CROP PROTECTION PROGRAMME

CONTROL OF YAM DISEASES IN FOREST MARGIN FARMING SYSTEMS IN GHANA

DFID CPP Project R6691 (ZA0138)

FINAL TECHNICAL REPORT

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Project Leader: Jeff Peters

Project Leader's institution: University of Reading, UK

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Collaborators

Dr. Lawrence Kenyon,
Plant Pathologist/Virologist,
Natural Resources Institute,
Central Ave, Chatham Maritime, Kent ME4 4TB.
Tel: +44 1634 883634; Fax: +44 1634 880077/66
Email: l.kenyon@gre.ac.uk

Council for Scientific and Industrial Research (CSIR), Ghana
Dr. Danquah, Dr J Lamptey, Mr Augustus Missah
Crops Research Institute (CRI), Kumasi
Tel. +233 51 60389
Email: crigdp@ghana.com

Dr. S Nutsugah, Mr F Tsigbey
Savannah Agricultural Research Institute (SARI), Nyankpala
Tel:+233 71 23483
Email: sari@africaonline.com.gh

Mr Fuseini Andan
Ministry of Food and Agriculture (MoFA)
Tamale, Ghana
Tel. +233 71 23350; Fax. +233 71 22793
Email: nritam@africaonline.com.gh

Dr Jacqueline Hughes
Virologist
International Institute of Tropical Agriculture (IITA)
Ibadan, Nigeria
Tel: +234 02 2412626
Email: j.hughes-IITA@cgnet.com

Mrs Barbara Hemeng
Univeresity of Science and Technology
Kumasi, Ghana

Dr Elizabeth Acheampong
Department of Botany
University of Ghana
Legon, Ghana
Tel: +233 21 500381

Dr A Jama
Department of Agriculture
The University of Reading
Earley Gate, Reading
RG6 6AT, UK
Tel. +44 (0)118 987 5123

Executive Summary
The main objectives of project R6691 were to determine the nature and impact of yam diseases in Ghana. Recommendations for improved and sustainable pest management practices were formulated and tested on-station. These recommendations were promoted to smallholder farmers.

A rapid rural appraisal of farmers' perceptions of yam pests and diseases was carried out during January 1998. Pests and diseases, grouped together, were ranked the second most important problem (after lack of finances) and were considered a major reason for the poor yam yields experienced by the majority of farmers in 1997. Furthermore, all but one of the farmer groups questioned said that pests and diseases had been increasing in severity over the previous five years. In the Northern and Upper West Regions, termites were ranked as the most important biotic constraint affecting yam production. Mealybugs and scale insects were considered to be the second most important biotic constraint, followed by anthracnose and nematode infestation in equal third place. Direct examination of seed tubers in the Northern Region confirmed that termites were the major cause of macroscopic damage to seed tubers. In the Brong-Ahafo Region, scale insects and mealybugs were considered to be the major yam pest/disease problem. Termites were considered to be the second most important problem, followed by anthracnose, viruses and nematodes in third equal place. Farmers were aware that seed tubers are a source of pests and diseases but were poor at recognising low levels of infection/infestation. Importantly, farmers did not have a reliable source of pest- and disease- free planting material.

Surveys established that anthracnose, caused by the fungus, *Colletotrichum gloeosporioides*, was the most common fungal disease in Ghana. The disease was estimated to cause severe yield losses (over 50%) in around 5 to 10% of farms. Results from field trials support the hypothesis that anthracnose is tuber-borne. Planting relatively disease-free seed improved yields by 61% in *Dioscorea rotundata* cv 'Puna' ($p=0.02$) and 28% in *D.alata* cvs 'Seidu bile' and 'Matches' ($p=0.01$) over that produced by infected seed. Chemical treatment (using a fungicide, Benlate, and a nematicide, Furadan) improved yields by 23% ($p=0.034$) in *D. alata* but was inconsistent in improving yield in *D. rotundata*.

Viral disease surveys during 1998 and 1999 showed that approximately 50% of the white yam (*D. rotundata*) and water yam (*D. alata*) plants in each of the regions surveyed carried virus-like symptoms. Variation in symptom incidence was generally as great within a region as between regions. Of the seven different antisera tested with yam leaves collected during the surveys, only those against yam mosaic virus (YMV) and *D. alata* virus (DAV) produced positive detections. YMV detection was strongly associated with mosaic or mottle symptoms in *D. rotundata*, while DAV was weakly associated with mosaic or mottle in *D. alata*.

The yam nematode, *Scutellonema bradys*, increased the rate of tuber weight loss over an 8-week storage period ($p=0.002$) compared to uninfested controls. The nematode also increased tuber colonisation by *Fusarium solani*, when the two organisms were present in soils surrounding micropropagated yam seedlings. (500 words)

1. Background

Ghana is the third largest producer of yams in the world (only Nigeria and Cote d'Ivoire produce more). In Ghana, during 1997 and 1998, the crop was ranked second in importance (in terms of tonnage) after cassava, and was the most important crop in terms of value (Fowler, 2000). A survey by GTZ of the Northern Region of Ghana identified yams as the most important cash and food crop in that region, followed by groundnuts, cassava and maize. Also, the National Agricultural Research Strategy Plan (NARSP) identified yam, cassava and cocoyam as first priority commodities for research, with yam receiving the highest priority rating of all crops. However, there are a number of serious constraints to yam production. These include: pests and diseases, the low multiplication rate (and hence low availability of planting material), declining soil fertility and the high and expensive labour inputs required (Tetteh & Saakwa, 1991; Degras, 1993).

Yams are almost entirely vegetatively propagated by planting pieces of tuber, or setts. Traditionally in Ghana, farmers have relied on obtaining their planting material either from their own farms, or by buying the surplus from neighbouring farmers. This means that the planting material is often of low quality, being infected with fungal pathogens, virus and/or nematodes, and may be relatively expensive; the habit of retaining the small and misshapen ware yams for seed for the following season probably exacerbates this since these are the ones most likely to be infected. In traditional cropping systems in Ghana, in order to ensure the survival and growth of the planting material, relatively large pieces of yam (220+ gm) are used (at least for white yam), which adds to the cost and results in a very low multiplication rate. In Nigeria, the cost of yam planting material was found to account for almost 20% of the production inputs (79% for labour) in a yam/cassava/legume/maize cropping system (Okorji, 1992). The high cost of planting material is exacerbated by post harvest losses estimated at 13% in the dry northern region of Ghana; of which, 17% are attributed to storage rots (GTZ, 1994). There has been no systematic survey of pre- or post harvest losses in the wetter, southern yam growing belt, where rotting is likely to be more of a problem. Collaboration between the International Institute for Tropical Agriculture (IITA) and the National Root Crops Research Institute (NRCRI) in Nigeria resulted in the development of the "minisett technique" for the rapid multiplication of yams, whereby only small pieces (25g) of tuber are planted. However, this technique has not been taken up by many growers, partly because the sprouting of such small pieces is only really reliable with some varieties of water yam, and because even when the pieces do sprout, the plant produces only a relatively small tuber in the first season. These small yams are ideal for use as "seed" in the following season when they will establish quickly to produce a good sized ware yam. The minisett technique is thus more suited to a cropping system involving the separate production of seed material rather like the system used for Irish potatoes in Europe.

