapt to this cropping system?**
- Competitive demands for land- the average farm size is 1.98 hectares (compared to 2.75 hectares in the Mukono study site), with an average of 0.25 hectares allocated to bananas (1.38 hectares at the Mukono study site).
- Land tenure- about 25% of farmers live on leased land, which is generally less than one hectare. Presumably these are poorer farmers, which DFID projects should be targeting. To what extent will insecure land tenure influence a farmer's decision to invest in a longer term/ perennial?? crop such as banana.
- **Farmer concerns with growing banana permanent/ perennial crop: -many farmers are no longer confident that bananas can be established on a permanent basis and once they observe signs of declining productivity they abandon the plot. This again raises the question of willingness to invest in banana production.**

Matooke (cooking bananas) is still the third most important food staple and *kayinja* (beer banana) the second most important cash crop. **The challenge will be to explore where the outputs from the non-chemical project can fit into the Luwero environment. If there is potential, farmer-farmer study visits between the Luwero BS and the Mukono study site would provide a good basis for developing initiatives.**

Other banana growing areas

The Uganda National Banana Research Programme's Benchmark Site programme is being developed at four sites across three zones:

- **The East and Central Zone, where banana production is in severe decline (Luwero Benchmark Site);**
- The South, where banana production is at an intermediate level of decline (Masaka and Ntungamo Benchmark Sites) ;
- The Western Zone, where banana production is still at its 'optimum' level of production (Bushenyi Benchmark Site).

At the Masaka Benchmark Site, there appear to be no current activities focused on nematode management, but nematode control is one of the stated objectives and this site may be an appropriate pathway possibly linking with the non-chemical project on-farm trial in the district.

The Bushenyi Benchmark Site is still being developed, with a baseline survey possibly to take place in 2001.

At the Ntungamo Benchmark Site research emphasis has been on weevil control and soil fertility management. Although there have been research activities in this area since 1996, there has been no socio-economic baseline survey. **The sustainable productivity of banana plants in this area would seem to suggest that the break crop approach may not be appropriate.**

The CPP has recently commissioned a study of factors influencing the uptake of outputs of crop protection research in banana-based cropping systems in Uganda (Gowen 2000)**. This study identified a large range of stakeholders involved in banana research and uptake and explored means for improving the process of technology uptake. The study emphasised the importance of understanding farmer context; identifying and targeting different groups of farmers; understanding farmers' (and other stakeholders') preferred sources of information and technology attributes and the need to improve partnerships between stakeholders.** The application of these findings should contribute towards improved uptake of research outputs from the non-chemical control of banana nematodes project.

4.4.2.3 Discussion of issues raised by Lamboll (2000)

<u>The break crop technology</u>

The main socio-economic and uptake issues from this study were as follows:

Farmer perceptions of causes of decline

1. Farmers are less aware of the nematode problem than of other pests (e.g., weevils);

2. They generally do not readily associate decline with nematodes;

3. The availability of free cassava planting material may have been a major motivation for farmers to participate in this project;

4. In the later impact study when all participating farmers were asked about the purpose of the project –14% understood it to be concerned with soil improvement, 46% promoting cassava and 32% pest control (Bagamba 1999);

Farmer expectations of research

5. The articulation of demand for improved methods of nematode control may be interpreted as success in raising farmer-awareness of nematodes, a first step leading to uptake. Were they convinced by the break-crop approach? The impact assessments indicate that project farmers were sufficiently enthusiastic to offer help in disseminating the break crop technology.

Farmer expectations of success & implications for monitoring and evaluation

Asked how they would judge success, farmers cited crop quality (vigour, 2nd harvest yield, bunch size) and number of years that good yields should be sustainable (10-15 years). Lamboll (2000) noted that validation of these farmer criteria would have implications for monitoring and evaluation of trial crops with farmers. The first harvest is normally reduced, with small hands, whereas the yield at the second harvest (first ratoon) and subsequently, is normally greater and therefore a better indicator. This would have required an evaluation with farmers in the second half of 2000, some 6 months or more beyond project end (the crop had subsequently been held back somewhat by very dry weather prior to flowering). Although a period of 10-15 years of crop (and nematode population) monitoring was impractical and un-necessary for trial validation, it was foreseen that about two years' further crop monitoring and soil-sampling would provide a good indicator of the longevity of nematode suppression/clearance under farmer-conditions. This would have permitted monitoring and evaluation for 3 years and 4 months (from re-planting in November 1998 to end-March 2002), including the first ratoon crop. An application was made for two years' Additional CPP Funding to complete this work under a new CPP project with the UNBRP Benchmark Sites (Outreach) Programme intended to develop an Integrated Productivity and Pest management (IPPM) approach. Although the break-crop project trials are not in the new benchmark areas (they are within 100 Km), the technology and findings would be applicable to the IPPM project. The additional input was agreed in principle through the project leader in early 2000 but was subsequently not implemented in the second half of 2000 due to unforeseen shortage of CPP funds. New project start-up obligations and more numerous assignments for NARO by local project staff precluded further sampling, monitoring and evaluation visits to the break crop sites by the researchers. This therefore ranks as a lost opportunity.

Potential for uptake of the management methods

The provision of free cassava planting material was attractive to many of the farmers participating in the trials. The SS4 variety of cassava was at the time limited in availability to farmers and was also ACMV-resistant, offering an opportunity to compensate for their decimated crop varieties. However, in selecting farmers it was already known (i) that they had a progressive banana decline problem in the area and (ii) that all grew cassava and/ or sweet potato and that they were growing more because of falling banana yields. The attraction of the free material was therefore not seen by the project team as the main reason for farmers' participation in the trials. However, the prospect of getting improved yields of both cassava and banana would understandably be an incentive to any farmers, and one not at variance with the overall objectives of the project. It was reasoned that, in the more adverse decline situations where farmers abandoned the growing of bananas in a plot due to very low yields, and turned to growing cassava, sweet potato and other crops, then the break crop method would be very much in tune with these farmers' alternative practices. The practices would not preclude a return to bananas and would provide good yields for consumption and sale in the mean-time.

Access to clean planting material: One of the considerations for sustainability and uptake of the break crop technology is the availability of clean (tissue cultured) banana planting material. This needs to become more generally available locally, rather than coming from Kampala, and at a price and quality which farmers can afford. It is clear that the district extension service in Mukono district has made a good start with the tissue cultured banana plant demonstrations at the various Sub-county HQ's, with material from Makerere and Kawanda (see Lamboll, 2000, Section3.2.1). The cost per plant varied between 500 - 1000 Uganda Shillings. This facility needs to develop into outlets for purchase of the plants, enabling farmers to maintain nematode-free areas and to much reduce the risk of transmission of nematodes on infected planting material. The survival problems with the plants sampled in March 1999, when approximately one third of plants provided to farmers died, was due to timing and adverse weather, as described by Namaganda, 2000 (see **Appendix 8**). The first batch of tissue cultured plantlets were ready for field planting before the farmers' experimental plots were ready for banana replanting, so the plantlets were used to establish a mothergarden at KARI. The objective of establishing a mothergarden was to increase production of clean planting by rapid field multiplication. On-farm experimental plots consisted of 25 mats, in a mixture of cultivars Nakitembe and Ndibwabalangira.

The planting material was delivered to the farmers at three different times because at the time the farmers' plots were ready for banana replanting, there were not enough tissue cultured plants available to go round, and the suckers in the mother garden were not ready for transplanting. From past experience, farmers will not wait for clean planting material once their plots are ready, but will replant their plots with whatever crop or planting material that is available. In order to avoid farmers replanting the experimental plots with other crops, or with infested banana planting material, the available tissue culture plants were distributed equally to the 28 farmers in September 1998, with a promise to deliver the balance as soon as possible. However, initially most farmers were not convinced about the prospects for field establishment of tissue culture plants. They believed that the plantlets were too small to develop into robust plants capable of producing a bunch. In November 1998, suckers were obtained from the mother garden at KARI and delivered to the farmers in the form of pared corms, for completion of trial establishment. However, having seen how fast the tissue cultured plants had established, the farmers were now reluctant to plant corms because they believed they would not do as well as the tissue culture plants. There had thus been a reversal in farmers' preference for planting material from pared corms to tissue cultured plants. Farmers were even more convinced that corms were not good enough as planting material when a dry spell followed immediately after planting and all the corms died on germination. More tissue culture plants were delivered to farmers in late February 1999 to replace the dead corms and also to fill gaps in fields where a few tissue culture plants had not established. The survival of the TC banana planting material would be as good or better as conventional material. However, bananas have a high water requirement, particularly planting material and, unless well nurtured by farmers, no planting material performs well under prolonged dry conditions (very low rainfall) as between December, 1998 and March 1999 (see Fig.). The survival rate of tissue cultured plants should therefore rarely be a problem. The wider availability of TC plants at affordable prices needs to be further developed and promoted.

Farmers' perceptions of nematodes and other causes of banana decline: It is no surprise that most non-participating farmers, and participating farmers at the time of the baseline survey in the inception phase of the project are unaware of nematodes. In Uganda and East Africa generally, banana weevils and weeds have long been regarded as the main pest problems until recent times, and it is only since the early 1990's that intensive research in Uganda has revealed a much more serious and spreading problem with nematodes and various diseases such as sigatoka. The word "nematode" or its equivalent is virtually unknown by farmers, although they admit to, and are aware of yield decline, one of its main symptoms. In the light of nematodes being generally unknown previously, it is to be expected that very few farmers are aware of methods for controlling nematodes. It appears that farmers can become aware of nematodes, but they take a lot more induction and farmer-researcher/ trainer contact time than with well known and visible pests. The proportion of participating farmers being aware of nematodes rose from zero in 1997 to 41% in 1999 and then to >70% in early 2000 (Bagamba, 2000). Being invisible, nematodes, like diseases, are not as easily recognised as the much more visible weevils, although their symptoms often are. Given an element of intangibility about the pest itself, it is not unreasonable that farmers who are exposed to awareness and practical training by the break crop project team should understand the project objectives without undue precision (i.e., in slightly "fuzzy" but not totally inaccurate concepts). The farmers' response when asked about the purpose of the break crop project: 14% understood it to be concerned with soil improvement, 46% promoting cassava and 32% pest control (Bagamba 1999). In the author's view, these farmers were actually correct in functional terms. Clearing nematodes from the soil <u>is</u> soil improvement. Cassava <u>was</u> promoted as an effective break crop, particularly with the strength of good yield and generally good characteristics; even if they preferred not to revert to banana, this was a good strategy for food security. Removing nematodes from the soil with break crops <u>is</u> pest control.

Appropriateness for poor farmers. Farmers who suffer severe banana yield decline appear to have few practical options. Obvious possibilities are:

1. Do nothing (accept low or negligible yields) - may see no problem or too costly;
2. Adopt better management practices (good weeding, sanitation, manure, mulch, etc) in the hope that this will improve crop performance and inhibit pests;
3. Grow alternative annual and perennial crops (some may be banana nematode hosts);
4. Use nematicide (unreliable, costly and has user and environmental safety hazards);
5. Fallow the land (no crop, so no food security or cash return) and try again next year;
6. Move to new, uninfected land on-farm or elsewhere;
7. Grow break crop(s) rather than fallow, and re-plant with clean banana material after 1-2 years.

The only one of these options suitable for a very poor farmer suffering severe yield decline is probably to grow alternative crops or, if feasible, to grow banana on an uninfected area on the land he cultivates. This would be his choice without the break crop technology. The break crop approach could be appropriate for a proportion of poor farmers. This will depend on their level of understanding and ability to acquire or afford at least some tissue-cultured or conventional clean planting material. This is something which should be studied in more detail with a cohort of the poorest farmers in the Luwero benchmark area.

Sufficient Institutional capacity to provide farmers with the appropriate knowledge? Strictly, this was beyond the remit of the break crop research project. There were limits on the ability of the small break crop project team and collaborators to interact with many more farmers than were involved. However, it is likely that a larger, more integrated project with a portfolio of tested technologies, and therefore less research obligation, could maintain a greater and expanding area coverage. Simple integrated protocols would make the awareness and practice process easier for other stakeholder groups to disseminate and promote. At this stage, the issue of institutional capacity should be assessed.

Evidence of existing uptake in Mukono District. The establishment of demonstration plots using tissue cultured planting material by the district extension service in Mukono is a good indicator of the interest in this technology and commitment to banana production in the district. It is hopefully also an indicator that sources of reasonably priced planting material will evolve, so that farmers can obtain it without major effort or cost. Clean planting material is fundamental to good crop management, along with clean soil, particularly of banana nematodes. The stakeholder involvement in disseminating the technology (FOSEM, farmers' groups and agricultural officers) also indicated an understanding of the need for nematode control and a commitment to promote the technologies. The involvement in the training of trainers workshop was also evidence of commitment. A number of the stakeholder organisations are involved in areas such as improved seed provision, farmer training and mobilisation and so have common or complementary interest (Lamboll, 2000, Section 3.2.2).

Uptake beyond Mukono. The most likely immediate uptake pathways are through the Benchmark Site Programme of the UNBRP and its partners. This has the aim of incorporating and accelerating the movement of promising technologies along uptake pathways for promotion. The main requirement for successful uptake is to promote the technology where there is clear demand because of yield decline due to banana nematodes. This means that the candidate Benchmark site will probably be in the Central (Luwero)Zone where there are areas of severe production decline, or South Zone (Masaka or Ntungamo) where there are intermediate levels of decline.

It should be clear that the break crop technology is not intended as a general method for controlling or preventing banana nematodes. It is intended wholly or partially to repair a specific problem (decline due to nematodes) and cater for a demand. The demand is by the farmer wishing to continue growing at least moderate-yielding banana crops, rather than moving to new land, or permanently growing alternative crops. The break crop project was conceived and accepted by CPP to address the worsening problem of banana yield decline in Uganda, to which nematodes make a large contribution (typical yield losses of 51% by 3rd ratoon, as opposed to 50% by 4th ratoon for weevils). Many farmers will not want, or cannot afford, to simply give up growing bananas, but neither will they wish to persevere with derisory yields. A problem obviously exists in parts of central Uganda, whether or not farmers are currently able to recognise its cause (i.e., can currently diagnose it and/or recognise the link with nematodes). The break crop technology, wholly or in part, can contribute to halting the decline and needs to be integrated with a basket of practices, so that there are economies of activity on farmers' time. Whether it will be necessary, or possible, to frame control practices in relation to specific symptoms, rather than individual pests, needs to be determined and will be one of the challenges to achieving successful uptake.

4.5 *Conclusions*

This study developed, demonstrated and promoted, within the available time-frame, a strategy for non-chemical control of the main banana nematodes in Uganda and elsewhere in

East Africa. The two main Output objectives (**Strategy developed** and **Local people trained**) were therefore achieved. These are summarised below.

4.5.1. Strategy developed

1. Culture techniques for mass-production of nematode material were successfully developed and used in host status (screen-house) experiments and for bioassays of soil at the end of field trials. Based on these techniques, host status experiments with common banana system crops and weeds were conducted. These revealed that weeds were generally poor or non-hosts of banana nematodes but that some crops were as good or better hosts than bananas of the three banana nematodes *R. similis* (groundnut), *P. goodeyi* (beans and maize) and *H. multicinctus* (beans). As would be expected, the root and tuber break crops were found to be poor or non-hosts of these nematodes. However, the findings clearly indicate that inter-cropping groundnuts, beans or maize with bananas should be avoided.

2. Methods for the production, weaning and hardening of pest and nematode-free tissue-cultured banana plants were developed. The most appropriate strategies for transferring plants to farmers' fields and minimising plant losses were assessed and implemented.

3. On-farm and on-station field trial results confirmed that it is possible to clear the main banana nematodes from soil in infected plots, or to reduce any pockets of survival to negligible numbers with the use of (non-host) root and tuber break-crops and without the use of pesticides. There was insufficient time to determine an optimum break-crop interval but it was found that a duration of 18 months gave at least as good results as as longer intervals of 23 and 27 months in these trials. It appears that other variables, such as cultural and agro-ecological factors may help determine the minimum time required under break-crops to clear banana nematodes. This should be investigated further under any future adaptive project.

4. The sustainability of the non-chemical nematode management method, or length of time before it is necessary to implement another break-crop cycle, could not be determined within the project period. Nor could the yield differentials be estimated between initial infested crops and subsequent "nematode-free" ratoon crops. To permit effective monitoring and evaluation, it is recommended that this is done as part of a future project which should continue for five to ten years, or even 10-15 years, as suggested by Lamboll (2000).

5. The particular importance of potassium (and nitrogen) for banana nutrition and production, means that the effects of growing a break-crop (or inter-crop) on soil nutrients needs to be understood. Cassava (and also maize) was found to deplete the soil of potassium compared with banana. This needs to be taken into account by applying appropriate fertilisers when re-planting bananas after a break-crop, so that the crop yield and quality is not seriously diminished by low potassium levels. Unlike cassava, sweet potato did not significantly reduce soil potassium levels.

6. In general, farmers perceived that plant growth characteristics, vigour and quality were better in the tissue-cultured field trial bananas than in their conventional plots (Bagamba, 2000). Tissue-cultured plants are more resistant to handling and dry conditions than conventional plants or pared corms and can recover more quickly. Some farmers had expected uniformly higher yields over their conventional plots, something which was feasible but was constrained in these trials by the farmer-selected local varieties (e.g., Ndyabalangira), which were chosen for their taste, texture, early maturing and tolerance to local conditions, rather than high yields. Some local varieties (e.g., Mpologoma) did give higher yields, but bunch sizes were still generally held back by very dry weather at key times, which affected the overall ability to achieve significant yield differentials between trial and conventional

bananas. Farmers said that tissue-cultured bananas were healthier, produced good food and were more resistant to extreme dry conditions. Researcher assessments of relative crop quality in farmers' trial plots indicated that 84% were Average to Very good, with 58% above average. This high score was an indicator of farmer uptake of the management methods as well as a demonstration of the achievable crop quality.

7. By the end of the project, achievement of higher yields for market had became more of a priority for farmers than simple food security, for which they had originally chosen local banana varieties. Farmers are now prepared to grow tissue-cultured high-yielding varieties in order to achieve this, something which most would not consider at the outset. The future prospects for achieving higher yields, as well as crop quality, with a combination of suitable variety and "normal" rainfall are therefore good.

4.5.2 Local people trained

This Output also includes dissemination and promotion of the banana crop management technologies.

1. Four **project technicians were trained** in banana management and nematode sampling, processing and identification techniques. Three remain as a resource with KARI and provide inputs into NARO IPM projects.

2. A range of **training, dissemination and promotion activities** was conducted with different stakeholders. These included various farmer training activities (regular monitoring and sampling visits, field days, seminars and field visits, farmer to farmer training), training of trainers, induction of interested NGO's and presentations at various fora, including provision of verbal advice and information leaflets at agricultural shows, seminars for NGO's, NARS and others.

3. It is estimated that about 300 farmers and other stakeholders were trained by the project in the non-chemical control of nematode technologies, with a similar or greater number being trained in, or exposed to, the methods or component technologies by project farmers and other trained stakeholders.

4. The main identified **promotion pathways** are as follows:

(i) Non-farmer **stakeholder organisations** and groups interested in the technologies, which comprised 15 NGO's including FOSEM, three women's groups, seven TOT's and officers from the district extension services. A number of these took part in seminars and field demonstrations and discussions with project and non-project farmers and/or representatives of farmer groups and could serve as a nucleus for furthering uptake and promotion of outputs for a future adaptive or integrated project;

(ii) The **Benchmark Site Programme**, being established in Iganga, adjacent to Mukono district and which is taking an 'Integrated Productivity and Pest Management' (IPPM) approach. The CPP is facilitating the development of this BS through the Integrated Management of Plant Diseases project and the Management Strategies for Banana Streak Virus project. The groundwork done with these stakeholders by the present project could be further developed or exploited to provide practical advice and support for project farmers in the new integrated (IPPM) project.

5. The project **dissemination outputs** are shown in **Section 6**. These outputs were of two types:

(i) Results of additional research conducted to obtain information to assist formulation of a more effective nematode control strategy (mainly published);
(ii) Information for stakeholders on various important techniques or crop management methods (mainly unpublished).

At least 18 publications, including 6 peer-reviewed publications, 10 internal reports and two further draft papers have been produced. These outputs should help to devise improved banana crop pest management strategies in any new IPPM project.

5. Contribution of Outputs

5.1 Contribution towards DFID's development goals

This project addresses the DFID goals of poverty alleviation by promoting sustainable livelihoods among poor people and protecting and improving the natural and physical environment. The technology provides farmers with a tool to avoid having to abandon the culture of their premier staple crop. The development of a non-chemical, sustainable control technology for banana nematodes would contribute to the capital asset base of farmers, improving their choice of livelihood strategies and increasing the prospects for sustainable livelihood outcomes.