Pathogens commonly associated with storage rots in yam tubers include: *Colletotrichum gloeosporioides*, *Botryodiplodia theobromae*, *Aspergillus* spp., *Penicillium* spp., *Sclerotium rolfsii*, *Curvularia verruculosa*, *Rhizoctonia solani* and *Fusarium moniliforme* (Nwankiti & Okpala, 1981 ; Green, 1994; Otusanya, 1995). Many of these fungi are also commonly isolated from foliar lesions (Green, 1994; Wharton, 1995; Green, Sangoyomi & Amusa, 1996). The role of these organisms in the infection process is not fully understood. However, Wharton (1995) demonstrated that, while most of these fungi exist as disease complexes in foliar lesions, *C. gloeosporioides*, the causal agent of anthracnose, was capable of infecting foliage in the absence of other microorganisms. Similarly, Green

(1994) demonstrated that, *C. gloeosporioides* was the causative organism of 'deadskin', a tuber disease in yams in the Caribbean.

Anthracnose has in the past been mainly associated with *D. alata* (Nwankiti & Okpala, 1981 ; Akem & Asiedu, 1994). However, in Nigeria recently there has been evidence that anthracnose is more severe on *D. rotundata* than previously thought (Green, 1996). Collaborative work between the University of Reading (X0235) and the Caribbean Agricultural, Research and Development Institute (CARDI) showed that *C. gloeosporioides* was capable of being transmitted from foliage to tuber, and from tuber to foliage the following season (CARDI, 1995; Peters & Simons, unpublished). This implicates at least one foliar pathogen, *C. gloeosporioides*, in the field being associated with post harvest diseases. The work identified infected planting material, alternative hosts and crop debris as the main sources of pathogen inoculum (Simons, 1993; Green & Simons, 1994; Ekefan, unpublished). This suggests that it is possible to reduce disease levels in the field by planting clean seed material; but only under conditions not conducive to disease spread, for example in low rainfall areas and where crop rotations are practised.

In addition to foliar pathogens causing rots in tubers, soil inhabiting fungi can penetrate root or tuber surfaces under certain conditions, for example when yam roots are damaged by nematodes. In Eastern Nigeria, Nwauzor & Fawole (1981), found that tubers attacked by *Meloidogyne* spp. were more likely to have storage rots compared to uninfested tubers. Other forms of wounding (including yam beetle and mechanical damage during harvest) were also found to predispose tubers to rots caused predominantly by *Fusarium* spp. (Morse & Oliver, 1995).

Research on the control of pre- and post harvest yam diseases has concentrated mainly in three areas: reducing pathogen and pest populations from planting material and crop plants; selecting for yam varieties resistant to pests and diseases; and developing better storage facilities. Project X0235 demonstrated that micropropagated yam plantlets could be used to produce clean seed material in the Caribbean, but only in low rainfall areas. Project F0006 (NRI and University of Agriculture, Makurdi [UAM], Nigeria) has been primarily concerned with identifying suitable pre-planting treatments for yam minisetts to improve establishment by reducing the effect of fungal rots and insect attack. Several readily available systemic fungicides, such as Benomyl and Imazalil, increased the viability of yam seed material, but none of the insecticides tested showed any significant beneficial effect on the survival or vigour of the yam minisetts. Hot water treatment has been shown to be effective in cleaning yam tubers of fungal pathogens (R5688) and nematodes on a small experimental scale, but little if anything has been done to adapt and test this technique for use in smallhold or small-scale commercial production systems (Bridge, 1975; Adesiyan & Adeniji, 1976).

Project A0209 (NRI/IIP) is currently concerned with developing simple methods for screening yam varieties for resistance or tolerance to the main nematodes attacking yam (*Meloidogyne incognita, Scutellonema bradys*), and using these methods to screen the IITA yam germplasm collection.

Potyviruses infect yam foliage throughout the Caribbean and West Africa, often accounting for yield losses in the region of 25% (Mohammed & Mantell, 1976; Thouvenel & Dumont, 1990) . Current work (C0640, Gatsby/IITA/NRI) suggests that there are several different strains of potyvirus infecting yam in West Africa that are likely to be

transmitted in planting pieces of yam. This work is primarily laboratory based; however, the work has produced tools for detecting the diseases which could enable field-based epidemiological studies to proceed. Goudou-Urbino (In press) have looked at the distribution of some serotypes of yam mosaic potyvirus in some areas of francophone West Africa (mainly Burkina Faso). However, this has not been done in either Nigeria or Ghana. The use of thermotherapy to eliminate virus from yam pieces on a field/ commercial scale apparently has not been investigated.

In summary, current and previous research has indicated that one of the main limitations to increased productivity from yam cropping systems in West Africa is the scarcity of healthy and reliable planting material. In Ghana, there is a paucity of information available on the primary pathogens or pests causing the poor survival or growth of yams. Various methods for controlling disease have shown promise in improving yam health in many yam growing regions, for example: treating planting material (chemical, hot water, tissue culture) immediately before planting; and various agronomic practices through the growing season, at harvest or during storage that reduce the rate of infection of the tubers for planting in the subsequent season. However, the efficacy of these treatments and their acceptance to farmers in Ghana has not been investigated. Depending on the complexity and acceptability, these practices could either be used directly by the farmers and growers, or they could be used as the basis for establishing separate commercial "seed yam" production systems. Women have a major role in the purchase, selection and transport of yam planting material. For this reason it will be important to determine the impact of the information gained and the technologies developed on this group and ensure that they are not disadvantaged by the implementation of improved technologies.

2. Project Purpose

In the last ten years or so there has been a great deal of work focused on diseases of yams world-wide. The objectives of the project were to integrate the current knowledge and determine the principal diseases infecting yams in Ghana. In addition, interactions between fungal pathogens and nematodes attacking yams in the field were investigated, and their effect on the health of tubers in storage ascertained. The importance of using clean or treated planting material was determined by assessing the extent to which the diseases are tuber-borne. Based on these results and on the findings of previous projects, improved and sustainable control practices were developed and tested, and their acceptability to smallholder farmers assessed.

3 Research Activities

3.1 Nature, distribution and extent of losses caused by the principal diseases of yam in Ghana. (Activities 1& 2)

3.1.1 Nematodes, Soil-borne Fungi and Foliar Fungal Pathogens

3.1.1.1 Farm survey

One or more villages in each yam-growing district of the Ashanti, Brong-Ahafo, Northern and Upper West Regions of Ghana were selected with the aid of personnel of the Agricultural Extension Services Department of the Ministry of Food and Agriculture. Surveys were carried out during September 1996 (foliar diseases; see Annex, Section 9), July 1997 (foliar diseases and nematode incidence), January 1998 (seed tuber health; see Annex, Section 8), August 1998 (foliar diseases) and July 1999 (foliar diseases). The area surveyed covered locations within the deciduous forest, transitional agroecologies (parts of Ashanti and Brong-Ahafo Regions), and guinea savanna zones in the Northern and Upper Regions (Fig. 3.1). Generally, annual rainfall and the number of rainy days decrease

towards the north of the country, with the forest zone receiving more rain over a longer period, followed by the transitional and the savanna zones (PPMED, 1991).

Wherever possible at each village, two representative farms were visited. However, in cases where only one farm was visited because of logistical problems, another farm was selected from a nearby village. In all, 50 farms in 27 villages were sampled.

3.1.1.2 Collection and analyses of soil and tuber samples for fungi and nematodes
Soil and root samples were collected by Mr A. Missah and assessed for nematodes in the Plant Pathology Laboratory of the Savanna Agricultural Research Institute (SARI), Nyankpala, Ghana and in the Plant Health Division of CRI and the Plant Entomology/Pathology Department of UST in Kumasi, Ghana.

A composite sample of about 1.5 l of soil was collected from around the rhizosphere of yam in 30 mounds on each farm visited. The samples were sealed in polythene bags and stored at 4^{o}C. Nematodes were extracted from 50-ml aliquot of soil from each sample (Missah, In prep.) and identified to the genus level. Root samples from crop plants commonly associated with yams were collected from 18 farms in 12 villages. The crops sampled were: cassava (*Manioc esculenta*), cocoyam (*Xanthosoma sagittifolium*), cowpea (*Vigna unguiculata*), kenaf (*Hibiscus cannabinus*), maize (*Zea mays*), melon (*Curcubita pepo*), okra (*Abelmoschus esculentus*), pepper (*Cuspicum* spp.), roselle (*Hibiscus sabdariffa*), and tomato (*Lycopersicon esculentum*). Each root sample was washed in tap water to remove soil particles, and then cut into small pieces for fungal isolation and nematode extraction.

In July 1998, during the first yam harvest, permission was sought from farmers to collect two or three yam tubers, if possible from those showing visible signs of disease such as stunting, foliar lesions and chlorosis. The tubers were labelled and stored under suitable conditions in a yam barn for approximately two months. Seven-two tubers, that had not been lost due to wet rot during storage, were assessed for the presence of fungi and nematodes. *D. rotundata* varieties represented were: Pona (28), Laribako (20), Muchumudu (6), Dokoba or Lorbere (3), Kachanga (2), Pona-kon (1), Veri (1), Beni (1), Monunyua (1), Tela (1). Matches (6) and Akaba (1) were the two *D. alata* varieties. Also included was one tuber of Asobayere (*D. praehensilis*?). The samples represented 29 farms. Fungal isolation and nematode extraction procedures are described in Missah (In prep.).

In January 1998, after the main harvest, seed tubers were collected to determine the incidence of nematode and fungi. Unlike the mid-season survey, the area covered was limited to locations within the forest/savanna transition zone. Ten tubers were selected from the seed store of each of the 11 collaborating farmers. At the end of the collection phase, the tubers were stored under ambient conditions for two months in the yam barn at CRI, Kumasi. A total of 48 tubers (31 *D. alata*, 14 *D. rotundata*, and 3 *D. cayenensis*) were analysed for the presence of pathogenic nematodes and fungi (Missah, In prep.).

3.1.1.3 Geographical distribution of fungi and nematodes associated with yam in Ghana
The geographical positioning satellite (GPS) co-ordinates (longitude and latitude) of the locations sampled were obtained using a handheld GPS reader. After laboratory analyses of the samples collected from the various locations visited, points indicating the incidence of fungi and nematodes in the soil, roots of intercrops or yam tubers were plotted on a map

of Ghana (Fig. 4.1). However, for convenience, points representing only the main fungal species (*Fusarium* spp.) and parasitic nematodes (*S. bradys*, *Pratylenchus* spp. and *Meloidogyne* spp.) were plotted.

3.1.2 *Foliar fungal pathogens*

The survey team visited yam farms in the Brong-Ahafo and Northern Regions during September 1996, July and October 1997, July 1998 and July 1999. At each farm, 30 *D. rotundata* and 30 *D. alata* plants were selected in two randomly chosen blocks of 15 mounds. This was done to give some information about the spatial distribution of diseases (not presented) whilst providing some representation of disease levels in the crop. However, logistically it was easier to score yams in this manner because farmers often plant the same cultivars in blocks. Therefore, this scoring method made identifying varieties easier. Thus disease levels were attributed to the correct variety. Each plant visited was scored for type and severity of lesions. Disease severity of foliar symptoms was assessed on a seven point scoring system based on the amount of disease on the whole plant (Sweetmore, Simons & Kenward, 1994).

J Peters, O-A Danguah and F. Tsigbey collected yam and associated crop samples, from plant parts showing symptoms of fungal infection, for later analysis to determine causes of disease. Plant samples were collected in paper envelopes, dried between sheets of absorbent paper as soon as practicable. Dried samples were stored in paper envelopes until material could be analysed in the laboratories of CRI, SARI and Reading.

3.1.3 *Virus diversity and distribution*

Antisera had been produced to a number of the viruses known to infect *Dioscorea* species. Our approach to identifying which viruses were infecting yam in Ghana was to obtain as many of these antisera as possible (Table 3.1), and use them to test yam leaf samples collected from various yam-growing regions in Ghana.

Much of the field survey, sample collecting and testing was carried out by a trainee virologist, Mr Olusegun Olatunde as part of his MSc research project. Timing of survey missions had to be arranged to coincide with other survey work for the project and to fit in with the MSc programme. Thus Olusegun had one mission during June-August 1998 and a second mission during July – August 1999. The period June-August was chosen because from previous experience, this is when most of the yams should be growing well and the virus-like symptoms are most pronounced.

In 1998, Olusegun visited yam-growing areas in Volta, Eastern, Western and Brong Ahafo regions (Fig 3.1). In each area he made contact with the district agricultural/extension officer to gain access to two yam farms. At each farm, 10 leaf samples were collected from different plants exhibiting virus-like symptoms. Samples were stored in a cool-box until they could be tested using ELISA for virus at the University of Ghana, Legon, Accra. While collecting the samples from each plant, Olusegun made a note of the type and severity of symptoms present. The samples were tested using ELISA with antisera raised against seven different viruses known to infect yam (Table 3.1).

Table 3.1. Antisera used to test for viruses by Enzyme-linked-immunosorbent assay (ELISA)

Virus	virus name	Virus genus	antisera code (& source[1])	Antiserum type	ELISA format
CMV	Cucumber mosaic virus	*Cucumovirus*	CMV (IITA)	PAb	PAS
DaBV	Dioscorea alata badnavirus	*Badnavirus*	500 (HRI)	PAb	PAS
DAV (YMMV)	Dioscorea alata virus = Yam mild mosaic potyvirus	*Potyvirus*	YV1 (HRI)	PAb	PAS
DbBV	Dioscorea bulbifera badnavirus	*Badnavirus*	465 (HRI)	PAb	PAS
DdPV	Dioscorea dumetorum potyvirus	*Potyvirus*	508 (HRI)	PAb	PAS
DLV	Dioscorea latent potexvirus	*Potexvirus*	438 (HRI)	PAb	PAS
YMV	Yam mosaic potyvirus	*Potyvirus*	YMV (IITA)	PAb & MAb	TAS

[1] IITA = International Institute for Tropical Agriculture, HRI = Horticulture Research International
[2] PAb = Polyclonal antiserum, MAb = Monoclonal antiserum
[3] PAS = protein-A sandwich, TAS = triple antibody sandwich

The survey procedure was modified in 1999 such that at each farm, 25 *D. rotundata* plants selected at random during a "zig-zag" walk through the field were scored for presence, type and severity of virus-like symptoms, so that an indication of the incidence of each type of symptom was obtained. Once again, samples were collected for virus testing from 10 plants showing virus-like symptoms in each field. The Northern Region of Ghana was included, and where possible, a nearby planting of *D. alata* plants was also scored and sampled in a similar fashion. Since no samples had tested positive in ELISA with antisera to DaBV, DbBV, CMV, DDV or DLV in 1998, in 1999 samples were only tested with antisera to YMV and DAV.