There is a long tradition of growing bananas in Uganda (and neighbouring countries) but productivity has been declining for about 45 years. The area under banana production in Uganda has roughly doubled from 643,000 hectares in 1956 to 1,538,000 hectares today but productivity has continued to fall. This project was premised on the concerns over banana productivity decline and its increasing impact on the livelihoods of the poorest people in a country with a rising population. This decline is believed to be due to changes in cultivation practices, reduction in soil fertility and to the arrival of alien pests and diseases, particularly banana nematodes. However, it is also known that many farmers cannot distinguish between damage caused by the rather obscure nematodes and the more visible banana weevils. In consequence much damage caused by nematodes is erroneously attributed to weevils and this may lead to indiscriminate and inappropriate recourse to pesticides and other costly, ineffective or harmful measures. This can exacerbate the low productivity problem, forcing farmers to abandon banana-growing.

Due to advances in the development of environmentally benign control technologies that target nematode host-specificity, the control of banana nematodes without user or environmental contamination or affecting natural enemies of key pests is now possible. Earlier fallowing methods for banana nematode control were hampered by the unreliability (i.e., not always pest-free) of new banana planting material. Developments in tissue-culture methods in recent years, with laboratories capable of mass-producing plants have provided the certainty of pest-free planting material which hitherto was missing. The aim of the current project was to validate these technologies as a viable crop protection strategy for resource-poor and emergent commercial farmers. Although fine-tuning and further integration will are advocated, the viability was successfully demonstrated and is therefore seen as an effective contribution to DFID's development goals.

5.2 Identified stakeholders and promotion pathways

5.2.1 Primary stakeholders

In addition to the project and non-project farmers and farmer groups, or **primary stakeholders**, that were trained in or exposed to the technologies(**Sections 3.2.3, 4.3.4.1 and 4.3.5**), the project involved and collaborated with identified local target institutions and beneficiaries. These were the **non-farmer stakeholder organisations, groups and individuals** involved in evaluating and promoting the technologies during the project duration. The **promotion pathways** likely to be most appropriate after the end of the project are also identified.

5.2.2 Secondary stakeholders and promotion by the project

Non-farmer stakeholders comprised 15 NGO's including FOSEM, three women's groups, seven TOT's and officers from the district extension services (**Sections 3.2.3 and 4.3.4.2**). Various of these took part in seminars/meetings and field activities and demonstrations and discussions with project and non-project farmers and/or representatives of farmer groups. They could serve as a nucleus for furthering uptake and promotion of outputs for a future adaptive or integrated project.

Post-project promotion pathways

The technology is aimed at halting yield decline due to banana nematodes and is therefore only appropriate for areas where banana nematodes are a major problem. The results of site surveys of four BS areas are not all complete but at least one site has areas of severe decline. The Benchmark Site Programme, being established in Iganga, adjacent to Mukono district and which is taking an 'Integrated Productivity and Pest Management' (IPPM) approach, appears to be the immediate most appropriate site to begin to integrate and take forward the technology (**Section 4.4.2.2**). The CPP is facilitating the development of this BS through the Integrated Management of Plant Diseases project and the Management Strategies for Banana Streak Virus project. Further sites in other areas can of course, be added if and when the surveys indicate a "demand" from farmers. The groundwork done with the farmer and non-farmer stakeholders by the present project could be further developed or exploited to provide practical advice or support to the IPPM project stakeholders. It can be expected that the integrated nematode/pest control technology will be similarly be promoted through NGO's, CBO's , the extension services and other agencies, as in Mukono and Masaka in the current project. The scope and need for alternative promotion pathways will become clearer as the project progresses.

5.3 Dissemination outputs

The documented and published outputs of the project are discussed above (**Section 4.5.1.2**) and references are listed in **Section 6**. The project team produced at least 18 outputs, comprising 6 peer-reviewed publications, 10 internal reports and two further draft papers. The outputs present key information, both techniques and findings of research, which will assist in future stakeholder training and in planning and optimising further adaptive research.

6. Publications

Formal publications

**(Includes contributions by project staff to shared outputs with other projects).*

BAKER, T. AND GOWEN, S.R. (1996). Influence of arbuscular mycorrizal fungi on *Radopholus similis* in banana roots. Paper presented at a *Meeting of the Association of Applied Biologists at the Linnean Society Meeting Room*, December 18, 1996.

COYNE, D.L. & NAMAGANDA, J. (1996). Plant parasitic nematode pests of root and tuber crops in Masindi District of Uganda. *African Journal of Root and Tuber Crops* **1**(2), 4-7.

KASHEIJA, J.M.; BRIDGE, J.; GOWEN, S.R. AND GOLD, C.S. (1996). Studies on the effect of temperature on nematode penetration in banana roots. *Abstract MusAfrica* **10**:27.

*LAMBOLL, R.I., GOWEN, S.R., SSEMWANGA, J.K., ASABA, J.F., BAGAMBA, F., ROBINSON, E. RUTHERFORD, M.A., TUSHEMEREIRWE, W.K. AND ARINAITWE, M. (2000) Factors affecting the uptake and adoption of outputs of crop protection research in banana-based cropping systems in Uganda. pp.49-64, In: *Sustaining change: proceedings of a workshop on the factors affecting uptake and adoption of Department for International Development (DFID) Crop Protection Programme (CPP) research outputs.* Hainsworth, S.D. and Eden-Green, S.J. (Eds.). Imperial College at Wye, Kent, UK. 21-23 June, 2000. Natural Resources International Limited, Chatham Maritime, Kent, UK

MUDIOPE, J, SPEIJER, P.R., MASLEN, N.R. AND ADIPALA, E. (1998). Evaluation of yam host plant response to nematodes in Uganda. *African Plant Protection* **4**(2): 119-122

NAMAGANDA, J.M.; BRIDGE, J. GOWEN, S.R. & NAMANYA, P. (1996). Studies on host range of the banana nematode, Pratylenchus goodeyi. *Abstract MusAfrica* 10:27.

TALWANA, H L, SPEIJER, P, ADIPALA, E AND MASLEN, N R (1997). 'Early screening of cassava for resistance to root-knot nematodes (*Meloidogyne* spp.). *Nematropica* **27**: 124-135.

TALWANA, H L, SPEIJER, P, ADIPALA, E AND MASLEN, N R (1997). Evaluation of cassava for reaction to root-knot nematodes (*Meloidogyne* spp.) in Uganda. *African Journal of Plant Protection*, Vol. 6, pp. 125-134.

*TUSHEMEREIRWE, W.K., KASHAIJA, N.I., TINZAARA, W. AND NANKINGA, C. (2000). Banana Production Manual: A guide to successful banana production in Uganda.

Draft papers:

KASHAIJA, N.I., NAMAGANDA, J.M. AND MASLEN, R. Nematode host suitability of selected crops commonly grown in the banana-based cropping system.

NAMAGANDA, J.M., KASHAIJA, N.I. AND MASLEN, R. Nematode host status of weeds common in banana plantations in Uganda

Reports and unpublished documents

BAGAMBA (1997) Socioeconomic Baseline Report (March 1997). Non-Chemical Control of Nematodes Project, Kawanda Agricultural Research Institute [KARI], Kampala, Uganda.

BAGAMBA (1999) Impact assessment report (May 1999). Non-Chemical Control of Nematodes Project, Kawanda Agricultural Research Institute [KARI], Kampala, Uganda.

BAGAMBA (2000) Impact Assessment of Non-Chemical Control of Banana Nematodes Project – 2nd Report, March 2000. Non-Chemical Control of Nematodes Project, Kawanda Agricultural Research Institute [KARI], Kampala, Uganda.

GOWEN, S.R. AND MASLEN R. (1995). Non-chemical management of banana nematodes in East Africa . ODA RNRRS Project Memorandum form. Natural Resources Institute, Chatham, Kent.

KASHAIJA, N.I. 1999. Growing bananas in Uganda: Nematodes and their management. Leaflet. National Banana Research Programme, Kawanda Agricultural Research Institute, Kampala, Uganda.

KASHAIJA, N.I. AND NAMAGANDA, J.M (1999). Field handling, planting and management of tissue cultured banana plants. National Banana Research Programme, Kawanda Agricultural Research Institute, Kampala, Uganda. 2pp.

MASLEN R. (1998) RNRRS Quarterly report 1 July – 30 September 1998 Non-chemical control of banana nematodes in E. Africa. NRI/ DFID Crop Protection Programme

NAMAGANDA, JOSEPHINE (2000). Report on production and handling of banana planting material (March, 2000): project report and NARO training text. National Banana Research Programme, Kawanda Agricultural Research Institute [KARI], Kampala, Uganda. 4pp.

NAMAGANDA, J.M., KASHAIJA, N.I. AND NAMANYA, P. (1998) Rotating bananas with cassava and sweet potato to control banana nematodes. In: NARO (eds). Abstracts of centenary conference, 6th – 8th October 1998, Entebbe, Uganda

NAMANYA, P,. NUWAGABA, L.K AND NAMAGANDA, J. (1999). Rapid multiplication of clean planting material through Tissue culture and Decapitation. National Banana Research Programme, Kawanda Agricultural Research Institute [KARI], Kampala, Uganda.

References

ADESIYAN, S O, ODIHIRIN, R A and ADENIJI, M O (1975). Economic losses caused by the yam nematode, *Scutellonema bradys*, in Nigeria. *Plant Diseases Reporter*, **59**:477-480.

BAGAMBA (1997) Socioeconomic Baseline Report (March 1997). Non-Chemical Control of Nematodes Project, Kawanda Agricultural Research Institute [KARI], Kampala, Uganda.

BAGAMBA (1999) Impact assessment report (May 1999). Non-Chemical Control of Nematodes Project, Kawanda Agricultural Research Institute [KARI], Kampala, Uganda.

BAGAMBA (2000) Impact Assessment of Non-Chemical Control of Banana Nematodes Project – 2nd Report, March 2000. Non-Chemical Control of Nematodes Project, Kawanda Agricultural Research Institute [KARI], Kampala, Uganda.

BAKER, T. AND GOWEN, S.R. (1996). Influence of arbuscular mycorrizal fungi on *Radopholus similis* in banana roots. Paper presented at meeting of the Association of Applied Biologists at Linnean Society meeting room, December 18, 1996.

BLAKE, C.D. (1969). Nematode parasites of banana and their control. In : J.E.Peachey (Ed). Nematodes of Tropical Crops. *Technical Communication of the Commonwealth Bureau of Helminthology* **40** : 109 -132.

BRIDGE, J (1978). *Pest control in tropical root crops*. PANS *Manual No. 4*. Centre for Overseas Pest Research. Ministry of Overseas Development, London 4:163-168.

BRIDGE, J. (1988). Plant nematode pests of banana in East Africa, with particular reference to Tanzania. In: INIBAP ed. *Nematodes and the borer weevil in bananas: Present status of research and outlook.* INIBAP, Montpellier. pp. 35-39.

BRIDGE, J., G.W. OTIM-NAPE AND J.M. NAMAGANDA. (1991). The root-knot nematode, *Meloidogyne incognita* causing damage to cassava in Uganda. *Afro-Asian Journal of Nematology* 1(1):116-117.

CAVENESS, F.E. (1982). Root-knot nematodes as parasites of cassava. *IITA Research Briefs* 3(2): 2-3.

CHANDLER, S. (1995). Nutritional value of bananas in *Bananas and Plantains*.Ed. S Gowen, pp. 468-480. Chapman and Hall: London.

COYNE, D.L AND J.M. NAMAGANDA 1994. Root-knot nematodes, *Meloidogyne* spp. incidence on cassava in two areas of Uganda. Roots, **1**(1): 12-13.

COYNE, D.L. & NAMAGANDA, J. (1996). Plant parasitic nematode pests of root and tuber crops in Masindi District of Uganda. *African Journal of Root and Tuber Crops* **1**(2), 4-7.

CRBP (1994). Centre Regional Bananiers et Plantains (CRBP) Annual Report (1994). Douala, Cameroon.

DELVAUX, B. (1995). Soils *in* GOWEN, S. (1995). Soils in Bananas and Plantains. Ed. S Gowen, pp. 230-257. Chapman and Hall: London.

DROPKIN, V.H. (1972). Pathology of *Meloidogyne* spp: galling, giant cell formation and effect on host physiology. *OEPP/EPPO Bulletin*, **6**, 23-32.

EISENBACK, J.D and. TRIANTAPHYLLOU, H.H. (1991). Root knot nematodes, *Meloidogyne* species and races. In: Manual of Agricultural Nematology, pp. 191-241 (ed Nickle, R.W). Marcel and Decker, Incorporated. New York.

GAPASIN, R.M. (1980). Reaction of golden yellow cassava to *Meloidogyne* spp. inoculations. *Annals of Tropical Research*, **2**, 49-53.

GEORGE, E.F (1993). *Plant propagation by Tissue culture*. Part 1. The technology. Exergetics Ltd., UK.

GEORGE, E.F. AND SHERRINGTON, P.D. 1984. Plant propagation by tissue culture. Exergetics Ltd., Basingstoke, UK.

GOLD, C. S., OGENGA-LATIGO, M W, AND TUSHEMEREIRWE, W, KASHAIJA, I. AND NANKINGA, C. (1993). Farmer perceptions of banana pest constraints in Uganda: Results from a rapid rural appraisal. p3-24. *In:* Gold, C S and Gemmill, B (Eds.). *Biological and Integrated Control of Highland Banana and Plantain Pests and Diseases*. IITA, Cotonou, Benin.

GOWEN, S. (1995). Bananas and Plantains. Chapman and Hall, London. 612pp.

GOWEN, S. AND QUENHERVE, P. (1990). Nematode pests of bananas and plantains in *Nematodes of sub-tropical and tropical agriculture.* Eds: Luc, M, Sikora, R and Bridge, J. CABI, Wallingford.

HOOPER, D.J. (1986). Extraction of nematodes from plant material. In : J.F. Southey (Ed). *Laboratory Methods for Work with Plant and Soil Nematodes.* Reference Book **402** : 51 - 58.

HUNT, D.J. and BRIDGE, J. (1991). Nematology techniques. *A guide presented at the Fifth International Training Course on Identification of Plant parasitic nematodes of Economic Importance*, 1st July - 9th August 1991. International Institute of Parasitology, St. Albans, UK: CAB International.

HUSSEY, R.S. and BARKER, K.R. (1973). A comparison of methods of collecting inocula for *Meloidogyne* spp., including a new technique. *Plant Disease Reporter* **57**, 1025-1028.

IITA (1985). Common African pests and diseases of cassava, yam and cocoyam. IITA, Ibadan, Nigeria:108 pp.

IITA (1992). Ministry of Agriculture and Fisheries, Makerere University and the International Institute of Tropical Agriculture. Project proposal for the East and Southern Africa Regional Centre for the improvement of cassava, banana and plantain: 69 pp.

IITA (1995). Plant health management division. IITA Annual Report (1995):181 pp.

INGRAM, W. R. (1970). Pests of banana. In: Agriculture in Uganda. Jameson, J D (*Ed*.). p.145

JATALA P & BRIDGE J (1990). Nematode parasites of root and tuber crops. In: Plant Parasitic Nematodes in Subtropical and Tropical Agriculture, ed. M. Luc, R.A. Sikora and J. Bridge, pp. 137-180. CAB International 629 pp.

KASHAIJA, I. N., SPEIJER, P. R., GOLD, C. S. AND GOWEN, S. R. (1994). Occurrence, distribution and abundance of plant parasitic nematodes of bananas in Uganda. *African Crop Science Journal* **2**, 99-104.

KASHAIJA, I. N. (1996). factors influencing nematode population densities and root damage on banana cultivars in Uganda. *PhD Thesis, University of Reading.*

KASHEIJA, I. N.; BRIDGE, J.; GOWEN, S.R. AND GOLD, C.S. (1996). Studies on the effect of temperature on nematode penetration in banana roots. *Abstract MusAfrica* **10**:27.

LAHAV, E. (1995) Banana Nutrition in *Bananas and Plantains*. Ed. S Gowen, pp.258-316. Chapman and Hall: London.

LAMBOLL, R.I., GOWEN, S.R., SSEMWANGA, J.K., ASABA, J.F., BAGAMBA, F., ROBINSON, E. RUTHERFORD, M.A., TUSHEMEREIRWE, W.K. AND ARINAITWE, M. (2000) Factors affecting the uptake and adoption of outputs of crop protection research in banana-based cropping systems in Uganda. pp.49-64, In: *Sustaining change: proceedings of a workshop on the factors affecting uptake and adoption of Department for International Development (DFID) Crop Protection Programme (CPP) research outputs.* Hainsworth, S.D. and Eden-Green, S.J. (Eds.). Imperial College at Wye, Kent, UK. 21-23 June, 2000. Natural Resources International Limited, Chatham Maritime, Kent, UK.

MCSORLEY, R. & PARRADO, J.L. (1986). *Helicotylenchus multicinctus* on bananas : an international problem. *Nematropica* **16** (1) : 73 - 91.

MUDIOPE, J., SPEIJER, P., MASLEN, N.R. AND ADIPALA, E. (1998), 'Evaluation of yam host plant response (*Dioscorea* spp). to root-knot nematodes in Uganda', *African Plant Protection*, **4**(2): 119-122.

MUDIOPE. J., SPEIJER, P.R., MASLEN, N.R. AND ADIPALA, E. (1998). 'Pratylenchus the dominant genus affecting yam (*Dioscorea* spp.) in Uganda', *Poster presentation, European Society of Nematologists, Dundee, June, 1998*.

NAMAGANDA, J.M., (1996). Nematode parasites of banana-root crop systems in Uganda. *PhD Thesis, University of Reading.*

NAMAGANDA, J.M,. GOWEN, S. AND KARAMURA, E.B. (1993). Plant parasitic nematodes associated with root and tuber crops in Uganda. In: Proceedings of the First East and Southern African Crop Science Conference. *African Crop Science Journal*, **1**, 312-314.

NAMAGANDA, J.M.; BRIDGE, J. GOWEN, S.R. & NAMANYA, P. (1996). Studies on host range of the banana nematode, Pratylenchus goodeyi. *Abstract MusAfrica* **10**:27.

NAMANYA, P,. NUWAGABA, L.K AND NAMAGANDA, J. (1999). Rapid multiplication of clean planting material through Tissue culture and Decapitation. National Banana Research Programme, Kawanda Agricultural Research Institute [KARI].

NATIONAL BANANA RESEARCH PROGRAMME (2000). Planning meeting for Luwero benchmark site 25th-26th July 2000. Kawanda Agricultural Research Institute, Kampala, Uganda.

ORTON-WILLIAMS, K.J. 1972. *Meloidogyne* javanica. Commonwealth Agricultural Bureau, Commonwealth Institute of Helminthology Descriptions of Plant-parasitic nematodes, Set 1 (3), 4.

PRICE, N. S. (1994). Alternate cropping in the management of *Radopholus similis* and *Cosmopolites sordidus*, two important pests of banana and plantain. *International Journal of Pest Management* **40** (3): 237-244.

PRICE, N.S. & BRIDGE, J. (1995). *Pratylenchus goodeyi* (Nematoda : Pratylenchidae) : a plant-parasitic nematode of the montane highlands of Africa. *Journal of African Zoology* **109** (5/6) : 435 - 442.

SARAH, J.L. (1989). Banana nematodes and their control in Africa. *Nematropica* **19**: 199-216.

SAS (1987). SAS-Statistical package, 1987. SAS Institute Inc., Cary, NC 27512-8000, USA.

SASSER, J.N., Carter, C.C and Hartman, K.M. (1984). Standardisation of host suitability studies and reporting resistance to root-knot nematodes. North Carolina State Graphics, Raleigh, 7 pp.

SUDHA, S. & PRABHOO, N.R. (1983). *Meloidogyne* (Nematoda: Meloidogynidae) induced root galls of the banana plant *Musa paradisiaca* - a study of histopathology. *Proceedings of the Indian Academy of Sciences, Animal Sciences* **92** (6): 467 - 473 (Abstract).

SWENNEN, R AND DE LANGHE, E. (1989). Threats to the highland banana in Eastern Africa. *Musarama* **2**, 2-5.

TALWANA, H L, SPEIJER, P, ADIPALA, E AND MASLEN, N R (1997). Evaluation of cassava for reaction to root-knot nematodes (*Meloidogyne* spp.) in Uganda. *African Journal of Plant Protection*, Vol. 6, pp. 125-134.

TAYLOR, A.L. and SASSER, J.N. (1978). Biology, identification and control of root-knot nematode (*Meloidogyne* species). International *Meloidogyne* project. North Carolina State University Graphics, Raleigh. vii + 111pp.

TEZANAS DU MONCEL, H. (1985). Le bananier plantain, ed. Maisonneuve & Larose, Paris. 143p.

TEDFORD, E.C. & FORTNUM, B.A. (1988). Weed hosts of *Meloidogyne* arenaria and M.incognita common in tobacco fields in South Carolina. Annals of Applied Nematology 2 : 102 - 105.

TALWANA, H L, SPEIJER, P, ADIPALA, E AND MASLEN, N R (1997a). 'Early screening of cassava for resistance to root-knot nematodes (*Meloidogyne* spp.). *Nematropica* **27**: 124-135.

TALWANA, H L, SPEIJER, P, ADIPALA, E AND MASLEN, N R (1997b). Evaluation of cassava for reaction to root-knot nematodes (*Meloidogyne* spp.) in Uganda. *African Journal of Plant Protection*, **6**:125-134.