During the 1999 survey, Olatunde experimented with a tissue-printing (direct-tissue-blot-immunoassay; DTBI) for detecting YMV and DAV, and compared this technique with the traditional polystyrene microplate format ELISA used throughout the surveys. Also in 1999, Dr Ed Canning visited Ghana as part of the Gatsby Charitable Foundation funded project on yam virus diagnostics, and this was used as an opportunity to compare the immunocapture-reverse transcriptase, polymerase chain reaction (IC-RT-PCR) assay for YMV with the standard ELISA and the DTBI).

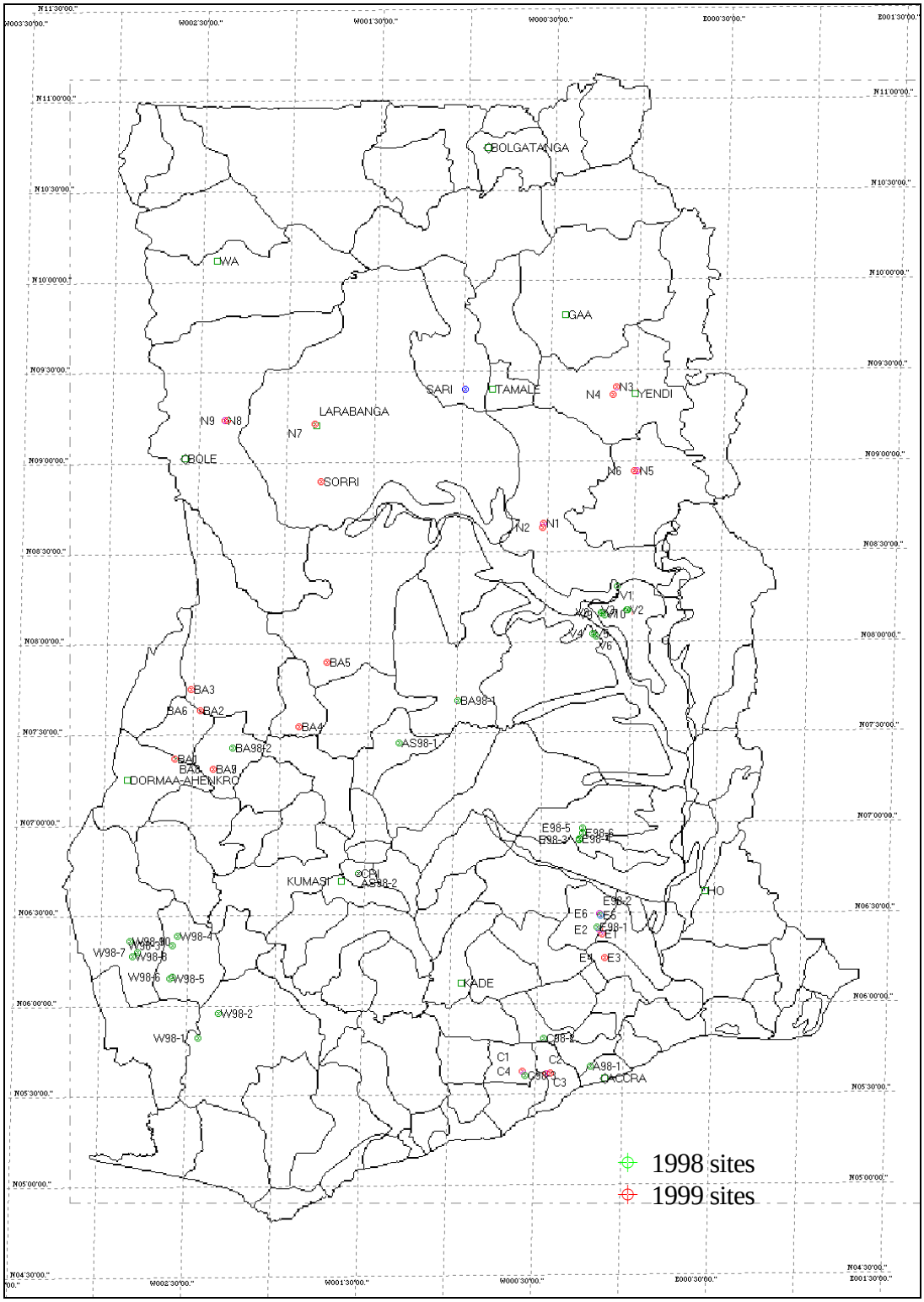

Figure 3.1 Viral survey sites in Ghana

3.2 Efficacy of various methods for treating and cleaning yam planting material and for producing clean seed yams tested under Ghanaian conditions. (Activities 3 & 4)

A dual-site (CRI in the Brong-Ahafo Region and SARI in the Northern Region) field trial was set up in May 1997 to determine the effect of seed sanitation on yam yield. Seed tubers from parent plants that had been grown on farms identified in the 1996 survey as having low disease levels, relative to other farms visited, were labelled 'Clean' seed (Table 3.2). Conversely, seed tubers from parent plants grown on farms that had been identified as having high disease levels, relative to other farms visited, were labelled 'non-clean' tubers (Table 3.2). In order to standardise the size of planting material, each seed was cut into approximately 200g pieces (setts). In addition to tuber health, a sanitation treatment consisted of a fungicide (Benlate @2g/l water used as a dip) and a nematicide (Furadan or Marshall 5G, 1g powder applied evenly around the sett in the soil) was used as a treatment to determine whether yield could be improved using chemical disease control (when compared to control setts that had no chemical applied). In the second year, in an attempt to investigate the reason for yield differences between clean and non-clean seed, treatments consisting of fungicide, nematicide and a combination of both were carried out. In the final year (1999), clean seeds were those that had been produced by a two year cycle of growing tubers from 'healthy' plants (ie those from 'clean' seed and sanitised using fungicide and nematicide). Non-clean seeds were those that had been produced from untreated plants from non-clean seed (poor germination had necessitated the purchase of new seed grown from plants identified in subsequent surveys as being heavily infected with anthracnose). Each plot consists of seed planted in a 4*8 matrix (12 test plants surrounded by 20 guard plants) using standard spacing between mounds (1600 mounds/ha or 1.2 metre apart). Each treatment was replicated 5 times and arranged in a randomised block design.