TALWANA, H L, SPEIJER, P, ADIPALA, E AND MASLEN, N R (1997c). 'Effect of pre-plant population densities of root-knot nematodes (*Meloidogyne* spp.) on establishment of cassava cuttings.' *Proceedings of the All Africa Crop Science Congress,* Pretoria, S. Africa, 13-17 January, 1997. 128pp

WEHUNT, E.J. and EDWARDS, D.I. (1968). *Radopholus similis* and other nematode species on bananas. In : G.C.Smart & J.G.Perry (Eds).*Tropical Nematology.* University of Florida Press, Gainesville : 1 - 19.

WALKER, P. T., HEBBLETHWAITE, M. J., AND BRIDGE, J. (1984). Project for banana pest *control and improvement in Tanzania*. EEC report for government of Tanzania. London. TDRI 129pp.

WILSON, J E, ROCHERS, K Des and EVENSEN, C I (1988). *Rapid multiplication of yams*. Institute for Research, Extension and Training in Agriculture (IRETA), Apia, Western Samoa: 11 pp.

Appendix 1:

NEMATODE PROJECT: KAYUNGA

On-farm evaluation Questionnaire:

1. Farmer's name: …………………………………………………………..

2. Size of plot (m^2)………………………………………………………….

3. Break crops

a) ……………………………
b) ……………………………

4. Labour utilized in the plot (hours)

	male	female	children
Bush clearing	…………	…………	………….
1st ploughing	…………	…………	………….
2nd ploughing	…………	………….	……………
Planting	………….	…………..	……………
1st weeding	…………..	…………..	……………..
2nd weeding	…………..	…………..	……………..

5. Spacing used at planting…………………………………………………………………

6. Spacing usually used…………………………………………………………………..

7. Who takes care of the plot

a) Man
b) Woman
c) Children
d) Hired labour

8. Who usually takes care of the crops in question

a) Man
b) Woman
c) Children
d) Hired labour

9. State of the crop

a) Well managed
b) Poorly managed
c) Abandoned

10. If 7b) or c),why

Appendix 2:

NEMATODE PROJECT – ON-FARM TRIALS

Baseline data

1. LOCATION

(a) Village……………………………..

(b) Parish………………………………

(c) District…………………………….

2. RESPONDENT'S CHARACTERISTICS

(a) Names……………………………………………

(b) Head of household Yes/No

(c) If no, what is his/her relationship to the head of household…………………………..

(d) Age of respondent…………….

(e) Gender of respondent……………..

3. **WEALTH STATUS OF HOUSEHOLD** (from Key informants; Also cretria for catagorizing farmers to be obtained from farmers)

(a) High

(b) Medium

(c) Low

4. CROPPING SYSTEM

(a) Land

- (i) Total household land owned…………………………………………….
- (ii) Who makes decisions about use of land………………………………
- (iii) Land under crops (acres)………………………………………………..
- (iv) Land under bananas (acres)…………………………………………….

(b) Crops grown in order of decreasing importance (with regard to acreage and/or output)

- (i) 2major staple food crops……………………. ………………….
- (ii) 2 major cash crops…………………………… ………………….

(c) Food crops preferred in order of decreasing preference

- (i) For food security……………………… ………………….
- (ii) For taste………………………………… …………………..

(d) Banana cultivars preferred in order of decreasing preference

(i) ………………………………………………………

(ii) …………………………………………………..

(iii) ………………………………………………………

(iv) ………………………………………………………

5. RESEARCH OPTIONS (FARMER'S PREFERENCE)

(a) Planting clean material directly in plots formerly under bananas but later replaced by break crops (state year when bananas were removed)

(b) Clear banana plot and plant break crop first

(c) Both (a) and (b)

6. **IN CASE OF 5 (a) ABOVE, WHAT IS THE CROPPING HISTORY OF PLOT PREFERED FOR TRIAL**

(a) Current year

(i) 1st season

(ii) 2nd season

(b) Previous year

(iii) 1st season

(iv) 2nd season

7. SKETCH MAP FOR PREFFERED TRIAL PLOT AND ADJACENT PLOTS

Appendix 3:

MID-TERM DATA FOR KAYUNGA SITE OF THE BANANA BREAK CROP PROJECT

Date:____

A. Name of head of household……………………………………………………………..

B. Cultivars currently grown on the farm

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

C. How large was the banana plantation before 1997_________(acres)

D. How many banana mats have been planted since 1997_______

E. What methods did you use in establishing the new plantations?

(i)Land opening/ Bush clearing

a) Burn
b) Cut and burn
c) Slash and let rot
d) Slash and throw away

(ii) Planting

(a) Pit depth and width
(b) Manure added: Yes/No
(c) Planting material

Source………………………………….
Type…………………(peepers, sword, corm, T.C, etc.)
Treatment…………………………..

(iii) Manuring/fertilization (type, when applied, how applied*).
…………………………………………………………………………….
Put in the hole before planting, around/closeto the plant, or spread in the whole field or in trenches?

(iv) Mulching a) Type………………….Source………………………..

b) Area of application (Close to OR away from the mat)
……………………………………………………………………………
(v) Any tillage after crop establishment
……………………………………………………………………………
(vi) Timing and frequency:

(a) Weeding………………………
(b) Pruning……………………….

(c) detrashing……………………
(d) no. of suckers left per stool and why?

……………………………………..

E . Productivity

i) Any change in the production capacity since 1997: Yes / No

ii) Currently;

a) What is the average bunch size
b) How many bunches do you harvest in the month of highest production

____

c) How many bunches do you harvest in the month of low production

____

iii) What are the pests associated with banana production? (tick appropriate answer)
(a) Banana weevil
(b) Nematodes
(c) Kaasa
(d) Earthworms
(e) Others (specify)

iv) What are the control measures known to you for the above banana pests? (For each control measure, specify the source of information)

(a) Banana weevil source of information

(b) Banana nematodes

(V) What measures do you use to control the above banana pests?

(a) Banana weevil
(b) Banana nematodes

F. What do you about break crop technology?

G. What comments do you have about the break crop technology?

Appendix 4:

Site and farm selection criteria

Site selection criteria

- Nematode species (mainly) R. similis, P. goodeyi) present
- Area in a banana production decline (due to production problems) but farmers interested in obtaining solutions and continuing to grow bananas
- Strong interest from local community to participate in solution development projects

Farm/farmer selection criteria

- Farmer says s(he) is willing to plant break-crops and tissue-cultured banana (?local variety)
- Farmers willingness to provide experimental plot
- Farmers willingness to take care of the experimental crop's husbandry
- Size of the availed plot (big enough to accommodate the experiment treatments)
- Plot in a plantation that is in a declining state, or bananas were removed not more than 2 years before start of the project
- Presence, in substantial quantities, of the target nematode species

Appendix 5

Non-chemical control of East African banana nematodes

Socioeconomic Baseline Report (March 1997)

Fredrick Bagamba

Introduction

The project operates in four parishes in Mukono county, Mukono district. Thirty-three participating farmers from 7 villages were initially involved in the project whose purpose is on-farm testing of use of break crops (cassava and sweet potatoes) to control nematodes affecting bananas. A cross sectional survey of farms and households was done in May 1996 to identify factors that would be influential in implementing and execution of the project. All households selected for participation in the research were interviewed. A follow up was made to seek views from the participating farmers regarding strengths, weaknesses, opportunities and threats to the project.

Farm and household characteristics for the project area are provided in Table 1. A list of the households had earlier been made and farmers asked to categorize them into 3 groups: the high, medium and low wealth categories. Three of the households were ranked high wealth, 20 middle wealth and 7 low wealth. Three were not ranked. Indicators used for wealth ranking included non-farm income, nature of house owned, household farm size, number of livestock owned and income from crops.

Majority of the farmers in the middle socioeconomic strata had good houses most likely built when coffee/banana production and prices were remunerating before late 1970s. However, after that, incomes for these farmers declined tremendously reducing on their socioeconomic status from top to middle class. Currently, farmers considered rich in the area are ones earning considerable amount of income from activities other than crops.

Of the 33 respondents interviewed, 27 were the heads of households. Forty percent of the respondents were female. There were more female respondents in the low and medium wealth categories than in the high wealth. Average age of respondents was 46. Average age of farmers in the high wealth category was lower than that of low and medium wealth farmers.

On average, the household had access to 6.8 acres. Lowest farm size was 2.5 acres and highest was 39 acres. Fifty five percent of the households had access to less than 5 acres of land, 43% had access to between 5 and 10 acres and 3% above 10 acres. There was no significant difference in amount of land owned by medium and high wealth farmers. Farmers in the low wealth group had less access to land.

Table 1. Farm and household characteristics for project area.

Characteristics	Socioeconomic status			
	Top	Middle	Bottom	Overall
Average household size	11	9	12	10
Males >18 years	3.0	1.5	1.6	1.7
Females >18years	2.0	1.6	1.6	1.6
Children >=12years	2.7	2.2	3.8	2.5
Children <12years	3.0	4.0	5.0	4.0
Mean age of respondent (years)	39	48	45	46
Proportion female respondents (%)	33	40	43	40
Total household land (acres)	7.7	7.5	5.6	6.8
Land under crops (acres)	5.1	4.9	5.4	5.0
Land under bananas (acres)	3.3	4.0	2.3	3.4
Food crops grown (Proportion of farmers)				
Ranked bananas first	67	90	71	79
Sweet potatoes first	33	10	29	21
Maize first	0	5	0	0
Cash crops (Proportion of farmers)				
Ranked bananas first	33	30	0	22
Coffee first	67	70	86	75
Maize first	0	0	14	3
Crops preferred for food security (Proportion of farmers)				
Ranked bananas first	67	60	43	52
Sweet potatoes first	0	5	14	6
Cassava first	33	35	14	33

Maize first	0	0	14	6
Beans first	0	0	14	3
Crops preferred for good taste (Proportion of farmers)				
Ranked bananas first	100	90	100	93
Cassava as first	0	0	0	0
Sweet potatoes first	0	5	0	3
Maize first	0	5	0	3

Most of the land was allocated to crops. Farmers in the low wealth group cultivated almost all their land whereas farmers in the medium and high wealth groups had a sizeable amount left uncultivated. Overall, land allocated to bananas was 70% of total land committed to crops. On average, the household grew 3.4 acres of bananas, well above the acreage allocated to other crops. Farmers in the medium wealth group had more land allocated to bananas (4 acres) compared to high wealth (3.3 acres) and low wealth (2.3 acres) farmers. This shows that farmers in the middle socioeconomic strata have more interest in crop production and are likely to commit more resources to technologies that could improve banana productivity.

Despite low yields of bananas, farmers still attached high importance to the crop, reflected in large proportion of land allocated to the crop. Seventy nine percent of the farmers regarded bananas as the most staple food crop. Sweet potato was ranked as second staple food crop grown with 21% ranking it first. Other food crops grown included beans, maize and yams.

Overall, banana was second to coffee in terms of cash income generating, where 22% ranked it as first cash crop. Coffee was ranked first cash crop by 75% of the farmers. Other crops regarded as income sources included maize, yams, exotic beer bananas (‘kayinja’ AB genome group), cocoa and beans, but with lower ratings.

In terms of food security, bananas were most preferred, ranked first by 51.5% of the farmers and this was attributed to its being harvested throughout the year. Cassava was ranked second despite the fact that it is not widely grown. The reason for cassava preference was that it stayed in the soil for a long time without rotting. Sweet potatoes were ranked third and yams fourth. Matooke (East African highland cooking bananas – AAA group) were the most preferred food crop in terms of taste by 93% of the respondents. Cassava ranked second and sweet potatoes third. Cassava production was limited by cassava mosaic virus, which had almost wiped out the crop. Access to cassava planting material resistant to mosaic virus was very limited. Availability of good planting material was probably a major motivation for farmers to participate in this project but in itself, this is not a defect, since a liking for cassava due to poor banana yields is perfectly reasonable. Cassava planting material was supplied free to farmers.

Farmers were asked to rank the matooke cultivars in terms of preference to help in future selection of banana planting material to supply to farmers. Ndibwabalangira, Nakitembe, Ntikka, Siira and Mayovu were some of the cultivars cited as most preferred.

Production constraints and management

Changes in banana productivity. All respondents reported change in banana productivity with 93% of the farmers claiming to have experienced a decline in production. On average, bunch weight reduced from 15kg to 6kg over the years. Number of bunches harvested monthly in a bumper period shrunk from 140 bunches to 29 bunches (Table 2). Farmers in the top socioeconomic strata experienced decline in banana productivity more where bunch size shrunk from 20kg to 6kg. Farmers in the middle strata experienced decline in bunch size of about 10kg (Table 2). Serious decline in banana in banana production was experienced by farmers in the middle strata where number of bunches reduced from 165 to 35 bunches per month but still they harvested more (35 monthly in bumper period) than farmers in the top and bottom strata.

Table 2. Changes in banana productivity

Productivity characteristics	Top	Middle	Bottom	Overall
Average age of current banana plot (years)	1.2	15.8	3.2	11.9
Minimum age of banana plot (years)	0.7	1.0	1.0	0.7
Average bunch weight (kg) before decline	20.0	15.8	9.8	14.7
Monthly harvested bunches before change				
Bumper period	50.0	165.3	47.3	140.0
Scarcity	-	28.4	-	28.0
Current bunch weight (kg)	6.0	5.5	7.4	5.9
Current bunches harvested per month				
Bumper period	10.0	35.1	14.8	28.6
Scarcity	4.0	5.8	5.3	5.5

Factors attributed to the decline in order of decreasing importance included pest buildup, drought, poor soil fertility and poor management practices (Table 3). Pests associated with the decline included the banana weevil (reported by 79% of the farmers), ants ('Kaasa') (71%) and to a lesser extent earthworms ('Obusiringanyi') (7%) (Table 3). Few farmers (7%) differentiated toppling from weevil damage implying that farmers are less aware of the nematode problem.

Table 3. Causes of banana production decline

Reasons for		Proportion of farmers (%)		
Production decline	Top	Middle	Bottom	Overall
Decline in soil fertility	33.3	50.0	0.0	39.3
Drought	66.7	45.0	40.0	46.4
Poor management	33.3	25.0	20.0	15.0
Pest buildup	66.7	65.0	40.0	63.0
Kind of pests				
Weevil	33.3	85.0	80.0	78.6
Ants	66.7	70.0	80.0	71.4
Earthworms	0.0	10.0	0.0	7.1
Toppling	66.7	10.0	0.0	7.1

Production constraints can further be established from the reasons given for cultivar disappearance (Table 4). Pest buildup was reported to have contributed to the disappearance of all cultivars whereas some cultivar disappearance was attributed to decline in soil fertility. Poor management contributed to the disappearance of Nakabululu, Mbwazirume and mukubakonde. Drought contributed to the disappearance of Siira, Ndibwabalangira and kibuzi.

Table 4. Cultivar disappearance

Cultivar	**% farmers Reporting cultivar** Disappearance	**Reasons for disappearance** **Poor** soils	**Pests** buildup	**Small** bunches	**Poor** management	**Drought**
Nakabululu	21.4	*	*	*	*	
Nakitembe	14.3		*			
Siira	21.4		*			*
Mayovu	3.6		*			
Ndibwabalangira	14.3	*	*			*
Mbwazirume	7.1		*			
Namwezi	11.1	*	*		*	
Kibuzi	14.3	*	*			*
Musakala	3.6		*			
Mukubakonde	7.1	*	*		*	

Most preferred cultivars were Nakitembe (preferred by 57%), Ndibwabalangira (50%), Siira (43%), Nakabululu (32%) and Musakala (29%) (Table 5). Reasons for preference of certain cultivars included big bunch size, good taste and soft, and drought resistance implying that farmers are aware of the need for high productivity (both quality and quantity).

Table 5. Cultivar preferences

Cultivar	**% farmers** Preferring	**Reasons why preferred**						
		Soft Food	good taste	mature early	big bunch	drought resistant	good suckering	Large Fingers
Nakabululu	**32.1**	*****	*****	*****				
Nakitembe	57.1	*	*		*	*	*	
Siira	42.9		*		*	*		
Mayovu	14.3		*		*			
Ndibwabalangira	50.0	*	*		*			
Ntiika	32.1	*	*	*	*	*		
Nfuuka	17.9			*	*	*	*	
Kibuzi	10.7	*	*		*			
Kisansa	14.3	*			*			
Musakala	28.6	*	*		*	*		*

Very few farmers reported use of specific practices to address some of the above constraints (Tables 6 and 7). Farmers reported various ways of land opening where 42% carry out slash and burn method. Most planting material is secured from own plantations and treatment to control pest spread is very minimal. 97% of the farmers plant maiden suckers, which by the time of planting will have had pest accumulation (weevil and nematodes), and thus encouraging pest buildup and dispersal.

Few farmers employ practices that could improve soil fertility and moisture management. Despite the fact that weeding is done frequently (6 times annually), this is done using a hoe which leads to root damage.

Table 6. Management practices

Method	Proportion of farmers by socioeconomic strata (%) Top	Middle	Bottom	Overall
Land opening				
Slash and burn	33.3	45.0	40.0	42.9
Slash and let rot	33.3	30.0	60.0	35.7
Slash and remove	33.3	10.0	0.0	10.7
None	0.0	15.0	15.0	10.7
Source of planting material				
Own plantation	50.0	84.2	100.0	84.6
Off-farm	50.0	15.8	0.0	15.4
Type of planting material				
Maiden suckers	100.0	95.0	100.0	96.4
+Sword suckers	0.0	5.0	0.0	3.6
Planting material treatment				
None	0.0	55.0	40.0	46.4
Pesticide	33.3	10.0	20.0	14.3
Reduce root mass	66.7	30.0	20.0	32.1
Ash	0.0	5.0	20.0	7.1
Field management				
Manuring	33.3	35.0	20.0	32.1
Type of manure				
Coffee husks	33.3	15.0	0.0	67.9
FYM	0.0	5.0	0.0	3.6
Compost	0.0	10.0	0.0	7.1
Scanty cow manure	0.0	5.0	20.0	7.1
Mulching	35.7	33.3	35.0	35.7
Type of mulch				
Elephant grass	0.0	5.0	0.0	3.6
Banana trash	33.3	35.0	40.0	35.7
Other	0.0	10.0	0.0	7.1
Loosening soil	66.7	70.0	80.0	71.4

Other practices (Frequency of operations)

Weeding (times/year)	5.7	6.0	6.8	6.0
Deleafing (times/year)	3.7	3.3	4.4	3.5
Desheathing (times/year)	3.7	3.1	4.0	3.4
Number of suckers per mat	3.4	3.3	3.8	3.4

Pest management in the field is minimal with 32% of the farmers not carrying out any pest management (Table 7). Other farmers reported to be using a variety of methods to control the pests but on a less intensive scale. Majority of the farmers reported not to be satisfied with the methods used to control the pests (Table 8). Only 18% rated the methods used as moderately effective and 18% rated the effectiveness as low. Those that reported the methods used as ineffective were 11%.

Table 7. Pest control measures

Management	Proportion of farmers (%)			
	Top	Middle	Bottom	Overall
None	0.0	40.0	20.0	32.1
Trapping	0.0	15.0	20.0	14.3
Plant new field	33.3	0.0	0.0	3.6
Pesticide	0.0	10.0	0.0	7.1
Urine + pesticide + trap	0.0	5.0	0.0	3.6
Apply urine + ash	0.0	5.0	0.0	3.6
Apply ash	0.0	5.0	20.0	7.1
Mulch placement	0.0	0.0	20.0	3.6
Stop mulching	0.0	5.0	20.0	7.1
Remove corms	33.3	5.0	0.0	7.1
Sanitation alone	0.0	5.0	0.0	3.6

Table 8. Farmers' satisfaction with the pest control methods used

Rating of methods used	Proportion of farmers (%) Top	Middle	Bottom	Overall
Very effective	0.0	0.0	20.0	3.6
Moderate	0.0	20.0	20.0	17.9
Low	33.3	20.0	0.0	17.9
Not effective	0.0	5.0	40.0	10.7
Not decided	0.0	5.0	0.0	3.6
No pests	66.7	45.0	20.0	32.1
No response	0.0	5.0	0.0	14.3

Limited access to information was a major constraint to pest management. 11% of the respondents reported lack of access to information, 11% received information from the extension service and only 4% receive information from the radio. A higher proportion of farmers (25%) got information from fellow farmers.

Table 9. Sources of information for controlling pests

Information source	Proportion of farmers (%) Top	Middle	Bottom	Overall
None	0.0	5.0	0.0	10.7
Extension	0.0	15.0	0.0	10.7
Radio	0.0	5.0	0.0	3.6
Fellow farmers	0.0	20.0	60.0	25.0
No pest control	33.3	40.0	20.0	32.1
No response	33.3	15.0	0.0	17.9

Monitoring cassava plots

The first cassava was planted in November 1996. Harvesting began in July 1997 without consent from researchers. Famine was one of the reasons that prompted them to harvest the cassava early. Most farmers in the area usually have less food for household consumption.

Most farmers complained that the cassava (variety SS4) was bitter. Below 12 months, the cynide content is still high but farmers were not patient for it to lower down. The 8 months period between planting and harvesting was also still too short to have an effect on the nematode population, which necessitated a second cassava planting.

Most of the farmers had inter-planted the cassava with other crops, especially beans, maize and groundnuts, without consent from the researchers. Beans and maize are known hosts to *Pratylenchus goodeyi*. Farmers claimed to have been advised by the extension agent residing in the area, who had been involved in the project in the early stages, to go ahead with inter-cropping. More so, inter-cropping cassava with other crops is a tradition in the area to enable the farmer to get some output in a period when cassava is not yet ready.

Most of the plots were well weeded, 3-4 times, which shows the importance attached to cassava in the area. Only one farmer opted to plant sweet potatoes in anticipation of getting planting material for bananas from the project. Another farmer planted both cassava and sweet potatoes because she had more space than provided for in terms of cassava planting material. Four farmers dropped out. One sold off his land, the second misappropriated the cassava planting material and the third fell sick. The fourth one did not manage his plot well.

Recommendations

For the success of the project, there is need to improve farmers' knowledge base on pest control and soil-improvement as away of improving banana productivity, which will encourage farmers to adopt the break crop technology. Controlling nematodes is a necessary but not satisfactory condition for improving banana productivity in the area. There is need to integrate all the cultural, agronomic, biological, social and economic aspects when promoting the break crop technology.

Appendix 6

Rapid multiplication of clean planting material through Tissue culture and Decapitation

P. Namanya, Nuwagaba, L.K. and Namaganda, J..
National Banana Research Programme
Kawanda Agricultural Research Institute [KARI].

ABSTRACT

Meristem and shoot tip culture is a routine method used in rapid multiplication of bananas that are true to type. Adventitious buds induced from shoot tips on a modified MS media are repeatedly dissected to increase the number of buds. Rooted plants, after acclimatization in the nursery for 1-2 weeks, are potted in plastic pots for 1.5-2 months and supplied to farmers for field planting. *In vitro* micropropagated plants are disease free, more vigorous in growth, have higher rates of survival and a uniform growth compared to suckers. Decapitation is a technique in which the apical meristem is destroyed to suppress apical dominance and stimulate sucker development. This produces 8-12 suckers (depending on cultivar) 3-4 months earlier than normal regeneration of 10-12 months. Ongoing work is aimed at improving plant quality and increased production of planting materials to meet the farmers' needs.

Key words*: In vitro*, shoot tip culture, decapitation, micropropagated.

INTRODUCTION:

Shortage of clean planting material is a major constraint to expansion and improvement of banana production in Uganda. Suckers consisting of fairly well developed buds are scarce owing to the nature of the plant i.e. exhibiting low output of buds and their slow development (Tezenas du Moncel 1985). Establishment of commercial plantations is also limited by this lack of clean planting material. Tissue culture and decapitation are the current efforts towards addressing this problem. Plant tissue culture is the science of growing plant cells, tissues or organs isolated from other plants, on artificial media under artificial growing conditions (George 1993). Rapid clonal multiplication is one of the first major practical applications of the science of tissue culture (George and Sherrington, 1984). Other important applications include eradication of pests and diseases, conservation and exchange of germplasm, plant breeding and biotechnology. At Kawanda Agricultural research Institute (KARI), tissue culture is used for rapid multiplication of disease and pest free planting material.

METHODOLOGY.

Two methods are currently used for rapid multiplication of banana clean planting materials .
In vitro shoot-tip culture technique and decapitation (a field technique).

SHOOT TIP CULTURE

In vitro propagation proceeds through a sequence of 3 major steps as defined by Murashige (1974).
Stage 1. Initiation of aseptic cultures
Stage 2. Multiplication of propagules.
Stage 3. Regeneration of plants for transfer to soil (includes rooting and acclimatization).

Establishment of the aseptic cultures.
The first stage in micropropagation of *Musa* involves establishing an aseptic culture of shoot tips. This is achieved by disinfection, excision and incubation of explant on appropriate, sterile media (Vuylsteke, 1989).

Media composition.
Successful plant tissue culture techniques depend on the choice of nutrient medium (Murashige, 1974). In the tissue culture Laboratory at KARI, a protocol established for micropropagation of East African Highland Bananas is used (Talengera *et al*. 1994). This comprises of MS basal media supplemented with MS vitamins (without myo-inositol), and cytokinin BAP at 5.0mg/l. BAP is an important component of plant propagation media through which organ development on the explant is regulated. No auxin is incorporated for both multiplication and rooting media.

Explant selection and preparation.
Shoot tips are usually obtained from healthy looking buds, peppers, and small sword suckers. These are a preferred source of material due to their greater ease of handling (Jarret *et al*.1985) and proliferate for longer times while in culture compared to parental pseudostems (personal observation). Suckers harvested from the source plants are usually contaminated with microorganisms, so they must be surface sterilised before the explants (i.e. shoot-tips) are isolated and transferred into culture. Shoot apices are naturally protected by tightly overlapping leaf sheaths so sterilisation is easily done (Vuylsteke, 1989).

Sterilisation procedure:
Trim away the outer leaf sheaths and corm tissue until a 1-2cm cube enclosing the shoot apex is obtained (Fig. 2). Wash tissue in a solution of commercial laundry bleach (e.g. Jik) at 15% (v/v) sodium hypoclorite (NaOCL) plus a few drops of a detergent for 20minutes.
Working under aseptic conditions, preferably in a horizontal airflow hood, rinse in 96% ethanol for 5minutes.
Immerse in a solution of commercial laundry bleach (as above). Tween 20 (a liquid detergent) at 2 drops per 100mls is added to break surface tension and enhance surface sterilant contact.
Rinse three times with sterile distilled water. The shoot-tip cubes are now ready for excision.

Multiplication of propagules.

Multiple buds or shoot formation is achieved by incorporating ahigh level of cytokinin in media to reduce apical dominance. This results in formation of adventitious and auxiliary buds. These are eventually subdivided and cultured every three to four weeks to allow more bud formation (Fig 1). In addition De Guzman's (1980) technique of using fragmented shoot apex is employed to stimulate multiple bud formation.

Culture conditions.

Cultures are grown in transparent glass tubes or jars. They are incubated under controlled light and temperature regimes. Temperature is controlled by air conditioning at 27-28^{o}C. Cool white fluorescent tubes are used at a light /dark cycle of 14/10 hours.

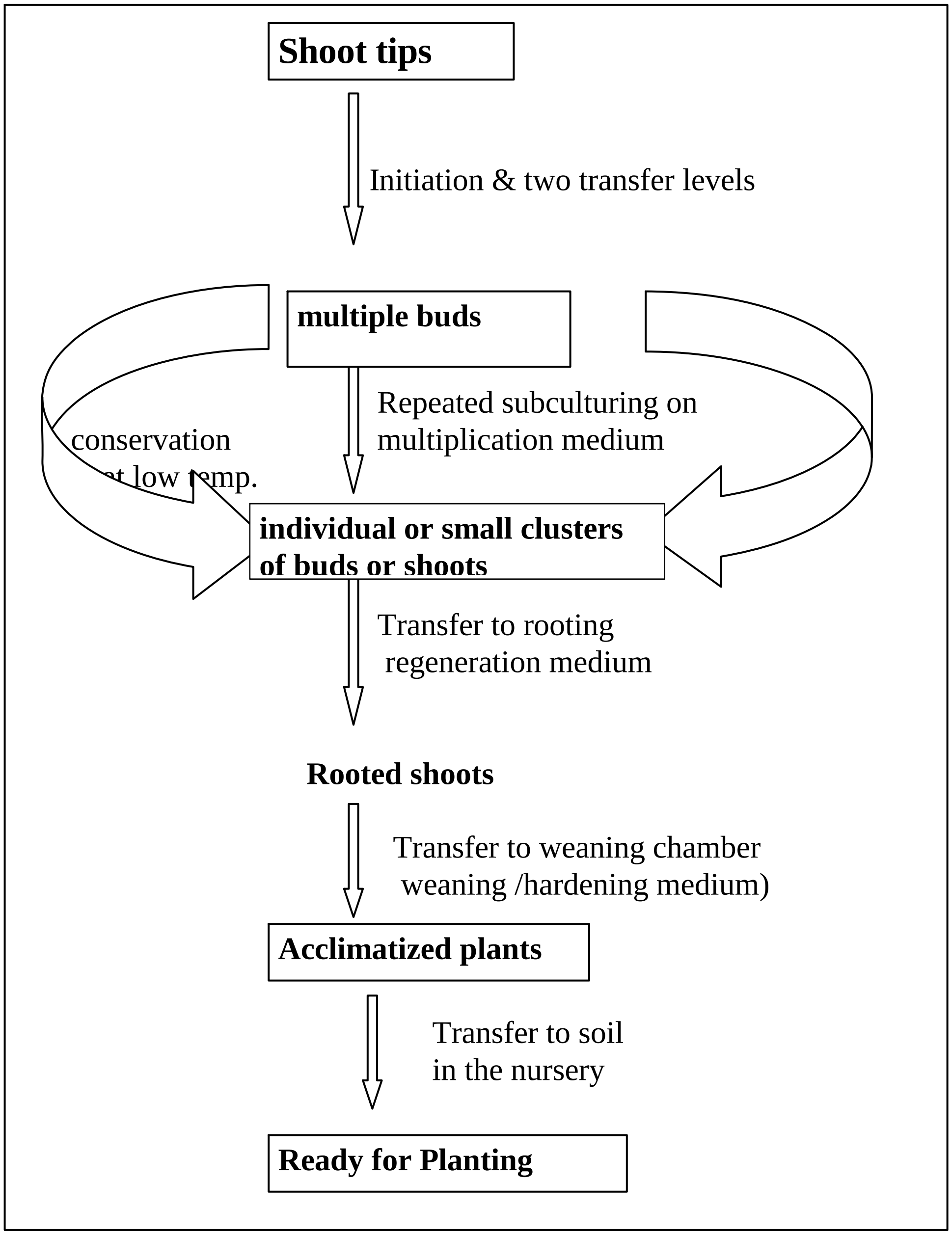
Regeneration of plants.

Root initiation in micropropagated shoots as well as elongation of buds into shoots, is accomplished by transferring propagules to auxin free MS media as described by (Talengera e*t* . al. 1994). Rooted shoots are acclimatised in a humid weaning chamber before they are transferred to soil in the nursery (Fig 1).

DECAPITATION.

Decapitation, is a field based multiplication technique in which the apical meristem is destroyed to suppress apical dominance thereby stimulating sucker development. Mature healthy plants four to six months old are identified, a window about 50cm^2 is cut at the base of the pseudostem, the meristem is then completely scooped out. Foliage is retained as a major source of photosynthates. Its retention provides a suitable source of nourishment, hence more vigorous sucker growth. The banana plants produces eight to ten suckers, three to four months earlier than normal regeneration of 10-12 months and are ready for planting.

Fig 1: Schematic procedure for multiplication and regeneration of banana plants by shoot-tip culture *In vitro*.



Discussion.

The constraints encountered in *in vitro* micropropagation of East African Highland bananas is the endogenous auxin which causes precocious rooting starting after the first subculture, even at BAP level of 5.0mg/l (Talengera *et al*.1994). In addition there are differences in proliferation as well as suckering (on field) rates of the different cultivars. However, at KARI, the National Banana Research Programme, through tissue culture and decapitation has been able to provide clean planting material for 22 mother gardens in seven districts of Uganda (Masaka -1, Kamuli -1, Rakai-1, Kibale -3, Mpigi -4, Luwero-11, Mbarara-1). Germplasm evaluation fields have been established in 18 districts (four fields each) i.e.

Kitgum, Gulu, Lira, Katakwi, Arua, Soroti, Pallisa, Kumi, Tororo, Bugiri, Iganga, Kamuli, Jinja, Rakai, Masaka, Nakasongola, Sembabule, & Kisoro. Materials have been provided for Individual farmers, Non GovernmentalOranisations and Research scientists' experiments (both on farm and on station).

REFRENCES

De Guzman, E. V., Decena, A.C and Ubalde, E.M. 1980. Plant regeneration from unirradiated and irradiated banana shoot tip tissues cultured *in vitro*. Phil. Agric., 63: 140-146.

George, E.F 1993. Plant propagation by Tissue culture. Part 1. The technology. Exergetics Ltd., England.

George, E.F. and Sherrington, P.D. 1984. Plant propagation by tissue culture Exergetics Ltd., Basingstoke, UK.

Jarret, R.L., Rodriguez, W. & Fernandez, R. 1985. Evaluation, tissue culture propagation & dissemination of 'Saba' and Pelipita plantains in Costs Rica. Sci. Hort., 25: 137-147.

Murashige, T. 1974. Plant propagation through Tissue culture. Ann Rev. Plant Physiol., 25: 135-166.

Talengera . D 1994. Micropropagation of East African Highland Bananas (*Musa* spp) Msc Thesis. Dept of Crop Science. FAF. MUK.

Tezanas du Moncel, H. 1985. Le bananier plantain, ed. Maisonneuve & Larose, Paris. 143p.

Vuylesteke, D.R. (1989). Shoot tip culture for the propagation, conservation and exchange of *Musa* germplasm. International Board for Plant Genetic Resources.

Wilson, G.F., Vuylsteke, D. Swennen, R. 1985. Rapid multiplication of plantain: An improved field technique In: International Cooperation for Effective Plantain and Banana Research: proceeding of the 3rd meeting of IARPB, 27th- 31st May 1985, Abidjan, Cote d'Ivoire. P. 24-26.

Appendix 7

Field handling, planting and management of tissue-cultured banana plants

I. Kashaija and J. Namaganda

Tissue cultured banana plants are normally kept in the nursery for a period of 2 -4 months before field planting. This prepares them for direct sunshine under field conditions. By this time, the plants are 20 –30 cm tall with at least 3-5 broad leaves. These are then ideal for field planting.

Guidelines for planting.

1. Planting should be done in a clean field, planted at the recommended spacing in the morning or late afternoon to avoid heat.

2. Plants should be watered well just before planting, transported to the prepared field and placed next to the planting hole.

3. The bottom part of the polythene bag should be stripped off to avoid damaging the roots during planting.

4. Place the plant in the planting hole, partly covered with soil, to provide stability to the plant and its root-soil clump in the bag.

5. Remove the polythene bag (without its bottom) by gently pulling it over the leaves and the top of the plant.

6. Add more soil (usually top-soil) to the planting hole.

Note : The first new leaves form within 2-6 weeks after planting in the field.

Precautions

Plants may be watered in the field if necessary and feasible. This is necessary because young micro-propagated plants (as well as conventional suckers and corms) cannot withstand dry weather conditions.

Special attention should be given to the plants during the first 3-4 months after planting.
Plants should be kept free of weeds, should be mulched, manured and fertilised according to recommended cultural practices in the areas.

If the tissue culture plants are planted in an area where goats and cows graze freely, plants should be fenced in, or otherwise protected, because the succulent leaves of young plants are favoured by livestock. Ensure that the field where you are going to plant is free of pests and diseases.

Advantages/ benefits of tissue cultured banana plants.

- Micropropagated bananas in combination with other good cultural practices (e.g. correct planting time, fertilizer or manure , mulch)
- will establish quickly
- grow more vigorously and taller,
- produce bigger and heavier bunches,
- have a shorter and more uniform production period.

Tissue culture plants are a good choice for planting material to reduce the risk of introducing pest and diseases in the new planting field.

In general the superior performance of micro-propagated bananas is due to the fact that they already posses an active root and shoot system at the time of planting.

Appendix 8

PROJECT A0508: NON-CHEMICAL CONTROL OF BANANA NEMATODES

Report on production and handling of banana planting material

Josephine Namaganda

Background

Banana nematodes have been identified among the major production constraints in Uganda. Use of infested planting material is the major means of spread of banana nematodes. Use of clean planting material in nematode-free soil would be the most effective nematode management practice. However, the majority of farmers in Uganda have no access to clean planting material, so they obtain planting material from established banana plots which are nearly always infested with nematodes.

The ever increasing pressure on land has resulted in a reduction in the size of holdings. In an attempt to maximise production from the small holdings, farmers have to crop all the land available to the family. As productivity decreases due to continuous cropping and lack soil nutrient replenishment, intercropping becomes a more common practice. Since banana is a major food crop, this would mean that smallholders who are the majority of the Ugandan farming population, have no access to banana nematode-free land. Nematode-free land would be either virgin land, or land that is free of banana plants.

Use of non-host crops, or breakcrops, is an inexpensive and effective method of eliminating plant parasitic nematodes from soil. Cassava and sweet potato eliminated banana nematodes from soil in 18 months when planted as breakcrops in an on-station trial (Namaganda, 1996). Since cassava and sweet potato are second and third in importance as food crops in central Uganda and have been planted as replacements to banana, this technology was considered appropriate for the resource poor farmers in the region. Plant parasitic nematodes were identified as one of the major causes of banana decline in this region. A trial aimed at validating the technology on- farm was, therefore, established in 1997 in Kayunga, Mukono district.

Use of clean planting material is a pre-requisite for any cropping programme. Production of clean planting material was, therefore, initiated at Kawanda Agricultural Research Institute (KARI), to provide an adequate supply of nematode-free material for banana replanting under the breakcrop trial.

Cultivar selection

The East African Highland cooking banana (*Musa* AAA-EA) cultivars Nakitembe and Ndibwabalangira were selected, basing on the results of a baseline survey carried out earlier on. According to the survey results, the cultivars Nakitembe, Ndibwabalangira and Ntikka were the most preferred. The major reasons given for preference of these cultivars were early maturity and good culinary characteristics. Consumers of cooking bananas in Uganda prefer cultivars that make 'good' food.

Early maturing cultivars may not necessarily have the biggest bunches, but more bunches are harvested in a year, ensuring a steady supply of food. In addition, early maturing cultivars will provide mature bunches much earlier in the season than the late maturing ones, thus alleviating food shortages. Good food, according to the consumers, should be soft and have a flavour when cooked.

Multiplication

Primary multiplication

Primary multiplication was initiated in June 1997 in the Tissue Culture laboratory at KARI. The KARI tissue culture laboratory procedures were employed. The starting material, or explants, are shoot tips excised from either sword suckers or peepers. Sword suckers and/or peepers are preferred because less work is involved in removing the leaf sheaths in order to excise the shoot tips. Shoot tips consist of the meristem and a few leaf primordia.

The explants are maintained on induction medium for 3 - 4 weeks, after which they are split into halves and transferred to proliferation medium. The subculture period is 3 -4 weeks and only 6 - 7 subcultures are done, in order to safeguard against somaclonal variations. Fully developed banana shoots are transferred to rooting medium before they are taken to the nursery for acclimatisation. All cultures are maintained at a temperature of 26 - 28°C and a photoperiod of 14 hours.

Acclimatisation is the weaning and hardening of plantlets in preparation for field establishment. The weaning process consists of transferring rooted plantlets to a soil based potting substrate and maintaining them under shade at a very high humidity of 75 -100% for 1 - 2 weeks. The high humidity prevents desiccation of the delicate plantlets. Weaned plantlets are hardened by transferring them to bigger pots and maintaining them under shade at normal humidity for 4 - 6 weeks. Only hardened plantlets can be taken out of the nursery, for field establishment.

Secondary multiplication

The first batch of tissue culture plantlets were ready for field planting before the farmers' experimental plots were ready for banana replanting, so the plantlets were used to establish a mothergarden at KARI. The objective of establishing a mothergarden was to increase production of clean planting by rapid field multiplication.

The mothergarden was planted during the last week of April 1998. It consists of 609 banana mats, at a spacing of 2 x 2m. It was established on a piece of land that had been under pastures for over 30 years and had not been planted with bananas before. Post-planting application of chicken manure was done to enhance sucker production. The mothergarden is mulched regularly using elephant grass. Other normal management practices such as weed control and deleafing and detrashing are also carried out. The weeds are controlled using a herbicide.

Rapid field multiplication is usually achieved by decapitation. Decapitation is the destruction of the growing point, or meristem of the mother plant in order to remove apical dominance and induce germination of the lateral buds into suckers. This technique allows a large number of suckers to grow on one banana mat at the same time. All the suckers on the mat, except one, are uprooted for use as planting material at a height of about 45 cm, usually after 1 - 2 months after decapitation. The single sucker left at each mat is allowed to grow to a height of about 1.5m before the process is repeated.

Advantages of the decapitation technique include rapid multiplication and uniformity of suckers. Whereas only about 4 suckers are produced per mat per year under ordinary circumstances, 10 - 20 suckers may be produce per mat per year under decapitation, if decapitation is done twice a year. In addition, suckers produced by decapitation are usually uniform in height since they germinate at the same time, while those produced under normal circumstances are at different ages at any one time because they emerge at different times, one at a time.

Decapitation can be done using several methods. One method involves cutting the pseudostem of the plant completely at ground level in order to access and remove or sever the meristem. The second method involves hammering a bamboo splinter through the meristem without cutting the pseudostem. In the third method a window is cut in the pseudostem at the base of the plant and the meristem is scooped out, but the plant is left standing. At KARI, the third method is used because it has been observed that it produces more suckers than the other two methods.