An attempt was made to ensure that the cultivar in one treatment was the same as that in the other treatment. DNA fingerprinting, using AFLP analysis was attempted by J Mignouna (IITA). Unfortunately, the DNA from collected fresh leaf samples had deteriorated during transit/storage. Direct observation revealed that what had been sold as *D. rotundata* cv 'Puna' was a mixture of four 'types': 'puna' type; 'labreko'type; 'intermediate' type and 'Puna Kona' type[1]. All *D. rotundata* treatments had an equal distribution of each type. The *D. alata* was either 'Seidu bile' in the northern regions (Northern and Upper West) or 'Matches' in Brong-Ahafo. At the time of seed collection, there was some debate as to whether the two cultivars were the same.

[1] 'Puna' type is characterised by having dark green, stiff, waxy leaves, and a single stem. 'Labreko' type has light green leaves, that are less stiff than those in the 'Puna' type, and has multiple stems. Various types exist that are intermediate between 'Puna' and 'Labreko'. 'Puna Kona' literally means "Puna with leprosy". The leaves have a typical puckering appearance. So far no pathogen has been associated with these symptoms.

Table 3.2. Source and foliar disease severities of parent plants of seed tubers used in the field trials.

Source (Village)	Region	% Mean disease severity/seed allocation (%)						Seed disease status [3]
		D. rotundata cv 'Puna' [1] (no. seed collected)	Seed allocation (%)		*D. alata* [2] (no. Seed collected)	Seed allocation (%)		
			CRI	SARI		CRI	SARI	
Boli	Northern	6.5 (382)	50	50	5.5 (137)	64	36	Low
Demon-naya	Northern	21.8 (191)	50	50	40.3 (100)	50	50	High
Gbungbalgba	Northern	17.3 (174)	40	60	19.6 (50)	0	100	High
Komoayili	Northern	3.7 (350)	50	50	7.5 (100)	50	50	Low
Mangwe	Northern	22.2 (100)	100	0	-	-	-	High
Abi #1	Brong Ahafo	3.5 (10)	50	50	11.1 (50)	50	50	High
Abi #3	Brong Ahafo	1.0 (10)	50	50	2.2 (50)	50	50	Low
Bamari	Brong Ahafo	23.5 (200)	50	50	14.8 (100)	50	50	High
Dromonkese	Brong Ahafo	3.12 (200)	50	50	16.3 (100)	50	50	Low

[1] This was a mixture of 'Puna' and 'Labreko'.
[2] In the Northern Region, the cv is known as 'Seidu bile'; in Brong-Ahafo, the cv is known as 'Matches'.
[3] Seed disease status designation is based on anthracnose severity scores during the survey of September 1996. However, high scoring *D. alata* in Dromonkese was designated as having 'low' disease status based on general health of yams on that farm.

3.3 Yam growers perceptions of yam diseases, and of their responses to new or improved control measures assessed. (Activity 5)

This study was carried out at the beginning of the yam cropping calendar (January/February 1998) when farmers had either just planted their yam seed or were preparing to plant. Not only was it considered the best period to carry out the survey because farmers would more easily be able to recall the health of their seed from the last season's harvest but their responses could be compared with disease scoring of seed carried out by the scientists. Data collection was undertaken by two teams of researchers, one in the Northern Region[2] and one in the Brong Ahafo Region.

The majority of the villages selected for the survey were those which had participated in the previous socio-economic and disease prevalence survey work carried out in 1996 (see Annex, Section 9). The three yam producing regions (Brong-Ahafo, Northern and Upper West) were selected on the basis of being major yam producing areas: Brong-Ahafo and Northern regions typically produce around 75% of yams grown in Ghana. However, some important regions (Eastern and Volta) were left out of the survey for logistical reasons. Village selection was done by the extension officers. Officers were asked to recommend villages where yam cultivation was practised. There is no reason to believe that selection was skewed towards either end of the production/wealth scale. The locations of the villages visited are shown in the survey report (Annex, Section 8). Group meetings were held in each village involving a number of farmers ranging from 7 to 15. In most villages the extension officers arranged the meetings with yam farmers, but in a couple of villages a group of farmers was formed on arrival in the village.

[2] Two of the fourteen surveyed villages which are referred to in this report as the Northern Region villages are actually in the Upper West Region. However, in order to simplify analysis the 2 Upper West villages have been grouped along with the Northern Region villages.

A rapid rural appraisal (RRA) approach was taken which involved group discussions and ranking exercises. A checklist was used to guide the discussions (see Survey Report, Annex, Section 8) although this outline was modified slightly during the course of the survey. Individual farmers were asked about the amount of yam they grew (previous year, present year and reasons for any changes). The group was then asked to name their main yam production and marketing problems. These were written and drawn on pieces of card and the group were then asked to rank them according to importance (1. most important, 2. second most important etc.). Farmers were then asked to discuss yam pests and diseases. Local names of the pests and diseases mentioned by farmers were used which meant it was possible to understand if farmers were referring to different diseases as the same thing (e.g. farmers often thought mealybugs and scale insects were the same). Farmers were asked as a group to rank the pests and diseases in terms of importance. They were then asked about the sources of the various pests and diseases, any control methods they use or know of, which varieties they affect and any changes in disease prevalence over the last five years.
This was followed by a discussion about yam seed. Farmers were asked about their sources of seed and their seed selection criteria. They were also asked about the different seed preparation methods they use (i.e. pricked at first harvest, buried small wares at first harvest etc.) and these different methods were drawn on cards.

3.4 Transfer of new or improved control strategies to yam growers. (Activity 6)

Approximately 100 farmers, extension staff and an NGO representative (CAPSARD) participated in two field visits at SARI/MoFA, Tamale in October 1999. During the morning, farmers and extension staff were shown short presentations in the MoFA conference facility (in English and translated into their local languages) on the main findings of ZA0138. Participants were also provided with information leaflets (Peters *et al*, 1999; Annex 5). After the presentations, participants were transferred to SARI in order to see the field trials and discuss the relevant findings.

4 Outputs

4.1 Nature, distribution and extent of losses caused by the principal diseases of yam in Ghana (Outputs 1).

4.1.1 *Nematodes and Soil-borne Fungi*

The incidence of fungi and parasitic nematodes found in soil samples from yam farms are presented in Table 4.1. The predominant fungi found in soils at the survey locations were *Aspergillus* spp., *Rhizopus* spp., *Penicillium* sp. and *Trichoderma* sp.. *Rhizoctonia solani*, a cause of die back in yams, was present in a surprisingly high proportion (12%) of farms visited. Other pathogens such as *Fusarium* spp. and *Curvularia* sp. were isolated to a lesser degree.

Five genera of nematodes that are known to be pathogenic on yams were identified in soil samples from around yam roots: *Scutellonema*, *Pratylenchus*, *Meloidogyne*, *Helicotylenchus* and *Rotylenchulus* (Table 4.1). Apart from *R. reniformis*, all the species were found in over 50% of the locations visited, with *Helicotylenchus* sp. being the most widespread. Other parasitic nematodes found in the soil samples included *S. clathricaudatum*, *Paratrichodorus minor*, *Rotylenchus* sp. and *Xiphinema* sp. The mean nematode population numbers in a 100-ml aliquot of soil ranged from 1.9 (*Meloidogyne* spp.) to 5.9 (*Helicotylenchus* sp.).