Distribution

On-farm experimental plots consist of 25 mats, a mixture of cultivars Nakitembe and Ndibwabalangira. The planting materials were delivered to the farmers at three different times because at the time the farmers' plots were ready for banana replanting, the available tissue culture plants were not enough to go round, and the suckers in the mothergarden were not ready for transplanting. From past experience, farmers will not wait for clean planting material once their plots are ready, but will replant their plots with whatever crop or planting material that is available at the time. In order to avoid farmers replanting the experimental plots with other crops or with infested banana planting material, the available tissue culture plants were, in September 1998, distributed equally to the 28 farmers, with a promise to deliver the balance as soon as possible. However, most farmers were very pessimistic about the field establishment of tissue culture plants. They believed that the plantlets were too small to develop into robust plants capable of producing a bunch.

In November 1998, suckers were obtained from the mother garden at KARI and delivered to the farmers in the form of pared corms, for completion of trial establishment. However, having seen how fast the tissue culture plants had established, the farmers were reluctant to plant corms because they believed they would not do as well as the tissue culture plants. Farmers were even more convinced that corms were not good enough as planting material when a dry spell followed immediately after planting and all the corms died on germination. More tissue culture plants were delivered to farmers in February 1999 to replace the dead corms and also to fill gaps in fields where a few tissue culture plants had not established.

Introduction of a cassava variety resistant to the cassava mosaic virus also served as an incentive that popularised the break-crop technology. Most farmers obtained cassava cuttings from the original material provided by the project and expanded the area under the break-crop so as to multiply cassava planting material, and at the same time clean their land of banana nematodes. Such farmers are being provided with clean banana planting material, either tissue culture plants or corms, from the mother garden at KARI, to replant the cleaned areas. Other farmers who have shown interest in the technology but are not participating in the project have also benefited by being provided with clean planting material from the mother garden at KARI whenever it is available.

Josephine Namaganda
February 2000

APPENDIX 9

Pre-treatment to post break-crop banana nematode densities at three sites

A. KAWANDA BANANA NEMATODE DENSITIES: PRE-TREATMENT TO POST BREAK-CROP

Mean no. nematodes per 1000ml soil and per 100g of roots for each taxon

P. goodeyi

SOIL

	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99
Banana	0	0	0	13	60	0	0	0	0
Cassava	20	0	0	30	10	30	0	0	0
S.Potato	0	0	0	80	0	0	30	0	0
Macuna	0	0	0	0	0	10	0	40	0
Maize	20	-	60	120	0	25	0	0	0
Beans	10	10	0	0	0	0	0	0	0

ROOTS

	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99
Banana	180	0	0	75	60	-	0	0	0
Cassava	-	-	0	20	0	-	-	0	0
S.Potato	0	0	0	0	-	-	0	40	0
Macuna	0	0	-	90	0	-	0	40	0
Maize	-	-	60	0	0	-	0	120	0
Beans	-	-	0	0	-	-	-	-	0

R. Similis

SOIL

	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99
Banana	100	200	50	75	30	0	40	10	10
Cassava	0	0	0	0	0	0	0	0	10
S.Potato	0	20	0	0	0	0	0	0	0
Macuna	0	0	0	0	0	0	0	0	20
Maize	0	-	0	40	0	0	10	0	0
Beans	0	20	50	0	0	0	0	0	10

ROOTS

	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99
Banana	1880	800	2200	625	30	0	360	120	-
Cassava	-	-	0	20	0	-	-	20	-
S.Potato	0	0	0	20	-	-	0	20	-
Macuna	0	0	-	0	0	-	0	0	-
Maize	-	-	0	0	0	-	0	0	-
Beans	-	-	0	0	-	-	-	-	-

PG = *Pratylenchus goodeyi* , HM = *Helicotylenchus multicinctus* , RS = *Radopholus similis* , ML = *Meloidogyne* spp.
Bananas re-planted Nov 99
- = No sample

A. KAWANDA (continued)

H. multicinctus

SOIL

	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99
Banana	230	688	350	475	310	190	350	70	350
Cassava	0	10	30	20	0	0	0	10	80
S.Potato	50	510	360	370	20	80	240	60	120
Macuna	140	2700	480	240	170	130	280	120	230
Maize	290	-	180	140	30	50	310	100	20
Beans	50	20	130	0	0	10	0	83	130

ROOTS

	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99
Banana	440	300	2575	100	310	-	840	320	20
Cassava	-	-	30	0	0	-	-	0	0
S.Potato	20	20	20	100	-	-	240	120	10
Macuna	0	42	-	440	0	-	80	320	50
Maize	-	-	180	0	0	-	100	20	0
Beans	-	-	20	0	-	-	-	-	0

Meloidogyne spp.

SOIL

	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99
Banana	0	0	17	0	0	0	0	0	0
Cassava	0	10	110	550	50	0	0	0	0
S.Potato	0	0	0	0	0	10	0	0	0
Macuna	0	10	0	10	0	0	10	0	0
Maize	20	-	0	0	0	0	10	0	0
Beans	0	20	190	140	0	50	0	0	0

ROOTS

	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99
Banana	160	0	0	25	0	0	0	20	-
Cassava	-	-	110	40	20	-	-	180	-
S.Potato	0	0	0	0	-	-	0	0	-
Macuna	0	0	-	0	0	-	0	0	-
Maize	-	-	0	0	0	-	0	20	-
Beans	-	-	420	0	-	-	-	-	-

(Appendix 9)

B. KAYUNGA BANANA NEMATODE DENSITIES: FROM PRE-TREATMENT TO POST BREAK-CROP

Mean no. nematodes per 1000ml soil and per 100g of roots for each taxon

P. goodeyi

SOIL	Pre-treatment	Break crop								Banana
	May-97	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Mar-00
Banana	3	-	0	0	0	0	29	12	2	-
Cassava	*	0	0	17	13	2	15	17	0	-
S.Potato	*	0	0	0	20	0	0	0	0	-

ROOTS										
	May-97	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	36281	Mar-00
Banana	58	-	20	0	0	212	46	38	19	193
Cassava	*	0	0	0	0	14	0	0	-	0
S.Potato	*	0	0	0	0	0	0	0	-	0

R. Similis

SOIL	Pre-treatment	Break crop								Banana
	May-97	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Mar-00
Banana	2	-	0	0	10	0	106	17	11	-
Cassava	*	10	4	0	11	0	0	2	8	-
S.Potato	*	0	0	0	20	0	0	0	0	-

ROOTS										
	May-97	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Mar-00
Banana	288	0	40	462	115	0	81	100	107	19
Cassava	*	0	94	88	0	0	0	0	-	4
S.Potato	*	0	25	0	0	0	0	0	-	0

*Pre-treatment counts from continuous banana are also assumed to be mean starting populations for break-crop plots.

Note: Data for Aug 99 and Dec 99 missing.

- = No sample

B. KAYUNGA (continued)

H. multicinctus

SOIL	Pre-treatment	Break crop								Banana
	May-97	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Mar-00
Banana	113	-	921	992	900	813	2254	896	622	-
Cassava	*	58	87	48	63	20	48	59	35	-
S.Potato	*	25	12.5	0	20	180	0	25	0	-

ROOTS	May-97	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Mar-00
Banana	1665	2500	2006	4462	1873	1296	844	873	2074	1589
Cassava	*	14	118	112	25	29	83	0	-	1936
S.Potato	*	0	0	0	67	33	33	0	-	660

Meloidogyne spp.

SOIL	Pre-treatment	Break crop								Banana
	May-97	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Mar-00
Banana	9	-	10	87	38	130	146	60	4	-
Cassava	*	350	65	175	297	278	108	34	6	-
S.Potato	*	63	0	40	20	30	10	13	0	-

ROOTS	May-97	Oct-97	Jan-98	Mar-98	May-98	Jul-98	Oct-98	Jan-99	May-99	Mar-00
Banana	48	18	10	92	108	0	73	38	22	59
Cassava	*	3586	200	612	1575	143	200	181	-	28
S.Potato	*	0	0	0	0	0	0	67	-	40

PG = *Pratylenchus goodeyi* , HM = *Helicotylenchus multicinctus* , RS = *Radopholus similis* , ML = *Meloidogyne* spp.

Bananas re-planted Nov 98

(Appendix 9)

C. MASAKA BANANA NEMATODE DENSITIES: PRE-TREATMENT TO POST BREAK-CROP

Mean no. nematodes per 1000ml soil and per 100g of roots for each taxon

P. goodeyi

SOIL	Pre-treatment	Break crop						Banana
	Aug-97	Jan-98	Mar-98	May-98	Jul-98	Jan-99	May-99	Mar-00
Banana	1860	167	0	-	50	25	0	-
Cassava	*	177	625	78	0	0	0	-
S.Potato	*	0	0	0	0	0	-	-

ROOTS								
	Aug-97	Jan-98	Mar-98	May-98	Jul-98	Jan-99	May-99	Mar-00
Banana	3000	1933	883	0	33	100	25	2000
Cassava	*	20	-	0	0	0	-	0
S.Potato	*	0	0	0	0	0	-	0

R. Similis

SOIL	Pre-treatment	Break crop						Banana
	Aug-97	Jan-98	Mar-98	May-98	Jul-98	Jan-99	May-99	Mar-00
Banana	170	0	0	-	0	50	0	-
Cassava	*	0	625	0	0	103	150	-
S.Potato	*	0	0	0	0	0	-	-

ROOTS								
	Aug-97	Jan-98	Mar-98	May-98	Jul-98	Jan-99	May-99	Mar-00
Banana	3300	0	917	0	0	1025	675	0
Cassava	*	0	-	0	0	0	-	0
S.Potato	*	0	0	0	0	0	-	0

Bananas re-planted Sep 99

Note: Sample data for Aug 99 and Dec 99 missing.

C. MASAKA (continued)

H. multicinctus

SOIL		Pre-treatment	Break crop						Banana
		Aug-97	Jan-98	Mar-98	May-98	Jul-98	Jan-99	May-99	Mar-00
	Banana	710	25	517	-	250	300	263	-
	Cassava	*	31	1094	0	0	176	1150	-
	S.Potato	*	0	50	0	0	0	-	-

ROOTS									
		Aug-97	Jan-98	Mar-98	May-98	Jul-98	Jan-99	May-99	Mar-00
	Banana	2300	0	6450	100	467	1350	2375	0
	Cassava	*	0	-	0	0	0	-	0
	S.Potato	*	100	0	0	0	0	-	100

Meloidogyne spp.

SOIL		Pre-treatment	Break crop						Banana
		Aug-97	Jan-98	Mar-98	May-98	Jul-98	Jan-99	May-99	Mar-00
	Banana	20	0	8	-	0	0	0	-
	Cassava	*	42	0	0	0	0	0	-
	S.Potato	*	50	0	0	0	0	-	-

ROOTS									
		Aug-97	Jan-98	Mar-98	May-98	Jul-98	Jan-99	May-99	Mar-00
	Banana	0	0	33	0	0	0	25	0
	Cassava	*	0	-	0	0	0	-	0
	S.Potato	*	600	0	0	100	0	-	600

PG = *Pratylenchus goodeyi* , HM = *Helicotylenchus multicinctus* , RS = *Radopholus similis* , ML = *Meloidogyne* spp.

*Pre-treatment counts from continuous banana assumed to be mean starting populations for break-crop plots.

APPENDIX 10

A. KAWANDA FIELD TRIALS: NUMBERS OF SAMPLES CONTAINING NEMATODES ON EACH SAMPLING DATE

Crop	Sample	Parameter	Period 1 (October 97)				Period 2 (Jan 98)				Period 3 (Mar 98)			
			PG	HM	RS	ML	PG	HM	RS	ML	PG	HM	RS	ML
BANANA	SOIL	Mean No. Nematodes per sample	0	230	100	0	0	680	200	0	0	380	50	17
		Number of Mats with nemas	0	9	4	0	0	9	7	0	0	8	3	1
		Number of mats sampled	25	25	25	25	20	20	20	20	16	16	15	15
		Total No. of Mats	26	26	26	25	26	26	26	26	26	26	26	26
		% Mats infected	0	36	16	0	0	45	35	0	0	33	20	7
	ROOTS	Mean No. Nematodes per sample	100	440	1000	100	0	300	800	0	0	2075	2200	0
		Number of Mats with nemas	5	8	7	1	0	2	8	0	0	12	11	0
		Number of mats sampled	25	25	25	25	20	20	20	20	20	20	20	20
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	20	32	28	4	0	10	40	0	0	60	55	0
MACUNA	SOIL	Mean No. Nematodes per sample	0	140	0	0	0	2700	0	10	0	480	0	0
		Number of Mats with nemas	0	2	0	0	0	15	0	1	0	11	0	0
		Number of mats sampled	26	26	26	26	26	26	26	26	26	26	26	26
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	0	8	0	0	0	60	0	4	0	44	0	0
	ROOTS	Mean No. Nematodes per sample	0	0	0	0	0	42	0	0	-	-	-	-
		Number of Mats with nemas	0	0	0	0	0	1	0	0	0	0	0	0
		Number of mats sampled	25	25	25	25	12	12	12	12	0	0	0	0
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	0	0	0	0	0	8	0	0	-	-	-	-
MAIZE	SOIL	Mean No. Nematodes per sample	20	200	0	20	-	-	-	-	90	180	0	0
		Number of Mats with nemas	1	7	0	1	0	0	0	0	1	5	0	0
		Number of mats sampled	26	26	26	26	0	0	0	0	26	26	26	26
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	4	30	0	4	-	-	-	-	4	20	0	0
	ROOTS	Mean No. Nematodes per sample	-	-	-	-	-	-	-	-	60	180	0	0
		Number of Mats with nemas	0	0	0	0	0	0	0	0	1	5	0	0
		Number of mats sampled	0	0	0	0	0	0	0	0	25	25	26	26
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	-	-	-	-	-	-	-	-	4	20	0	0
SWEET POTATO	SOIL	Mean No. Nematodes per sample	0	50	0	0	0	510	20	0	0	380	0	0
		Number of Mats with nemas	0	3	0	0	0	7	1	0	0	5	0	0
		Number of mats sampled	25	25	25	25	25	25	25	25	25	25	25	25
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	0	12	0	0	0	28	4	0	0	20	0	0
	ROOTS	Mean No. Nematodes per sample	0	20	0	0	0	20	0	0	0	20	0	0
		Number of Mats with nemas	0	1	0	0	0	1	0	0	0	1	0	0
		Number of mats sampled	25	25	25	25	25	25	25	25	25	25	25	25
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	0	4	0	0	0	4	0	0	0	4	0	0
BEANS	SOIL	Mean No. Nematodes per sample	10	90	0	0	10	30	20	30	0	130	60	198
		Number of Mats with nemas	1	2	0	0	1	2	1	1	0	3	1	8
		Number of mats sampled	26	26	26	26	26	26	26	26	26	26	26	26
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	4	8	0	0	4	8	4	4	0	12	4	32
	ROOTS	Mean No. Nematodes per sample	-	-	-	-	-	-	-	-	0	20	0	420
		Number of Mats with nemas	0	0	0	0	0	0	0	0	0	1	0	8
		Number of mats sampled	0	0	0	0	0	0	0	0	25	25	25	25
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	-	-	-	-	-	-	-	-	0	4	0	32
CASSAVA	SOIL	Mean No. Nematodes per sample	20	0	0	0	0	10	0	10	0	30	0	118
		Number of Mats with nemas	1	0	0	0	0	1	0	1	0	1	0	6
		Number of mats sampled	25	25	25	25	25	25	25	25	25	25	25	25
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	4	0	0	0	0	4	0	4	0	4	0	24
	ROOTS	Mean No. Nematodes per sample	-	-	-	-	-	-	-	-	0	30	0	118
		Number of Mats with nemas	0	0	0	0	0	0	0	0	0	1	0	6
		Number of mats sampled	0	0	0	0	0	0	0	0	25	25	26	25
		Total No. of Mats	26	26	26	26	26	26	26	26	25	25	26	25
		% Mats infected	-	-	-	-	-	-	-	-	0	4	0	24

Crop	Sample	Parameter	Period 4 (May 98)				Period 5 (Jul 98)				Period 6 (Oct 98)			
			PG	HM	RS	ML	PG	HM	RS	ML	PG	HM	RS	ML
BANANA	SOIL	Mean No. Nematodes per sample	13	475	75	0	80	310	30	0	0	130	0	0
		Number of Mats with nemas	1	8	1	0	1	10	3	0	0	9	0	0
		Number of mats sampled	20	20	20	20	26	26	26	26	26	26	26	26
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	5	40	5	0	4	40	12	0	0	36	0	0
	ROOTS	Mean No. Nematodes per sample	75	100	620	25	80	310	30	0	-	-	0	0
		Number of Mats with nemas	2	3	6	1	1	10	3	0	0	0	0	0
		Number of mats sampled	20	20	20	20	26	26	26	26	0	0	26	26
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	10	15	30	5	4	40	12	0	-	-	0	0
MACUNA	SOIL	Mean No. Nematodes per sample	0	240	0	10	0	170	0	0	10	130	0	0
		Number of Mats with nemas	0	7	0	1	0	9	0	0	1	6	0	0
		Number of mats sampled	26	26	26	26	25	25	25	25	25	25	25	25
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	0	28	0	4	0	36	0	0	4	24	0	0
	ROOTS	Mean No. Nematodes per sample	80	440	0	0	0	0	0	0	-	-	-	-
		Number of Mats with nemas	1	4	0	0	0	0	0	0	0	0	0	0
		Number of mats sampled	25	25	25	25	26	24	26	26	0	0	0	0
		Total No. of Mats	26	26	26	26	26	24	26	26	26	26	26	26
		% Mats infected	4	16	0	0	0	0	0	0	-	-	-	-
MAIZE	SOIL	Mean No. Nematodes per sample	120	140	40	0	0	30	0	0	20	60	0	0
		Number of Mats with nemas	4	5	3	0	0	3	0	0	1	4	0	0
		Number of mats sampled	26	26	26	26	26	26	26	26	20	20	20	20
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	16	20	12	0	0	12	0	0	4	16	0	0
	ROOTS	Mean No. Nematodes per sample	0	0	0	0	0	0	0	0	-	-	-	-
		Number of Mats with nemas	0	0	0	0	0	0	0	0	0	0	0	0
		Number of mats sampled	26	26	26	25	26	24	26	26	0	0	0	0
		Total No. of Mats	25	25	25	25	25	24	25	25	25	25	25	25
		% Mats infected	0	0	0	0	0	0	0	0	-	-	-	-
SWEET POTATO	SOIL	Mean No. Nematodes per sample	90	370	0	0	0	20	0	0	0	60	0	10
		Number of Mats with nemas	4	9	0	0	0	2	0	0	0	4	0	1
		Number of mats sampled	25	25	25	25	25	25	25	25	25	25	25	25
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	16	36	0	0	0	8	0	0	0	16	0	4
	ROOTS	Mean No. Nematodes per sample	0	100	20	0	-	-	-	-	-	-	-	-
		Number of Mats with nemas	0	1	1	0	0	0	0	0	0	0	0	0
		Number of mats sampled	25	25	25	25	0	0	0	0	0	0	0	0
		Total No. of Mats	25	26	26	25	26	26	26	26	26	26	26	26
		% Mats infected	0	4	4	0	-	-	-	-	-	-	-	-
BEANS	SOIL	Mean No. Nematodes per sample	0	0	0	140	0	0	0	0	0	10	0	60
		Number of Mats with nemas	0	0	0	4	0	0	0	0	0	1	0	2
		Number of mats sampled	26	26	26	26	26	26	26	26	26	26	26	26
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	0	0	0	16	0	0	0	0	0	4	0	8
	ROOTS	Mean No. Nematodes per sample	0	0	0	0	-	-	-	-	-	-	-	-
		Number of Mats with nemas	0	0	0	0	0	0	0	0	0	0	0	0
		Number of mats sampled	25	25	25	25	0	0	0	0	0	0	0	0
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	0	0	0	0	-	-	-	-	-	-	-	-
CASSAVA	SOIL	Mean No. Nematodes per sample	30	20	0	550	10	0	0	50	30	0	0	0
		Number of Mats with nemas	1	2	0	10	1	0	0	1	1	0	0	0
		Number of mats sampled	25	25	25	25	25	25	25	25	25	25	25	25
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	4	8	0	40	4	0	0	4	4	0	0	0
	ROOTS	Mean No. Nematodes per sample	20	0	20	40	0	0	0	20	-	-	-	-
		Number of Mats with nemas	1	0	1	2	0	0	0	1	0	0	0	0
		Number of mats sampled	25	26	25	25	25	25	26	25	0	0	0	0
		Total No. of Mats	25	25	25	25	25	25	25	25	26	26	26	26
		% Mats infected	4	0	4	8	0	0	0	4	-	-	-	-

Crop	Sample	Parameter	Period 7 (Jan 99)				Period 8 (May 99)				Period 9 (Aug 99)			
			PG	HM	RS	ML	PG	HM	RS	ML	PG	HM	RS	ML
BANANA	SOIL	Mean No. Nematodes per sample	0	350	40	0	0	70	10	0	0	300	10	0
		Number of Mats with nemas	0	13	4	0	0	3	1	0	0	11	1	0
		Number of mats sampled	26	26	26	26	26	26	26	26	25	25	26	26
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	0	52	16	0	0	12	4	0	0	44	4	0
	ROOTS	Mean No. Nematodes per sample	0	640	350	0	0	320	120	20	0	20	-	-
		Number of Mats with nemas	0	12	11	0	0	9	2	1	0	1	0	0
		Number of mats sampled	26	26	26	26	26	26	26	26	25	25	0	0
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	0	48	44	0	0	36	8	4	0	4	-	-
MACUNA	SOIL	Mean No. Nematodes per sample	0	200	0	10	40	120	0	0	0	230	20	0
		Number of Mats with nemas	0	11	0	1	1	6	0	0	0	9	1	0
		Number of mats sampled	26	26	26	26	26	26	26	26	26	26	26	26
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	0	44	0	4	4	24	0	0	0	36	4	0
	ROOTS	Mean No. Nematodes per sample	0	95	0	0	40	320	0	0	0	50	-	-
		Number of Mats with nemas	0	4	0	0	1	4	0	0	0	1	0	0
		Number of mats sampled	26	26	26	26	26	26	26	26	25	25	0	0
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	0	16	0	0	4	16	0	0	0	4	-	-
MAIZE	SOIL	Mean No. Nematodes per sample	0	315	10	10	0	100	0	0	0	20	0	0
		Number of Mats with nemas	0	11	1	1	0	5	0	0	0	2	0	0
		Number of mats sampled	26	26	26	26	26	26	26	26	26	26	26	26
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	0	44	4	4	0	20	0	0	0	8	0	0
	ROOTS	Mean No. Nematodes per sample	0	100	0	0	120	30	0	30	0	0	-	-
		Number of Mats with nemas	0	4	0	0	3	1	0	1	0	0	0	0
		Number of mats sampled	26	26	26	26	26	26	26	26	26	26	0	0
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	0	16	0	0	12	4	0	4	0	0	-	-
SWEET POTATO	SOIL	Mean No. Nematodes per sample	30	240	0	0	0	80	0	0	0	120	0	0
		Number of Mats with nemas	1	7	0	0	0	4	0	0	0	8	0	0
		Number of mats sampled	25	25	25	25	25	25	25	25	25	25	25	25
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	4	28	0	0	0	16	0	0	0	32	0	0
	ROOTS	Mean No. Nematodes per sample	0	240	0	0	40	120	20	0	0	30	-	-
		Number of Mats with nemas	0	4	0	0	1	3	1	0	0	1	0	0
		Number of mats sampled	25	25	25	25	25	25	25	25	25	25	0	0
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	0	16	0	0	4	12	4	0	0	4	-	-
BEANS	SOIL	Mean No. Nematodes per sample	0	0	0	0	0	60	0	0	0	130	10	0
		Number of Mats with nemas	0	0	0	0	0	5	0	0	0	7	1	0
		Number of mats sampled	26	26	26	26	24	24	24	24	26	26	26	26
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	0	0	0	0	0	21	0	0	0	28	4	0
	ROOTS	Mean No. Nematodes per sample	-	-	-	-	-	-	-	-	0	0	-	-
		Number of Mats with nemas	0	0	0	0	0	0	0	0	0	0	0	0
		Number of mats sampled	0	0	0	0	0	0	0	0	25	25	0	0
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	-	-	-	-	-	-	-	-	0	0	-	-
CASSAVA	SOIL	Mean No. Nematodes per sample	0	0	0	0	0	10	0	0	0	80	10	0
		Number of Mats with nemas	0	0	0	0	0	1	0	0	0	4	1	0
		Number of mats sampled	25	25	25	25	25	25	25	25	25	25	25	25
		Total No. of Mats	26	26	26	26	26	26	26	26	26	26	26	26
		% Mats infected	0	0	0	0	0	4	0	0	0	16	4	0
	ROOTS	Mean No. Nematodes per sample	-	-	-	-	0	0	20	180	0	0	-	-
		Number of Mats with nemas	0	0	0	0	0	0	1	5	0	0	0	0
		Number of mats sampled	0	0	0	0	25	25	25	25	25	25	0	0
		Total No. of Mats	25	25	25	25	25	25	25	25	25	25	25	25
		% Mats infected	-	-	-	-	0	0	4	20	0	0	-	-

PG = P. goodeyi; HM = H. multicinctus; RS = R. similis; ML = Meloidogyne spp.

(Appendix 10, contd.)

B. KAYUNGA FIELD TRIALS: NUMBERS OF SAMPLES CONTAINING NEMATODES ON EACH SAMPLING DATE

Crop / Part		PERIOD 1 (OCT 97) PG	HM	RS	ML	PERIOD 2 (JAN 98) PG	HM	RS	ML	PERIOD 3 (MAR 98) PG	HM	RS	ML	PERIOD 4 (MAY98) PG	HM	RS	ML
BANANA																	
SOIL	Mean No. Nematodes per sample	0	250	0	0	0	546	0	10	0	566	0	88	0	712	10	38
	Number of Mats with nemas	0	1	0	0	0	90	0	5	0	63	0	5	0	90	5	15
	Number of mats sampled	1	1	1	1	126	126	126	126	128	128	128	128	130	130	130	130
	Total No of samples (= mats)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	% Mats infected:	0	100	0	0	0	71	0	4	0	49	0	4	0	69	4	12
ROOTS	Mean No. Nematodes per sample	0	2500	0	0	20	2431	40	10	0	6058	462	77	0	2077	115	68
	Number of Mats with nemas	0	1	0	0	5	105	5	5	0	120	35	10	0	125	25	15
	Number of mats sampled	1	1	1	1	126	126	126	126	130	130	130	130	130	130	130	130
	Total No of samples (= mats)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	% Mats infected:	0	100	0	0	4	83	4	4	0	92	27	8	0	96	19	12
CASSAVA																	
SOIL	Mean No. Nematodes per sample	0	58	10	333	0	87	4	61	17	48	0	124	13	63	11	172
	Number of Mats with nemas	0	10	3	23	0	14	2	14	3	7	0	21	3	14	3	26
	Number of mats sampled	100	100	100	100	115	115	115	115	115	115	115	115	115	115	115	115
	Total No of samples (= mats)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	% Mats infected:	0	10	3	23	0	12	2	12	3	6	0	18	3	12	3	23
ROOTS	Mean No. Nematodes per sample	0	14	0	3586	0	118	94	200	0	112	88	612	0	25	0	1675
	Number of Mats with nemas	0	1	0	18	0	8	2	12	0	6	1	27	0	2	0	22
	Number of mats sampled	35	35	35	35	85	85	85	85	85	85	85	85	60	60	60	60
	Total No of samples (= mats)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	% Mats infected:	0	3	0	51	0	9	2	14	0	7	1	32	0	3	0	37
SWEET POTATO																	
SOIL	Mean No. Nematodes per sample	0	25	0	63	0	13	0	0	0	0	0	40	20	20	20	20
	Number of Mats with nemas	0	2	0	3	0	1	0	0	0	0	0	3	2	2	2	1
	Number of mats sampled	20	20	20	20	20	20	20	20	25	25	25	25	25	25	25	25
	Total No of samples (= mats)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	% Mats infected:	0	10	0	15	0	5	0	0	0	0	0	12	8	8	8	4
ROOTS	Mean No. Nematodes per sample	-	-	-	-	0	0	0	0	0	0	0	0	0	200	0	0
	Number of Mats with nemas	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Number of mats sampled	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	5
	Total No of samples (= mats)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	% Mats infected:	-	-	-	-	0	0	0	0	0	0	0	0	0	20	0	0

Crop / Part		PERIOD 5 (JULY 98) PG	HM	RS	ML	PERIOD 6 (OCTOBER 98) PG	HM	RS	ML	PERIOD 7 (JAN 99) PG	HM	RS	ML	PERIOD 8 (MAY 99) PG	HM	RS	ML
BANANA																	
SOIL	Mean No. Nematodes per sample	0	639	0	464	29	2262	106	119	12	936	17	60	2	591	11	4
	Number of Mats with nemas	0	70	0	21	4	89	17	21	4	83	5	14	1	53	5	1
	Number of mats sampled	131	131	131	131	130	130	130	130	130	130	130	130	135	135	135	135
	Total No of samples (= mats)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	% Mats infected:	0	53	0	16	3	68	13	16	3	64	4	11	1	39	4	1
ROOTS	Mean No. Nematodes per sample	212	1481	0	0	46	1015	81	108	38	915	100	38	19	2163	107	22
	Number of Mats with nemas	20	105	0	0	3	66	8	15	7	67	11	7	4	84	15	3
	Number of mats sampled	130	130	130	130	130	130	130	130	130	130	130	130	135	135	135	135
	Total No of samples (= mats)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	% Mats infected:	15	81	0	0	2	51	6	12	5	52	8	5	3	62	11	2
CASSAVA																	
SOIL	Mean No. Nematodes per sample	2	20	0	278	15	48	0	93	17	59	2	30	0	35	8	2
	Number of Mats with nemas	1	6	0	26	6	8	0	14	7	14	1	11	0	9	1	1
	Number of mats sampled	115	115	115	115	115	115	115	115	115	115	115	115	120	120	120	120
	Total No of samples (= mats)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	% Mats infected:	1	5	0	23	5	7	0	12	6	12	1	10	0	8	1	1
ROOTS	Mean No. Nematodes per sample	14	29	0	143	0	83	0	200	0	0	0	181	-	-	-	-
	Number of Mats with nemas	1	4	0	7	0	3	0	11	0	0	0	12	0	0	0	0
	Number of mats sampled	70	70	70	70	60	60	60	60	80	80	80	80	0	0	0	0
	Total No of samples (= mats)	120	120	120	120	115	115	115	115	120	120	120	120	120	120	120	120
	% Mats infected:	1	6	0	10	0	5	0	18	0	0	0	15	-	-	-	-
SWEET POTATO																	
SOIL	Mean No. Nematodes per sample	0	180	0	30	0	0	0	10	0	25	0	13	0	0	0	0
	Number of Mats with nemas	0	2	0	2	0	0	0	1	0	2	0	1	0	0	0	0
	Number of mats sampled	25	25	25	25	25	25	25	25	20	20	20	20	20	20	20	20
	Total No of samples (= mats)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	% Mats infected:	0	8	0	8	0	0	0	4	0	10	0	5	0	0	0	0
ROOTS	Mean No. Nematodes per sample	-	-	-	-	0	0	0	0	0	0	0	0	-	-	-	-
	Number of Mats with nemas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number of mats sampled	0	0	0	0	5	5	5	5	10	10	10	10	0	0	0	0
	Total No of samples (= mats)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	% Mats infected:	-	-	-	-	0	0	0	0	0	0	0	0	-	-	-	-

PG = *P. goodeyi*, **HM** = *H. multicinctus*, **RS** = *R. similis*, **ML** = *Meloidogyne spp.*

(Appendix 10, contd.)

C. MASAKA FIELD TRIALS: NUMBERS OF SAMPLES CONTAINING NEMATODES ON EACH SAMPLING DATE

		PERIOD 2 (JAN 98)				PERIOD 3 (MAR 98)				PERIOD 4 (MAY98)				PERIOD 5 (JLY 98)				PERIOD 6 (JAN99)				PERIOD 7(MAY 99)			
		PG	HM	RS	ML	PG	HM	RS	ML	PG	HM	RS	ML	PG	HM	RS	ML	PG	HM	RS	ML	PG	HM	RS	ML
BANANA																									
SOIL	Average no. nematodes	167	25	0	0	0	517	0	8	-	-	-	-	50	250	0	0	25	300	50	0	0	263	0	0
	Number of Mats with nemas:	10	1	0	0	0	15	0	1	0	0	0	0	1	2	0	0	1	8	3	0	0	8	0	0
	Number of mats sampled	30	30	30	30	30	30	30	30	0	0	0	0	5	5	5	5	20	20	20	20	20	20	20	20
	Total No. of samples (= mats):	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
	% Mats infected:	33	3	0	0	0	50	0	3	-	-	-	-	20	40	0	0	5	40	15	0	0	40	0	0
ROOTS	Average no. nematodes	1933	0	0	0	883	6450	917	33	0	100	0	0	33	467	0	0	100	1350	1025	0	25	2375	675	25
	Number of Mats with nemas:	19	0	0	0	17	29	15	1	0	5	0	0	1	8	0	0	1	13	14	0	1	19	5	1
	Number of mats sampled	30	30	30	30	30	30	30	30	25	25	25	25	30	30	30	30	20	20	20	20	20	20	20	20
	Total No. of samples (= mats):	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
	% Mats infected:	63	0	0	0	57	97	50	3	0	20	0	0	3	27	0	0	5	65	70	0	5	95	25	5
CASSAVA																									
SOIL	Average no. nematodes	0	70	0	30	0	0	0	0	38	13	38	25	0	0	0	10	25	0	0	0	25	0	0	0
	Number of Mats with nemas:	0	5	0	2	0	0	0	0	2	1	1	1	0	0	0	1	2	0	0	0	2	0	0	0
	Number of mats sampled	25	25	25	25	25	25	25	25	20	20	20	20	25	25	25	25	20	20	20	20	20	20	20	20
	Total No. of samples (= mats):	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	% Mats infected:	0	20	0	8	0	0	0	0	10	5	5	5	0	0	0	4	10	0	0	0	10	0	0	0
ROOTS	Average no. nematodes	20	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
	Number of Mats with nemas:	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number of mats sampled	25	25	25	25	0	0	0	0	15	15	15	15	25	25	25	25	20	20	20	20	0	0	0	0
	Total No. of samples (= mats):	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	% Mats infected:	4	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
SWEET POTATO																									
SOIL	Average no. nematodes	0	0	0	50	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
	Number of Mats with nemas:	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number of mats sampled	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0
	Total No. of samples (= mats):	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	% Mats infected:	0	0	0	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
ROOTS	Average no. nematodes	0	100	0	600	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	-	-	-	-
	Number of Mats with nemas:	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Number of mats sampled	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0
	Total No. of samples (= mats):	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	% Mats infected:	0	20	0	80	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	-	-	-	-

PG = *P. goodeyi*; **HM** = *H. multicinctus*; **RS** = *R. similis*; **ML** = *Meloidogyne spp.*

Appendix 11

TRAINING OF TRAINERS' WORKSHOP, LWEZA CONFERENCE CENTRE, 15 DECEMBER, 1999

FOOD PRODUCTION AND BETTER HEALTH IN THE NEW MILLENIUM

FOR BETTER HEALTH IN THE NEW MILLENIUM

- BE A **FARMER** AND **NOT** A **FOOD GATHERER**
- CONSIDER **FARMING AS A BUSINESS** AND **NOT A HOBBY**
- **MODERNIZE** AGRICULTURE
  - ◊ Set priorities
  - ◊ Maximise crop yields
  - ◊ Minimise post-harvest losses
  - ◊ Keep records
  - ◊ Keep updated on crop production constraints and available technologies

SETTING PRIORITIES

- Select a few agricultural enterprises to be focused on for
  - ♦ Food security
    - ⇒ Food crop
    - ⇒ Livestock
    - ⇒ Fish farming
  - ♦ Family income
    - ⇒ Cash crop
      - ◊ Traditional cash crop e.g. coffee, cotton
      - ◊ Non-traditional cash crops e.g. beans, banana, fruits, vegetables, spices, essential oil crops
    - ⇒ Livestock
    - ⇒ Fish farming

MAXIMIZING CROP YIELDS

- Prepare field properly
- Use recommended seed/variety
  - ♦ High yielding
  - ♦ Disease and pest resistant
  - ♦ Early maturing
  - ♦ Better quality
- Plant in time
- Use correct spacing
- Employ good husbandry practices
  - ♦ Soil and water management
    - ⇒ mulching
    - ⇒ digging water trenches and soil bands etc..
    - ⇒ manuring and/ or addition of inorganic fertilisers
  - ♦ Weed control

- Crop management
  - ⇒ pruning
  - ⇒ detrashing etc..
- Control pests and diseases

MAXIMIZING POST-HARVEST LOSSES

- Harvest at the right time
- Maximise harvest of produce
- Use correct harvest containers/equipment
- Handle produce properly to enhance quality
  - gather and load delicate produce carefully
  - dry promptly and properly
- Use correct packages
- Store properly to minimise disease and insect attack
- Process to prolong shelf life

KEEPING RECORDS

- Farm record keeping is a written account of events concerning a farm business
- Farm records include
  - Production records
  - Inventory records
    - ⇒ everything a farmer owns e.g. land, buildings, livestock, produce in store etc.
  - Cash records
    - ⇒ show date, particulars, amount of payment received and amount of money paid
  - Farm accounts
    - ⇒ analysis of farm records to assess whether profit is made

BANANA PRODUCTION

CURRENT PRODUCTION TRENDS (YIELD)

6 tons/ha in Central Uganda
17 tons/ha in South-western Uganda
Potential of 60 tons/ha at Research stations

CONSTRAINTS

- Decline in soil fertility
- Pests
  - Banana weevil
    - ⇒ yield losses of 50% by the fourth ratoon
  - Banana nematodes
    - ⇒ yield losses of 51% by the third ratoon
- Diseases
  - Black Sigatoka
    - ⇒ yield losses of up to 40% by the third ratoon
  - Fusarium wilt (Panama disease)
    - ⇒ yield losses of up to 100%

- Matooke wilt
  - Banana Streak Virus (BSV)
- Low genetic base of the East African Highland Bananas (Matooke)
  - Lack of resistance to diseases and pests
- Socio-economic factors
  - Lack of farm inputs e.g. planting materials, manures, mulches, implements etc..
  - Lack of labour
  - Lack of infrastructure e.g. roads
  - Increased pressure on land
    ⇒ reduction in plot size
    ⇒ multiple cropping
  - Lack of access to technical information
    ⇒ poor crop management and post-harvest handling and processing

AVAILABLE TECHNOLOGIES

SOIL AND WATER MANAGEMENT

- Compost
  - ◊ Household refuse
  - ◊ Farmyard manure etc..
- Mulching
  - ◊ Conserves soil moisture
  - ◊ Prevents water and wind erosion
  - ◊ Suppresses weeds
  - ◊ Adds nutrients to the soil
- Application of a combination of organic and inorganic fertilisers
- Use of grass or earth bands and trenches to conserve soil and water

BANANA WEEVIL

- Use of clean planting material in weevil-free soil
  - ◊ Corm paring (peeling)
  - ◊ Corm paring + chemical dip (15 ml in 10*l* of water for 1 hr.)
  - ◊ Tissue culture plants
- Trapping
  - ◊ Pseudostem traps
  - ◊ Pheromone traps (still being tested, but very promising)
- Removing corms and splitting pseudostems
- Resistant cultivars

BANANA NEMATODES

- Clean planting material in nematode-free soil
  - ◊ Corm paring
  - ◊ Corm paring + Hot water treatment (52 - 55°C for 20 minutes)
  - ◊ Tissue culture plants
- Tissue culture plants in clean soil
- Resistant cultivars

Nematode-free soil

- ◊ Virgin land
- ◊ Rotation of banana with cassava and/ or sweet potato for at least 18 months

BLACK SIGATOKA

- Resistant cultivars
  - ◊ FHIA hybrids, Km 5
- Deleafing

FUSARIUM WILT

- Resistant cultivars
  - ◊ FHIA hybrids, Km 5, Cavendish, Matooke

FOREIGN BANANA TYPES

BANANA TYPE	DISEASE/PEST RESISTANCE	AVERAGE BUNCH WEIGHT (Kg)	USES
FHIA 01	Black Sigatoka, Fusarium, Weevils, Nematodes	70	Cooking, Dessert, Juice
FHIA 03	Black Sigatoka, Fusarium, Weevils, Nematodes	70	Cooking, Dessert, Juice
FHIA 17	Black Sigatoka, Fusarium, Weevils	80	Dessert
FHIA 23	Black Sigatoka, Fusarium, Weevils	70	Dessert
Km 5	Black Sigatoka, Fusarium, Weevils, Nematodes	40	Cooking, Dessert, Juice
Cavendish	Fusarium, Weevils	60	Dessert

RAPID MULTIPLICATION OF PLANTING MATERIALS

TISSUE CULTURE

Plant tissue culture is the propagation of plants from small plant parts under aseptic conditions in a controlled environment (*in vitro* propagation). Major uses include:

- Eliminating diseases and pests from planting materials
- Rapid multiplication of planting materials

RAPID FIELD MULTIPLICATION BY DECAPITATION

Rapid field multiplication of planting materials involves establishment of a mother-garden in a banana pest and disease free field using clean planting material (tissue culture plants or pared treated corms).

Decapitation is the destruction of the growing point of the plant (meristem) in order to allow a large number of lateral buds to germinate into suckers. The suckers are harvested after one to two months, leaving only one sucker for the repetition of the process.

Appendix 13

Impact Assessment of Non-Chemical Control of Banana Nematodes Project – 2nd Report, March 2000

By: Bagamba Fredrick

Introduction

The Non-Chemical Control of Banana Nematodes Project has been on since 1996 with the aim of controlling banana nematodes by cleaning fields of nematodes through planting non-host crops, mainly cassava and sweet potatoes (break crops). The project started with 33 participants but 28 farmers continued to the end. They began by uprooting devastated banana plantations and then plant either cassava or sweet potato. Most farmers planted cassava (25), two planted both cassava and sweet potato and only one farmer planted sweet potato alone. Each participant planted two crop cycles of cassava and/or sweet potato in the experimental plot (maximum of two years) to ensure that the fields were cleared of nematodes. Bananas were then returned to the plots cleaned of nematodes using tissue culture plantlets and corm pared suckers from mother gardens at Kawanda. Planting was done in November 1998. Most farmers (over 55%) have harvested their bananas at least once. During the course of the project, participating farmers were trained in most banana production techniques including pest control and soil fertility improvement practices. The group came to Kawanda Research Station to have a hands-on experience of the technologies used at the research station. Three of the participants were selected to attend a course at Kawanda in December 1999 organised by the Banana Programme so as to go back and teach other farmers (both participating and non-participating farmers).