4.1.1.1 Fungi and nematodes from roots of intercrops

Nine species of fungi were isolated from the roots of intercrops commonly associated with yams in Ghana (Table 4.2). *Fusarium* spp. were by far the commonest, being associated with all 10 species of intercrops sampled and were isolated from 96% of all samples assessed. All five pathogenic genera of nematodes were associated with three or more intercrops (Table 4.2).

Table 4.1. Incidence of fungi and parasitic nematodes, and nematode population numbers in soils from yam mounds in Ghana

Fungi/nematode species	Incidence (%)[1]	Nematodes/100 ml soil
Fungi		
Aspergillus spp.	92	
Rhizopus spp.	58	
Penicillium spp.	10	
Trichoderma sp.	14	
Rhizoctonia solani	12	
Fusarium sp.	4	
Curvularia sp.	2	
Nematodes		
Helicotylenchus sp.	74	5.9
Pratylenchus spp.	62	2.9
Scutellonema bradys	58	3.9
Meloidogyne spp.	56	1.9
Rotylenchulus reniformis	34	2.3

Table 4.2. Fungi and parasitic nematodes associated with intercrops commonly associated with yams in Ghana

Fungi/nematode species	Host	[1]Incidence (%)
Fungi		
Fusarium spp.	Cassava, cocoyam, cowpea, pepper, tomato, kenaf, maize, melon, okra, roselle	96
Aspergillus sp.	Cassava, okra, tomato	22
Curvularia spp.	Cassava, maize	7
Nigrospora oryzae	Maize	4
Botryodiplodia theobromae	Okra	4
Stachybotrys sp.	Okra	4
Phomopsis sp.	Okra	4
Penicillium sp.	Okra	4
Nematodes		
Pratylenchus spp.	Cassava, maize, okra, cowpea, pepper	26
Meloidogyne spp.	Maize, pepper, okra, tomato	15
Scutellonema bradys	Cassava, okra, roselle	11
Helicotylenchus sp.	Okra, pepper, roselle	11
Rotylenchulus sp.	Cassava, okra, roselle	11

[1]Data based on 27 root samples from 18 farms in 12 villages at the time of first yam harvest (July)

4.1.1.2 Fungi and nematodes associated with early harvested yam tubers

Thirteen genera of fungi were isolated from early harvested (July 1997) yam tuber samples (Table 4.3). Species of *Fusarium* (*F. solani*, *F. equiseti*, *F. moniliforme*, and *F. oxysporum*) were the most commonly isolated fungi from yam tubers. These were present in 74% of tubers and 90% of locations sampled. More specifically, *F. solani* was obtained from 68% of tubers and 90% of farms, making it the most prevalent fungal species associated with yam tubers. All the fungal genera isolated were associated with the periderm. But, some fungi (particularly *Fusarium* spp. and *Penicillium* spp.) were isolated from the tuber periderm and, to a lesser degree, from the inner storage parenchymal tissues. Under specific conditions (see Section) these fungi might be able to invade rot-susceptible tissues. However, in generally, isolated fungi were not associated with symptoms of rotting or foliar lesions.

The incidence and mean population of parasitic nematodes extracted from early harvested tubers of different yam varieties are presented in Table 4.4. Three nematode genera were extracted from yam tubers: *Scutellonema bradys*, *Pratylenchus* sp. and *Meloidogyne* sp.. *Scutellonema bradys* was by far the most commonly found pathogenic nematode affecting yam (it was extracted from 36% of all tubers with mean populations of 75.5 to 1221.8 nematodes/5 g peel). *Meloidogyne* spp. was the least commonly extracted nematode (being found in 6% of tubers with mean populations of 1 to 15 nematodes/5 g peel). Multiple infestation of tubers by the two migratory endoparasitic nematodes, *S. bradys* and *Pratylenchus* spp., was observed in 21.9% of samples. Wherever this occurred, the population of *S. bradys* generally exceeded that of *Pratylenchus* spp.. In 28.8% of tubers, those invaded by *Fusarium* spp. were also infested by either *S. bradys* and *Pratylenchus* spp or both.

Fig 4.1 shows the geographical distribution of farms sampled during the early harvest survey with pictograms representing the presence of the important yam nematodes and

Fusarium spp.. The three main pathogenic nematode genera (*Scutellonema, Pratylenchus* and *Meloidogyne*) were ubiquitous throughout the regions sampled. There was no obvious geographical factor influencing their distribution. However, *Fusarium* spp. were found in all locations except from tubers on farms in the Upper West Region.

Table 4.3. Incidence of fungi in early harvested tuber tissues in the Northern and Brong-Ahafo Regions, Ghana.

Fungal species	Incidence (%)		
	Tubers[1]		Farms[2]
	Periderm	Cortex	Sampled
Fusarium solani	68.5	13.7	89.7
Fusarium spp.	74.0	17.8	89.7
Aspergillus spp.	21.9	4.1	79.3
Penicillium sp.	39.7	26.0	72.4
Botryodiplodia theobromae	26.0	4.1	48.3
Acremonium strictum	13.7	1.4	24.1
Rhizoctonia solani	4.1	0.0	6.9
Rhizopus sp.	2.7	0.0	6.9
Nigrospora oryzae	2.7	2.7	6.9
Sclerotinia bataticola	4.1	0.0	10.3
Phomopsis sp.	1.4	0.0	3.4
Cladosporium herbarum	2.7	0.0	6.9
Pestalotia sp.	1.4	0.0	3.4
Ascochyta sp.	1.4	1.4	3.4

[1]Incidence in 72 tubers following a 2-month storage under ambient conditions in a yam barn.
[2]Incidence in 50 farms sampled.

Table 4.4. Incidence and mean population (/5 g tuber peel) of parasitic nematodes in early harvested yam tubers sampled in the Northern and Brong-Ahafo Regions, Ghana.

Nematode species	Incidence (%)[1]		Nematodes/5 g peels
	Tubers	Farms sampled	
Scutellonema bradys	35.6	58.6	411
Pratylenchus spp.	24.7	37.9	22
Meloidogyne spp	5.5	13.8	8

[1]Mean from 72 yam tubers from 29 farms.

4.1.1.3 Fungi and nematodes associated with late harvested yams in the Northern and Brong-Ahafo Regions of Ghana.

A limited sample of 24 yam tubers, showing symptoms of anthracnose, was collected from yam farms and experimental plots during October 1997 and 1998. Table 4.5 presents the main pathogens isolated from the tubers. It is difficult to draw conclusions from a small sample. However, some general observations can be made. Unlike the tubers collected

earlier in the season, *Colletotrichum gloeosporioides* was isolated from some (17%) of the late season tubers. *Fusarium* sp. (including *solani* and *oxysporum*) was present in the majority of both early- and late- harvested tubers (90% and 100% respectively). The incidence of *Scutellonema bradys* (and or *Pratylenchus* spp.) scarcely differed between the early- and late- harvested tubers (36% and 33% respectively). Therefore, a likely explanation for the patterns observed is that soil-borne pathogens (nematodes and fungi) may be present in tubers from the moment of tuber initiation onwards. However, in the case of tuber-borne diseases, pathogens such as *C. gloeosporioides* need to build up inoculum on the host foliage before invading tuber tissue. This implies that only foliage with high disease levels will produce tubers infected *with C. gloeosporioides*. Indeed, the tubers that were found to be infected with *C. gloeosporioides* were those collected from plants with anthracnose severity exceeding 50%.