This study was done in March 2000 to evaluate improvement in farmers' knowledge and effectiveness of the break crop technology, especially after having monitored the banana plants for over a year.

Methodology

Participatory evaluation techniques were used to assess both the effectiveness of the non-chemical control of banana nematodes using break crops and the impact made on farmers (participating and non-participating). Two groups, one from Ntooke and another from Ntenjeru, of farmers participating in the project each group comprising of nine participants were involved in the appraisal of the project (Table 1). One group interview was also conducted with 9 non-participating farmers to evaluate their perception of the break crop technology and the impact made relating to knowledge spill over. In all the interviews, farmers were encouraged to contribute freely to the discussion.

Farmers' experimental plots were also assessed by the researchers and ranked as very good, good, fair, poor and very poor depending on the type of management and performance of the banana plants (Table 2).

Table 1. Participants of the non-chemical control of banana nematodes technology evaluation meetings in Kayunga, March 2000

Participating farmers		Non-participating farmers
Ntooke group	Ntenjeru group	
1. Lameck Kibugo	1. A.K. Ziwa Zirimala	1. Hareem Lutwama
2. C. Nyanzi	2. Senkatuka	2. Sylivia Kirabira
3. Faith Mutyaba	3. Edward Semakula	3. Katale (Mrs)
4. Regis Tamale	4. Nathanail Ssebagereka	4. Jackson Sekajjugo
5. Deborah Zabasajja	5. Joanita Kasoomba	5. Betty Kyeyune
6. Sarah Kibugo	6. Simon Sengendo	6. Jane Frances Baibirye
7. Namwandu Damulira	7. Martin Senkatuka	7. William Enyonu
8. Sam Kagwa	8. Haliima Mohamood	8. Mukasa
9. Proscovia Ssajjabi	9. Karim Gabula	9. Bernard Mutyaba

Table 2. Rating of management and performance of banana experimental plots

Rank	Type of management	Performance of banana plants
Very Good	Manure added Mulched Weed free All sanitation practices done	- Over 60% flowering - Some big bunches - High sucker production - Very healthy plants
Good	Mulched Weed free All sanitation practices done	- 50% flowering - High sucker production - Healthy plants
Fair	Weed free Some sanitation practices done	- Healthy plants - Average sucker production
Poor	Some weeds Some sanitation done	- Stunted plants - Very little or no Flowering - Poor sucker production
Very poor	No management practice applied	- Very stunted plants - 0-2 suckers produced

Results

1. Management and performance of the banana experimental plots

Table 3. Scientists' assessment of performance of banana experimental plots

Farmer	Management	Performance
Damulira	Fair	Fair
Deborah Zabasajja	Very good	Good
Zamu	Poor	Poor
Mama Zamu	Very poor	Very poor
Kagwa	Good	Good
Suubi	Fair	Fair
Herbert Mayanja	Good	Good
Kawama	Fair	Fair
Lamek Kibugo	Good	Good
Tamale (Mrs)	Very good	Very good
Nalongo Kafero	Good	Fair
Proscovia	Fair	Fair
Sam Matovu	Good	Good
ZZiwa	Good	Good
Hadija Nagawa	Poor	Fair
Lutaya Kasomba	Good	Good
Karim Gabula	Poor	Fair
Philip Nsubuga	Poor	Poor
Ssemakula	Good	Good
Ssekabere Ssabwe	Good	Good
Mwanje	Fair	Fair
Ssebagereka	Very good	Good
Simon Sengendo	Good	Good
Senkantuka	Very good	Very good
Musisi N. Mary	Very good	Very good

2. Results of the group interviews

A. Participating farmers

(i) Ntooke Group

Expectations of the participants from the meeting

The participants of this group anticipated the following objectives to be achieved at the end of the meeting

1. To analyse the positives and negatives experienced during the course of implementing the experiment
2. To asses the constraints/problems encountered while implementing the experiment
3. To get information on availability of planting material for new cultivars that had been promised (FHIA) (resistant to drought)
4. To get more knowledge from researchers regarding banana production
5. To get to know those that implemented banana management practices which had been taught

Objectives 1, 2 and 5 coincided with the purpose of the study of evaluating the benefits from the break crop project and impact on farmers' knowledge of banana production

The following benefits had been realised by the farmers

1. Food from cassava and bananas harvested
2. Income from bananas sold
3. Learnt new techniques of banana production
4. Learnt pests and diseases that attack bananas
5. Learnt to rehabilitate plantations whose productivity is declined
6. Learnt to keep records especially on measuring banana bunches
7. Learnt the rapid multiplication technique of banana suckers
8. Learnt to be responsible with regard to banana production requirements

Negative attributes observed during the course of the experiment

1. Small sized bunches (due to drought and cultivar selected)
2. The selected cultivar is not tolerant to drought
3. Discouraged from inter-cropping
4. Suckers planted from the plot take longer to establish than the tissue culture plants

Constraints experienced during the course of the trial

1. Lack of wheel burrow and spades for transporting and applying compost manure
2. Drought
3. Pests mainly the banana weevil and 'kaasa' (black ants). The weevil problem was observed on very few plants (2 cases reported each about 2 mats, which had been seriously affected.
4. Diseases mainly Black sigatoka
5. Very difficult to raise the necessary amount of compost manure
6. Compost manure encourages 'kaasa' multiplication
7. The plants produced a lot of suckers thus increasing the labour for de-suckering
8. Grass for mulching not easily accessible

Differences observed between experimental plot and traditional plots

1. Less labour requirement for weeding in the experimental plot as a result of mulching
2. Moisture retention enhanced in the experimental plot as a result of mulching

3. Plants in the experimental plot flower at the same time producing many bunches encouraging selling some
4. Plants more diseased and pests more in the traditional/farmer plot
5. Plants mature quickly in the experimental plots
6. Plants in the experimental plot produce very soft food even under drought conditions
7. Small sized banana bunches in the experimental plot.
8. Plants in the experimental plot produce a lot of suckers
9. Plants brought for the experimental not tolerant to weeds unlike their plants, which they have been leaving to grow in weeds.

(ii) Ntenjeru group

Expectations of the participants from the meeting

The participants of this group anticipated the following objectives to be achieved at the end of the meeting

1. To identify knowledge gaps regarding banana production
2. To share experience from the on-farm trials with other farmers (participating and non-participating
3. To receive research findings from scientists
4. To devise ways of disseminating the technology to other farmers and areas

Positive attributes about the trial

1. Good food produced from the trial plot
2. The bunches mature quickly
3. High rate of sucker production
4. Less weeding costs
5. Less labour for leaf and sheath removal because only dry ones are removed
6. Less leaf damage experienced due diseases
7. Less land needed because the spacing used is small

Negative attributes observed during the course of the experiment

1. Small bunches attributed to
   (a) drought
   (b) some farmers did not apply the recommended soil amendments (compost manure and mulch)
2. Inter-cropping not encouraged
3. Discouraged from removing leaves which are much wanted in cooking

Constraints experienced during the course of the trial

1. They are sceptical of the tissue culture plants. They think they could have effect on their soils
2. Collecting/gathering mulch is a problem
3. Lack wheelbarrow to transport soil amendments

4. Compost making is labour intensive
5. Termites destroy the mulch applied.

Differences between trial and other banana plots

1. Trial plots were weeded frequently
2. Trial plots were not inter-cropped
3. Trial plots were mulched
4. Easy to carry planting material used in the trial plot
5. Banana bunches in the trial plot were heavier and produced more food though small
6. Plants in the trial plot produced more suckers
7. Banana bunches harvested from the trial plot produced good food
8. Plants in the trial plot look more healthy and vigorous

B. Non-participating farmers.

Non-participating farmers expected to achieve the following objectives from the meeting

1. To learn about farming practices
2. To learn how to grow bananas

The farmers were asked to enumerate what they already knew about banana production and their sources of information.

Farmers knew the following about banana production:

(a) Spacing (3m, 10ft and 2 paces between plants). Sources of information on spacing included parents for farmers who use pacing, UNFA for farmers who use 10 feet and training seminar for farmers who use 10 metres.
(b) Soil amendments added at time of planting including use of compost, crop residues and animal manure
(c) Planting pest free suckers
(d) Removing only old and damaged leaf sheath

Knowledge about Break crop technology

Five of the non-participating farmers knew about farmers who grow bananas with methods different from traditional practices in the area. The methods used by the farmers referred to included use of contour bands, reduce sucker population, mulch application, and corm and sheath removal. Through mentioning names, the farmers referred to were found to be participants in the break crop trial. There was no mention of the break crop technology. However, on further probing, they conceded to know some two farmers planted bananas after cassava. The benefits from the break-crop technology had not yet been internalised by the non-participating farmers.

Comments about positive and negative attributes for participating in the project

Positive attributes

All farmers concurred that they improved their knowledge on banana production and especially on the following aspects:
(i) Mulching to improve soil moisture retention and fertility
(ii) Leaf and sheath removal (only dry leaves and sheath removed)
(iii) Plant spacing of 3 m between mats
(iv) Constructing contour bands to control soil erosion
(v) Reducing plant population by leaving the mother, daughter and grand daughter plants on the mats
(vi) Trapping weevils to control the weevil population
(vi) Removal of leaves infested with black Sigatoka
(vii) Use of break crops to control banana nematodes and
(viii) Use of compost manure to improve soil fertility and plant vigour

Negative attributes

Some farmers complained that suckers removed from the experimental plot take long to establish. However, one of the participants said it depends on where you plant them. The suckers she planted where she had removed sweet potatoes established well. She attributed the problem of the poor establishment of the suckers, experienced by these farmers, to fields that could be infested with pests. This was confirmed by one of the complainants who admitted to have planted the suckers in an existing coffee plantation.

Drought was also given as a major limiting factor for newly planted suckers to get established, especially for pared suckers. Tissue culture plants were reported to recover easily from drought shock.

One farmer attributed small sized banana bunches to the type of the cultivar that was given to the farmers. Other farmers concurred that the cultivar Ndyabalangira generally produces small bunches. They had preferred it to other cultivars during the baseline study because it is tolerant to the environment in the area and produces very good food. It is also early maturing. They argued that by then, their main problem was food security and the three attributes of Ndyabalangira i.e. tolerance to the area constraints, producing good food and early maturing were appealing. But now that production for business is taken seriously, they would prefer a cultivar that produces big bunches which are appealing to buyers. One, Mrs Tamale reported that she received Mpologoma cultivar in her planting material, which performed very well. “The bunch was very big and I got two meals out of one bunch unlike other cultivars where I have to combine 2 to 3 bunches for one meal,” said Mrs Tamale.

Conclusions

The consultations made with both participating non-participating farmers revealed that there was some impact made from the project especially through increasing farmers' awareness of new banana production techniques (tissue culture planting material, compost making, mulching and non-chemical control of pests). The baseline study had revealed farmers' unawareness of the nematode problem. The subsequent assessment studies also showed that farmers took long to internalise the nematode problem. However, this study shows that most of the participating farmers (>70%) now do understand the problem after a series of training sessions.

The study also reveals some constraints that might limit adoption of the break crop technology. The constraints include:

(i) Unwillingness by farmers to abandon the practice of intercropping cassava and legumes (beans and ground nuts)
(ii) Unwillingness to uproot all banana mats/plants during the period of the break crop by hopping that they will still get some harvest. Bananas are the most preferred food and farmers are hesitant to uproot the crop so longer as they expect some output
(iii) The management required for the new banana crop is labour intensive and some farmers fail to cope with this demand
(iv) Most required soil amendments (e.g. mulch, manure and compost) are less available, limiting the productivity of bananas
(v) The area receives intermittent rains and in most cases not, thereby affecting the productivity of the banana crop. Farmers fail to realise the benefits of the break crop technology since bunch sizes remain small under drought conditions.

Despite the constraints, farmers appreciated the differences between the trial plots and traditional banana plots, especially the high suckering rate and plant vigour in the trial plots. Dissemination of the technology will require vigorous training sessions especially for the farmers to first internalise the nematode problem.

Appendix 14

NON-CHEMICAL MANAGEMENT OF BANANA NEMATODES IN EAST AFRICA: REPORT ON SOCIO-ECONOMIC AND UPTAKE ASPECTS OF THE PROJECT (A0508)

by R Lamboll*

1. Introduction

1.1 Bananas in Uganda

Banana is the major staple food crop over much of Uganda, which is currently the world's largest producer (c. 9.0m tons per annum in 1996), accounting for approximately 15% of total global yield. There has been a major decline in banana production in Uganda over the last 25 years, which has been reflected by a shift in production from the Central to the Western region. In the two regions production is estimated at 6 and 17 tons/ha respectively, while longevity of banana plantations has fallen from about 50 years to only 5-10 years in some areas.

Research led by the Uganda National Banana Research Programme (UNBRP) suggests that a number of interrelated factors have contributed to the recent decline in production. These include: socioeconomic constraints, low genetic diversity, declining soil fertility, a pest complex involving banana weevils, parasitic nematodes and a number of diseases and post harvest problems. Socioeconomic constraints, as perceived by farmers themselves, in[*]clude labour, road accessibility, priority rating problems, management options and other sources of income. Rising population pressure, land use intensification and diminishing farm size have resulted in, for example, shortened fallow periods, and have been key contributors to declining soil fertility. The genetic variability of bananas in Uganda is currently very limited and many of the preferred cultivars are susceptible to pests and diseases. Most of these constraints to banana production are not unique to Uganda but are of importance regionally (Gowen 2000).

1.2 Background to the non-chemical management of banana nematode in East Africa project

Nematodes cause root destruction, which decreases stability, eventually resulting in toppling of plants and the loss of the fruit. This project has aimed to improve nematode control by promoting the concept of disease-free planting material planted after an alternative break crop has been in the ground for a suitable period of time (Gowen and Maslen 1995). This is not a new concept, but the development of tissue-cultured planting material has provided fresh opportunities for it's application in countries such as Uganda. After clearing infected bananas and planting a non-susceptible break crop (in this case

[*]*With minor additions by R Maslen

cassava) for a sufficient period of time, tissue culture should provide a guaranteed source of nematode-free planting material. The project has been implemented through a collaboration between the Uganda National Banana Research Programme. (UNBRP) and the Natural Resources Institute (NRI). It was initiated in 1996, with an original life of three years.

1.3 Project activities

Project activities have focused on two sites of on-farm activities (Mukono and Masaka districts), together with an on-station trial at Kawanda ARI. Most of the on-farm research has been in Mukono and the activities are outlined below.

Site selection- Mukono district was selected as an area where bananas are in decline, but the crop is still important and the trials sites would be easily accessible to Kawanda researchers. In August 1996 a joint UNBRP/ NRI team, together with Mrs Doreen Kalaama (the Deputy Director of Agriculture in Mukono District) visited Mukono county. An initial meeting was held with farmers to better understand their situation and perceptions of banana production and to explain the aims of the project.

Farmer/ plot selection- 33 participating farmers from seven villages in four parishes[1] in Mukono county were initially selected by researchers in the project. A nematode survey was carried out in the selected banana plots. A baseline survey of participating households was carried out to identify factors that would be influential in implementing the project. A follow up was made to seek views from the participating farmers regarding strengths, weaknesses, opportunities and threats to the project.

Distribution of cassava planting material- having cleared their plots of banana plants farmers were provided with cassava planting material at no cost in November 1996.. This material was African Cassava Mosaic Virus (ACMV) resistant and in very high demand because of the prevalence of the disease, which had almost completely removed the crop from the area.

Monitoring of nematodes -research technicians periodically sampled for nematodes in farmers' plots/ trials.

Distribution of tissue cultured banana planting material -farmers were asked to rank the *matooke* (cooking bananas) cultivars in terms of preference to help in future selection of banana planting material to supply to farmers. Ndibwabalangira, Nakitembe, Ntikka, Siira and Mayovu were some of the cultivars cited as most preferred. The first tissue cultured material was distributed in September 1998. In November 1998, suckers (in the form of pared corms) from the mothergarden at ARI were distributed. Although it was originally envisaged that only suckers from mother gardens at Kawanda ARI would be distributed, these were later supplemented with material from the screen house. Drought and other

[1] Bukooloto, Buyobe, Kayuni and Ntenjeru parishes.

factors resulted in the need for a significant amount (c. 30%) of re-planting (gap-filling) but this was due to drying out of the pared suckers and hardly at all to the surprisingly hardy tissue cultured plants (Kashaija, 2000).

Monitoring and evaluation of and with farmers- activities included: an initial socio-economic baseline survey (1996); a farmer participatory evaluation of the use of break crop technology (July-September 1998); RRA of farmers perceptions of introduced methods of nematode management and assessment of the potential for uptake (mainly December 1998) and an intermediate impact assessment study (reported May 1999).

1.4 Objectives of this report

This report aims to draw together socio-economic and uptake aspects of the project and in particular:

(1) Report on farmers' perceptions of introduced methods of nematode management;
(2) Assess the potential for uptake of the management methods;
(3) Suggest possible ways forward, depending on the outcome of 1 and 2 above.

2. Farmers' perceptions of introduced methods of nematode management

2.1 Introduction

This section draws on research carried out by NARO socio-economist Mr Fred Bagamba, together with UNBRP team assistance and joint UNBRP/ NRI fieldwork carried out mainly in December 1998.

2.2 Characterising farmers in the study areas

Mukono district

The project baseline survey only included the 33 farmers who were originally involved in the trials. Out of the 33 respondents 27 were heads of households; 40% were female and the average age was 46 (Table 1).

A wealth ranking exercise categorised participating farmers into high, medium and low wealth groups. Three of the households were ranked high, 20 middle and seven low. Three were not ranked. Indicators used for wealth ranking included non-farm income, nature of house owned, household farm size, number of livestock owned and income from crops. Non-farm income was the major indicator of wealth. The majority of the farmers in the middle group had good houses which were probably built when coffee/banana production and prices were high before the late 1970s. Currently, farmers considered rich in the area are those earning substantial income from non-farm activities.

The mean area of land available to each household is 6.8 acres[2], ranging from 2.5 acres up to 39 acres. Just over half the households had access to less than five acres of land and only 3% above ten acres. There was no significant difference in amount of land owned

[2] one acre = 0.4047 hectares

by medium and high wealth group farmers, however, farmers in the low wealth group had less access to land.

A high proportion of the land was allocated to crops, with farmers in the low wealth group cultivating almost all their available land. Overall, land allocated to bananas was 70% of total land committed to crops, with each household growing an average of 3.4 acres of bananas, well above the acreage allocated to other crops. Farmers in the medium wealth group had more land allocated to bananas (4 acres) compared to the high wealth (3.3 acres) and low wealth (2.3 acres) farmers. This suggests that farmers in the middle wealth group have more interest in banana production and are more likely to commit more resources to technologies that could improve banana productivity.

Table 1. Household and production characteristics for project area.

Characteristics	Socioeconomic status			
	Top	Middle	Bottom	Overall
	N =3	N = 20	N= 7	N = 30
Average household size	11	9	12	10
Males >18 years	3.0	1.5	1.6	1.7
Females >18years	2.0	1.6	1.6	1.6
Children >=12years	2.7	2.2	3.8	2.5
Children <12years	3.0	4.0	5.0	4.0
Mean age of respondent (years)	39	48	45	46
Proportion female respondents (%)	33	40	43	40
Total household land (acres)	7.7	7.5	5.6	6.8
Land under crops (acres)	5.1	4.9	5.4	5.0
Land under bananas (acres)	3.3	4.0	2.3	3.4
Food crops grown (Proportion of farmers)				
Ranked bananas first	67	90	71	79
Sweet potatoes first	33	10	29	21
Maize first	0	5	0	0
Cash crops (Proportion of farmers)				
Ranked bananas first	33	30	0	22
Coffee first	67	70	86	75
Maize first	0	0	14	3
Crops preferred for food security (Proportion of farmers)				
Ranked bananas first	67	60	43	52
Sweet potatoes first	0	5	14	6
Cassava first	33	35	14	33
Maize first	0	0	14	6
Beans first	0	0	14	3
Crops preferred for good taste (Proportion of farmers)				
Ranked bananas first	100	90	100	93
Cassava as first	0	0	0	0
Sweet potatoes first	0	5	0	3
Maize first	0	5	0	3

Source: Bagamba (1997)

Although yields are low, farmers still attached high importance to bananas as reflected in the large proportion of land allocated to the crop. Seventy nine percent of the farmers regarded bananas as their most important staple food crop. Sweet potato was ranked as the second staple food crop grown with, 21% ranking it first. Other food crops grown included beans, maize and yams.

Overall, *matooke* (cooking banana) was second to coffee in terms of earning income, (22% ranked it as first cash crop). Coffee was ranked first cash crop by 75% of the farmers. Other crops regarded as income sources included maize, yams, *Kayinja* (beer bananas), cocoa and beans.

In terms of food security, bananas were most preferred, ranked first by 51.5% of the farmers and this was attributed to its availability throughout the year. Cassava was ranked second (despite the fact that it is not widely grown) because it stayed in the soil for a long time without rotting. *Matooke* was the most preferred food crop in terms of taste (93% of the respondents) followed by cassava and then sweet potato.

Masaka district

In Masaka one large commercial farmer was included at a later stage after he was identified as having a major nematode problem over a large area of bananas.

2.3 Farmer perceptions of causes of banana decline

In the baseline survey, factors attributed to the decline of bananas in order of decreasing importance included pest build-up, drought, poor soil fertility and poor management practices (Table 2). Pests associated with the decline include weevil (reported by 79% of the farmers), *Kaasa* (ants) (71%) and to a lesser extent earthworms (7%) .Very few farmers differentiated toppling from weevil damage (7%) implying that farmers are less aware of the nematode problem. Farmers who reported earthworms to be a problem could have confused them with nematodes[3].

Table 2 Causes of banana production decline

Reasons		Proportion of farmers (%)			
		Top	Middle	Bottom	Overall
Decline in soil fertility		33.3	50.0	0.0	39.3
Drought		66.7	45.0	40.0	46.4
Poor management		33.3	25.0	20.0	15.0
Pest build-up		66.7	65.0	40.0	63.0
Kind of pests					
	Weevil	33.3	85.0	80.0	78.6
	Kaasa	66.7	70.0	80.0	71.4
	Toppling	66.7	10.0	0.0	7.1

[3] In the early stages of the project researchers had tried to explain nematodes in terms of being very small earthworms. It was later realized that this was misleading and the term nematode was used.

	Earthworms	0.0	10.0	0.0	7.1

Source: Bagamba (1997)

An RRA carried out in one of trial villages (Ntooke) with 6 female and one male (LC1) participants in December 1998 helps to further illustrate farmer perceptions. A farm map was drawn with Mrs Faith Mutyaba and she was asked to show the main features of the plot, how it had changed over time, any management activities she had carried out and reasons for doing so. A number of points emerged through this exercise:

The farm was about one acre in area, with bananas which had been planted at different times (ie before 1986/ 1986/ 1998 (trial)). Yields overall were poor-(one bunch/ stool/ year), but within the plot there were significant variations. Particularly low yields were explained as being the result of areas of thin rocky soils resulting in poor bananas with very small bunches and small fingers. *Kaasa* (black ants) were identified as a pest.

A number of elements emerged as part of the management strategy for the plot. In one location, where yields had been particularly low, bananas had been replaced with coffee in 1997. Intercropping (eg with beans) was important because of land (and although not reported, possibly labour) shortage. Some trees were considered beneficial to bananas, but the situation varied. Jack fruit, for example, provided shade only, whereas Ficus trees provided shade and contributed to fertility. Following this discussion Faith asked if trees could be planted on the trial plot. There was also discussion around the application of coffee husks as a fertilizer, with one farmer reporting that it had damaged her bananas.

In Masaka the trial is located on the farm of Haji, a commercial farmer. He first planted bananas there in 1982 using planting material from various places, but mostly from his former home near Masaka town. At the time of the visit some trial plots still contained banana plants (reason given by the farmer was that they still had bunches remaining) and two plots had been planted with maize (formerly sweet potato).

Coffee husks were being used as fertilizer and according to Haji this idea originated with a coffee processor applying husks to his bananas. Other farmers then copied. Agricultural extension staff eventually recommended that the husks should be kept away from the stool (to avoid scorching). Thiodan pesticide (bought from a farm supply shop) had been applied to control weevils and this was associated with drying of roots. The idea had come from Agricultural Extension service through mass media (radio) in the 1980s. The recommendation had been to apply the pesticide around the stool, but to try and be more effective he had applied directly to the stump after harvesting. The bananas have been mulched with grass.

Yields on these plots were initially high, but have since declined. He compared this experience with bananas in his neighbours' fields which have been growing longer and have maintained lower yields without inputs.

Some conclusions may be drawn from the above findings (which coincide with other studies). Farmers are operating in a complex system in which they are very knowledgeable about some aspects (eg variation in yields, incidence of very visible organisms eg weevils and *Kaasa)*, but not others (eg nematodes, diseases). In particular, farmers are generally not associating decline in bananas with nematodes. Even after two years contact with the project staff, nematodes don't emerge as an issue in discussions with farmers. This has clear implications with respect to uptake (see section 3 and 4).

2.4 Farmer perceptions of nematode management (trials)

Two participatory project evaluations were carried out in Mukono in July-September 1998 with 28 participating and eight non-participating farmers. The summary of outcomes (Maslen 1998) are as follows:

- 'All the farmers deplored that the bananas which they still value and respect very highly as their traditional staple food had severely declined and was in a very poor state due to a combination of biotic and abiotic factors;
- The participating farmers reports indicated that although they had cut down some bananas from the plots where they were growing cassava and/ or sweet potato as break crops, the social and economic benefits obtained from the break crops were now four times higher than those from their poor-yielding banana plantations;
- The project had done very well to introduce into the area the growing of break crops, especially cassava, which was dual purpose as a food security and a good source of farm cash income'.

The cassava appears to have been a major success. Cassava production was limited by ACMV, which had almost wiped out the crop, and access to resistant planting material was very limited. Availability of free planting material appears to have been a major motivation for farmers to participate in this project.

In December 1998 during the RRA a small number of farmers volunteered their understanding of the aims of the trials and the response was variable (Table 3). In the later impact study when all participating farmers were asked about the purpose of the project –14% understood it to be concerned with soil improvement, 46% promoting cassava and 32% pest control (Bagamba 1999). This follows 'sensitization about the objectives' at the beginning of the project, further training in the second quarter of 1998 which involved 'individual farmer contacts, farmer field schools at village level and seminars at parish level (Maslen1998) and researcher visits over a period of over two years. The majority of farmers perceived the aims of the project differently from researchers involved. One way in which the this may have been addressed is through regular feedback of results (as suggested by one farmer in Bwetwyaba village).

Table 3 Farmers explanations of the aims of the trials in their fields

Location	**Explanations**
Ntooke	The LC1 chairman understood the trial to be concerned

village	with the planting of cassava as a break crop in order to control nematodes.
Bwetwyaba village	Mary – the aim of the trial is to show farmers that if they plant this banana they are free of banana *ubuka* (identified as nematodes after some prompting). That's why they were asked to remove bananas and plant cassava in order to reduce *ubuka*. She will be looking for the difference compared to bananas that were there before.
	Second farmer- to provide food security through cassava and banana. Research results had not been brought back.
	Third farmer – similar response to Mary. Bringing *matooke* (cooking banana) back to the area through fighting one of the pests.
Masaka	The aim of the trial is to reduce the incidence of an insect affecting banana through the planting of sweet potato and cassava.

2.5 Farmer expectations of research/ training

Participating farmers were asked to identify at least two training needs that would help them better manage their bananas. The results are shown below (Table 4).

Table 4 Farmers requests for more knowledge in relation to banana management

Farmer	**Like to know**
Ntooke village	
Kibugo	1.How to recognise/ identify a plantation attacked by nematodes without sampling or use of a microscope 2. Planting-how to select clean sucker and then plant 3. Weed control 4. Male flower – is removal OK? 5. Number of leaves 6. De-sheathing –removing pseudostem sheath
Faith	1.Management-maintenance of relatively good high production after 3 years 2. To understand the nematode problem
Jane	1. Planting hole size 2. How to kill Kaasa, since they bite
Mrs Kaggwa	3. Mulching-distance from corm 4. Desuckering-number of suckers to leave on a mat

Kazei Ssaajabbi	5. Kaasa control 6. Weevil control
Proscovia	1. How to control pests-kaasa, nematodes and weevils
Bwetwyaba village	
Henry	1. Improving bunch size 2. Prolonging plantation life
Mary	1 Freeing plantation of biwuka
Simon	1. Kayovu (weevils) 2. Fertilization
Sebagereka	3. Kayovu 4. Weed control
Mwanje	1.Maintenance of the new bananas/ plots from KARI
Solomon	1.Weed control 2. Prevention/ eradication of biwuka
Masaka commercial farmer	
Haji	1. More information on planting 2. Pest management 3. Advice on improving fertility

A wide range of topics was identified ranging from the general to the very specific. The articulation of demand for improved methods for nematode control may be interpreted as a success in terms of raising farmer awareness of nematodes, but raises questions as to whether farmers were convinced about the break crop approach. It is also clear that farmers are grappling with a large number of management issues, of which nematodes is only one. This has implications for the likelihood of achieving uptake(see section 3).

2.6 Farmer expectations of success

Scientists in the project have monitored nematodes in the farmers' trial fields and following the removal of the old bananas the data shows a clear decline in nematode numbers. Participating farmers were asked how they would judge whether or not the trials have been a success. The indicators identified revolve around yields and sustainability of the banana crop (Table 5).

Table 5 Participating farmers' indicators of success for the trials

Village	Indicators of success
Ntooke village	1. Vigour of the growing plant 2. Yield of the 2nd harvest
Bwetwyaba village	1 Cassava already a success-not affected by the disease (ACMV), good yield and planting material now available. 2 Waiting to see bunches 1. When they start enjoying the bunches

	2. If bunches are better than those currently available. 3. If plants sustain yields for longer ie 10-15 years. 6 Like to see at least the first and if possible the second ratoon

2.7 Implications for monitoring and evaluation

The above indicators suggest that monitoring should continue until at least the second harvest (first ratoon). This suggests an evaluation with farmers in the second half of the year 2000. On a less intensive basis it would be worthwhile monitoring the performance of the bananas over a longer time period (10-15 years) to assess whether they meet farmer expectations.

2.8 Communications

Communication was an issue for farmers and researchers[4]. In each of the two farmer groups there is a co-ordinator who should inform the farmers of visits or other matters and provide feedback to researchers. Farmers emphasised the difficulties in contacting Kawanda by telephone[5] (nearest phone in Kayunga post office-can take a long time) or by post (very long time and unreliable). Researchers usually contact farmers through sending a technician with transport (time consuming and costly). The communication issue was not resolved.

3.Potential for uptake of the management methods

3.1 Introduction

The process of uptake of research outputs can be complex and influenced by many factors. In broad terms, uptake is dependent on the appropriateness for the end user and access to knowledge and required inputs.

3.2 Issues associated with uptake

Farmer motivation for being involved in the project - cassava production in Mukono was limited by ACMV, which had almost wiped out the crop. Access to resistant planting material was very limited. The provision of free planting material was a major motivation for farmers to participate in this project.

Access to clean banana planting material – the banana planting material was delivered at no cost to participating farmers. Approximately one third (92 out of 275) of the plants sampled in March 1999 had not survived. Uptake will be dependent on farmers access to clean planting material at an acceptable cost and an acceptable survival rate.

[4] For example, farmers had harvested cassava (break crop) 'early' because of food shortages. Cassava had also been intercropped in some cases with beans which is known to be an alternative host to *P. goodeyi.* The findings in his report emphasised the need to maintain close contact with the participating farmers throughout the trial.
[5] In another CPP project in neighbouring Iganga district one enthusiastic farmer co-ordinator used the phone and fax in Iganga town to contact members of the Cereal Programme at Namulonge ARI.

Farmers perceptions of nematodes and other causes of banana decline - although the proportion of participating farmers being aware of nematodes rose from zero in 1997 to 41% in 1999, very few of the participating farmers reported that they were aware of methods for controlling nematodes (14%) (Bagamba 1999).. This corresponds with farmers response when asked about the purpose of the breakcrop project –14% understood it to be concerned with soil improvement, 46% promoting cassava and 32% pest control (Bagamba 1999). Is there sufficient institutional capacity to provide farmers with the appropriate knowledge? To what extent can this 'technology' be applied without the knowledge?

Appropriateness for poorer farmers- the baseline survey suggests that it is the middle wealth group farmers who are most willing to invest in banana production. Unfortunately, the impact survey in 1999 didn't differentiate between farmers in different wealth groups. Is this approach appropriate for poorer farmers?

3.2 Uptake in Mukono district

3.2.1 Evidence of existing uptake in Mukono district
The district extension service has already established demonstration plots using tissue cultured planting material. The co-ordinator is Doreen Kataama, who originally helped to select sites for this project, but wasn't involved again until the 1998 RRA. The demonstrations have been established using district funds, which would appear to show a clear commitment towards banana production in Mukono. The details are shown in Table 6.

Table 6. Mukono district Government demonstrations of tissue-cultured bananas

Location	When established	Material	Source and price
Sub-county HQ Kaworo sub-county, Buikwe county	Original 50 plants planted in October 1997. Subsequent planting has taken number up to 100 plants	Cooking types-Kibuzi, Mbwazirume, Nyeriu. Fhia 3 and 17. Km 5.	Kabanyoro (Makerere university farm) - Ush 500/ plant
Sub-county HQ Goma sub-county Mukono county	Planted 50 plants in April 1998	Cooking types Fhia 3	Kabanyoro Ush 500/ plant
Sub-county HQ Kyampisi sub-county, Mukono county	Planted c.50 plants in October 1998	Cooking types	Kawanda ARI - Ush 1,000/ plant
10 farmers in Ntanzi parish Ntenjeru sub-county Mukono county	Each farmer received c.50 plants in April 1998	Cooking type	Kabanyoro Ush 500/ plant

3.2.2 Potential organizations to facilitate uptake

In the participating villages very few organizations appeared to be active and only two were identified by farmers. These were FEED, a Canadian NGO mainly concerned with strengthening education and BUCADEV, a Bagandan organisation aiming to strengthen culture and development of Bagandan people. The district extension service and UNAFA (Uganda National Farmers Association) do not appear to be very active in the participating villages.

The Mukono district extension office provided information on organizations generally active in agricultural service support in Mukono (see Table below).

Table 7. Stakeholders in agricultural service support in Mukono district

Organization	Activities
UNFA	Provision of extension; supply of seed; mobilizing farmers; organize agricultural shows and farmer competitions
USEP	Organize farmer competitions (sub-county level); extension education; exchange of resource persons
FOSEM (OFPEP)	Provision of improved seed; training farmers on seed technology
MUDDA	Training; Extension service; Provision of credit facilities
World Vision	Training; Field visits; Input distribution; Provision of credit facilities; Exchange of resource persons.
Feed the Children	Extension Services; Training
Mirembe Self-Help	Extension; Education on Environment and Agro-forestry
YWCA	Extension, Involvement in Credit; proposals
Church of Uganda	Provision of dairy cows; Extension (re dairy cows); Education on zero grazing

Source: The Mukono District AEP Seasonal review 2nd Rains 1997 and Action Plan 1st Rains 1998 :

3.3 Uptake beyond Mukono district

Beyond Mukono district, the Luwero and other benchmark sites are likely uptake pathways and findings from the CPP uptake study provide ideas for achieving uptake in banana growing areas in general (see section 4)

4. The Way forward

4.1 The project

In the development of the revised project action plan (December 1998) a number of approaches were discussed and agreed with a view to further developing approaches to technology uptake. These included:

1) Farmers to be provided with feedback from researchers – although farmers felt information had been collected from their banana plots they had received little feedback on the findings. This was subsequently addressed through activities such as informal and arranged meetings on researcher-visits and field days at the trial sites.

2) Increased interaction between farmers, researchers and extensionists: there appeared

to have been less than intended interaction between researchers, farmers and extensionists. For example, research technicians had often carried out nematode sampling without any contact with the farmer. The district extension office had been involved at the beginning of the project, but there had been much reduced contact, due in part to staff changes, availability and interests . Activities to address this included farmer visits to KARI, farmer meetings and at the appropriate stage, workshops in Kayunga.

3) Farmers priorities for training-linked to 2 above was the identified need to prioritise farmer training needs. This provides a means of assessing farmer perceptions of nematodes and other factors influencing bananas, which in turn gives an indication of how uptake may be facilitated.

4.2 Central Zone

The UNBRP and other partners are developing a Benchmark Site (Outreach) Programme which has the aim of incorporating and accelerating the movement of promising and tested technologies along uptake pathways for promotion. In Central Uganda a Benchmark Site (BS) is being established in Bamunanika sub-county, Iganga district, which is adjacent to Mukono district. The CPP is facilitating the development of this BS through the Integrated Management of Plant Diseases project and the Management Strategies for Banana Streak Virus project.

In July 2000 a planning meeting(NBRP 2000) for the Luwero BS was held at Kawanda ARI with researchers from NARO, ICIPE, IITA, CABI, University of Reading and NRI participating. During this meeting the diversity and complexity of the population, culture and farming systems in Luwero was emphasised, as was the need for an'Integrated Productivity and Pest management' (IPPM) approach.

There is clearly potential for Luwero BS to be an uptake pathway for the outputs of the non-chemical nematode control project. However, although the recently completed baseline survey (covering 117 respondents in six parishes) reported *kaasa* and weevils as important pests, none of the farmers described symptoms resulting from nematode damage. A linked biological baseline survey is to take place and this should reveal the incidence of nematodes in the locality. If they are a significant pest but, as is frequently reported, farmers are unaware of existence, the experiences of the non-chemical nematode control project suggest cost-effective approaches need to be developed which will allow farmers to understand the nature of the pest such that they are able to make informed decisions about how to control nematodes.

Other challenges to successful uptake which emerged from the Luwero baseline survey (NBRP 2000) are:

- Complex intercropping in banana plots- can the breakcrop/ clean planting material adapt to this cropping system?
- Competitive demands for land- the average farm size is 1.98 hectares (compared to

2.75 hectares in the Mukono study site), with an average of 0.25 hectares allocated to bananas (1.38 hectares at the Mukono study site).

- Land tenure- about 25% of farmers live on leased land, which is generally less than one hectare. Presumably these are poorer farmers, which DFID projects should be targeting. To what extent will insecure land tenure influence a farmer's decision to invest in a longer term/ perennial?? crop such as banana.
- Farmer concerns with growing banana permanent/ perennial crop-many farmers are no longer confident that bananas can be established on a permanent basis and once they observe signs of declining productivity they abandon the plot. This again raises the question of willingness to invest in banana production.

Matooke (cooking bananas) is still the third most important food staple and *kayinja* (beer banana) the second most important cash crop. The challenge will be to explore where the outputs from the non-chemical project can fit into the Luwero environment. If there is potential, farmer-farmer study visits between the Luwero BS and the Mukono study site would provide a good basis for developing initiatives.

4.3 Other banana growing areas

The Uganda National Banana Research Programme's Benchmark Site programme is being developed at four sites across three zones:

- The East and Central Zone, where banana production is in severe decline (Luwero Benchmark Site);
- The South, where banana production is at an intermediate level of decline (Masaka and Ntungamo Benchmark Sites) ;
- The Western Zone, where banana production is still at its 'optimum' level of production (Bushenyi Benchmark Site).

At the Masaka Benchmark Site, there appear to be no current activities focused on nematode management, but nematode control is one of the stated objectives and this site may be an appropriate pathway possibly linking with the non-chemical project on-farm trial in the district.

The Bushenyi Benchmark Site is still being developed, with a baseline survey possibly to take place in 2001.

At the Ntungamo Benchmark Site research emphasis has been on weevil control and soil fertility management. Although there have been research activities in this area since 1996, there has been no socio-economic baseline survey. The sustainable productivity of banana plants in this area would seem to suggest that the break crop approach may not be appropriate.

The CPP has recently commissioned a study of factors influencing the uptake of outputs of crop protection research in banana-based cropping systems in Uganda (Gowen 2000). This study identified a large number of stakeholders involved in banana research and uptake and explored means for improving the process of technology uptake. The study emphasised the importance of understanding farmer context; identifying and targeting different groups of farmers; understanding farmers (and other stakeholders) preferred sources of information and technology attributes and the need to improve partnerships between stakeholders. The application of these findings should contribute towards improved uptake of research outputs from the non-chemical control of banana nematodes project.

References

Bagamba F. (1998) Non-chemical Control of East African Banana nematodes: Socioeconomic baseline report, 1996/97. Unpublished project report

Bagamba F.(May 1999) Non-chemical Control of East African Banana nematodes: Impact assessment report. Unpublished project report

Gowen S. (2000) Study of factors affecting the uptake and adoption of outputs of crop protection research in banana-based cropping system in Uganda Final Technical Report DFID Crop Protection Programme/ University of Reading, UK

Gowen S. and Maslen R. (1995) Non-chemical management of banana nematodes in east Africa . ODA RNRRS project memorandum form.

Maslen R. (1998) RNRRS Quarterly report 1 July – 30 September 1998 Non-chemical control of banana nematodes in E. Africa. NRI/ DFID Crop Protection Programme

National Banana Research Programme (2000) Planning meeting for Luwero benchmark site 25th-26th July 2000. Kawanda Agricultural Research Institute

Farmer knowledge of pests associated with bananas

	% of farmers	
Pest	**1997**	**1999**
Weevil	78.6	90.9
Nematode	0	40.9
Kaasa	71.4	86.4
Earthworms	7.1	31.8

Source: Bagamba (1999)