Table 4.5. Incidence of fungi and nematodes in late harvested tuber tissues in Ghana

Pathogens isolated	% Incidence[1]
Fusarium spp	100
Bacteria	50
Penicillium sp.	50
B. theobromeae	46
Aspergillus sp.	38
Scutellonema/Pratylenchus	33
Sclerotium rolfsii and/or Macrophomina phaseolina)	25
Rhizoctonia Solani	25
Colletotrichum gloeosporoiodes	17
Phoma sp.	13
Rhizopus sp.	13
Phomopsis sp.	8
Alternaria sp.	8
Corynespora sp.	4
Curvularia sp.	4
Geotrichum sp.	4

[1] 24 tubers sampled

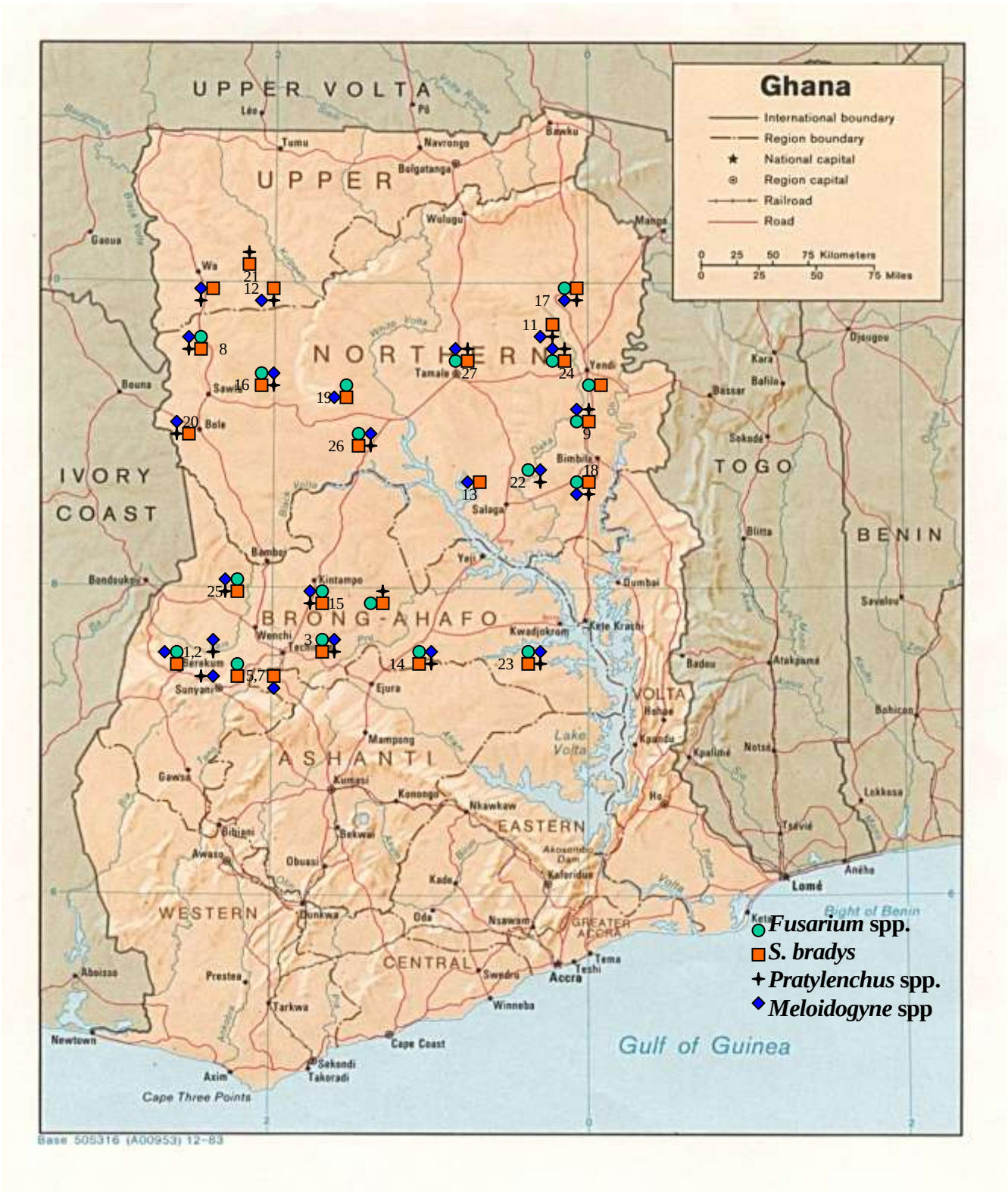

Figure 4.1 Locations sampled and presence of *Fusarium* spp., and nematodes in soils, roots of intercrops or yam tubers. (1,2,3,…27 represent location identification number)

4.1.2 Foliar Fungal Diseases

4.1.2.1 Pathogens associated with foliar lesions

The causal agent of anthracnose, *Colletotrichum gloeosporioides*, was isolated from yam leaves with foliar lesions (anthracnose and other leaf spots) in over 96% of all locations (Table 4.6). The pathogen was also isolated from asymptomatic tissue. This suggests that the pathogen, as well as being the primary cause of anthracnose, might exist as an endophyte in yam tissue. The pathogens, *Colletotrichum capsici*, *Phoma* sp., *Curvularia* spp., *Cercospora apii* and *Fusarium* spp., were found in over 50% of yam lesions. These pathogens, along with *C. gloeosporioides*, are generally regarded as pathogens associated with the anthracnose 'complex'. However, *Curvularia* spp., *Phoma* sp. and *Cercospora apii* were also associated with leaf symptoms that were distinct from anthracnose (see 'yam pest and diseases posters', Annex, Section 6). However, the non-anthracnose-type lesions accounted for an extremely small proportion of the lesions found on yams throughout Ghana (Table 4.7) and were not considered by the author to be the cause of significant yield loss. Also, die-back, associated with the anthracnose complex of pathogens (see Annex, Section 6), was regarded as 'anthracnose' for the purposes of the disease survey. Other forms of die-back were present in the survey area. These were found to be associated with *Fusarium* spp. and *Rhizoctonia solani*. Typically, infected plants become necrotic from the base upwards (in contrast to the anthracnose-type where plants become necrotic from the shoot tips downwards). Affected tissues have a light brown, necrotic appearance. Infection usually results in the complete death of the plant. However, the incidence of the non-anthracnose type of die-back was low and was not recorded at any of the survey fields.

Table 4.6. Pathogens Isolated from Yam Foliar Lesions . Incidence (%) was calculated from the presence or absence of each pathogen from two or more leaf samples (of the same cultivar and symptom type) per field. A total of 158 yam fields were sampled during the surveys carried out between 1996-98 throughout the major yam growing regions in Ghana.

Pathogens Isolated	% Incidence
Colletotrichum gloeosporioides	96.8
Curvularia spp.	75.9
Colletotrichum capsici	73.4
Phoma spp.	65.2
Phomopsis spp.	65.2
Fusarium spp.	62.0
Cercospora apii[1]	52.1
Botryodiplodia theobromae	38.6
Macrophomina phaseolina	20.3
Nigrospora spp.	18.4
Phyllosticta dioscoreae	17.7
Mycovellosiella dioscoreae[1]	14.1
Pestalotiopsis spp.	12.7
Cladosporium spp.	10.8
Corynespora sp.	10.1
Rhizoctonia solani	10.1
Alternaria sp.	9.5
Drechslera sp	7.6
Pseudocercospora sp.[1]	4.9
Periconia sp.	4.4
Stemphylium sp	4.4
Bipolaris sp	3.2
Colletotrichum sp.	3.2
Geotrichum sp	3.2
Exserohilum spp.	1.9
Rhizopus sp.	1.9
Sclerotium rolfsii	1.9
Aspergillus spp.	1.3
Chaetospermum sp	1.3
Diplodia sp	1.3
Myrothecium sp	1.3
Phytophthora sp	1.3
Cercosporella sp[1], *Ascochyta sp, Cheatomum sp, Dactylaria* sp., *Microsporium* sp., *Monocheata* sp., *Nematospora* sp., *Penicillium* spp. *Pleospora* sp., *Sclerotinia* sp., *Septoria* sp., *Trichoderma* sp.	<1.0

[1] Incidence calculated using data collected over 142 yam fields

4.1.2.2 Distribution and extent of anthracnose damage

Anthracnose was ubiquitous throughout the yam growing regions surveyed (Tables 4.7 & 4.8). However, during 1997 and 1998, 2 out of 37 farms and 2 out of 17 farms, respectively, disease severity was sufficient to cause estimated economic losses of 50% or more. However for the majority of farms fewer than 10% of trials or sites showed a certain minimum yield loss. These estimates are based on field trial data (at the SARI site) where yield (averaged over two adjacent plants) was plotted against anthracnose mean severity at the time of tuber bulking (July) (Fig 4.2). In general, anthracnose severity was lower in 1997. This was probably due to the late rainy season in that year which may have delayed the disease epidemic.

Table 4.7. Severity (% means of 30 plants) of anthracnose and other foliar diseases, and estimated yield losses due to disease[3] in *D. rotundata* var Puna/Labreko on 37 farms in the Northern (farms 1-29) and Brong-Ahafo (farms 30-37) Regions, Ghana. Survey carried out during early- and late- season 1997 (July/August and October).

Latitude	Longitude	Farm No	Village name	Mean severity (July)	Mean severity (October)	Estimated yield loss[3] (based on July data)
9 45 39N	0 25 21W	1	Gaa	1.1	10.5	<5
9 48 27N	0 25 17W	2	Gaa	0.2	5.2	<5
		2	Gaa	0.2[1]	-	-
9 50 14N	0 22 14W	3	Komoayili	3.3	-	11
9 50 50N	0 22 58W	4	Komoayili	4.8	45.8	19
9 20 59N	0 0 18W	5	Gbungbalgba	1.3	13.5	<5
9 22 01N	0 00 37W	6	Gbungbalgba	1.4	53.6	<5
9 23 22N	0 08 10W	7	Sambu	0.7	23.4	<5
		7	Sambu	0.2[1]	-	-
9 24 17N	0 07 19W	8	Sambu	0.5	15.0	<5
9 12 40N	1 50 34W	9	Larabanga	1.7	27.3	<5
		9	Larabanga	5.0	-	26
9 12 04N	1 49 42W	10	Larabanga	0.9	-	<5
9 02 13N	2 34 11W	11	Mandari	1.5	7.4	<5
9 01 32N	2 32 42W	12	Mandari	0.4	-	<5
9 14 03N	2 21 09W	13	Jentilpe 1	1.1	13.0	<5
9 14 17N	2 20 25W	14	Jentilpe	1.0	14.6	<5
9 55 23N	2 21 45W	15	Boli	5.0	34.1	26
9 57 37N	2 24 04W	16	Boli	1.1	22.1	<5
9 56 01N	2 16 27W	17	Goripie	2.8	-	<5
9 57 45N	2 18 03W	18	Mangwe	3.9	22.9	18
9 30 52N	2 25 59W	19	Dafierli	3.3	-	11
9 31 11N	2 25 38W	20	Dafierli	1.3	-	<5
8 53 30N	1 48 00W	21	Sorri #2	0.5	43.1	<5
8 55 52N	1 47 44W	22	Sorri #2	0.4	11.5	<5
8 37 40N	0 31 20W	23	Masaaka	0.7	-	<5
8 39 16N	0 31 14W	24	Masaaka	0.8	-	<5
8 48 26N	0 01 28W	25	Kpalsogo	0.7	-	<5
8 56 25N	0 00 20W	26	Demon Nya	0.8	38.8	<5
8 56 34N	0 00 39E	27	Demon Nya	1.5	10.2	<5
9 22 00 N	0 58 44W	28	Tuniyili #1	0.5	14.5	<5
9 22 29N	0 58 30W	29	Tuniyili #2	17.4	>75	72
		30	Dromonkese	2.0	-	<5
		31	Dromonkese #2	1.3	-	<5
		32	Bamiri	3.0	-	10
		33	Bamiri	35.0	-	>80
		34	Jema	2.5	-	<5
		35	Jema	1.3	-	<5
		36	Kokrompe	2.0	-	<5
		37	Hiawoanwu	1.4	-	<5

[1] Lesions caused by *Phoma*/*Curvularia* complex**.**

[3] Estimated from the SARI 1997-98 field trial. See Fig 4.2 for regression where yield is correlated against anthracnose severity (each data point represents the mean of two adjacent plants). The correlation is not absolute because other factors (such as nematode infestation and virus infection) are also influencing yield.

Table 4.8. Anthracnose severity (means of 30 plants) and estimated yield loss due to anthracnose[4] in *D. rotundata* cv Puna/Labreko on 17 farms in the Northern Region, Ghana. Survey carried out during mid-season (August 1998).

Location	Cultivar	Mean severity (%)	Estimated yield loss (%)[3]
Boli	Puna	1.05	<5
Boli	Labreko	1.56	<5
Boli(2)	Puna	2.19	<5
Boli(2)	Labreko	5.07	26
Dafierli (1)	Labreko	3.14	18
Demon Nya	Labreko	0.22	<5
Gaa #1	Labreko	6.34	37
Gbungbalgba	Puna	1.27	<5
Goripie (Mangwe)	Labreko	1.82	<5
Jentilpe	Labreko	1.58	<5
Jentilpe (2)	Labreko	2.88	<5
Larabanga (1)	Puna	0.93	<5
Larabanga (1)	Labreko	9.77	50
Mangwe	Labreko	23.38	>80
Masaka #1	Labreko	0.00	<5
Masaka #2	Labreko	0.15	<5
Sorri #2 (1)	Puna	16.39	76
Sorri #2 (1)	Puna	6.50	37
Sorri #2 (2)	Puna	0.20	<5
Tuniyili #1	Puna	3.44	18
Tuniyili #2	Labreko	3.41	18
Tuniyili #2	Puna	1.21	<5

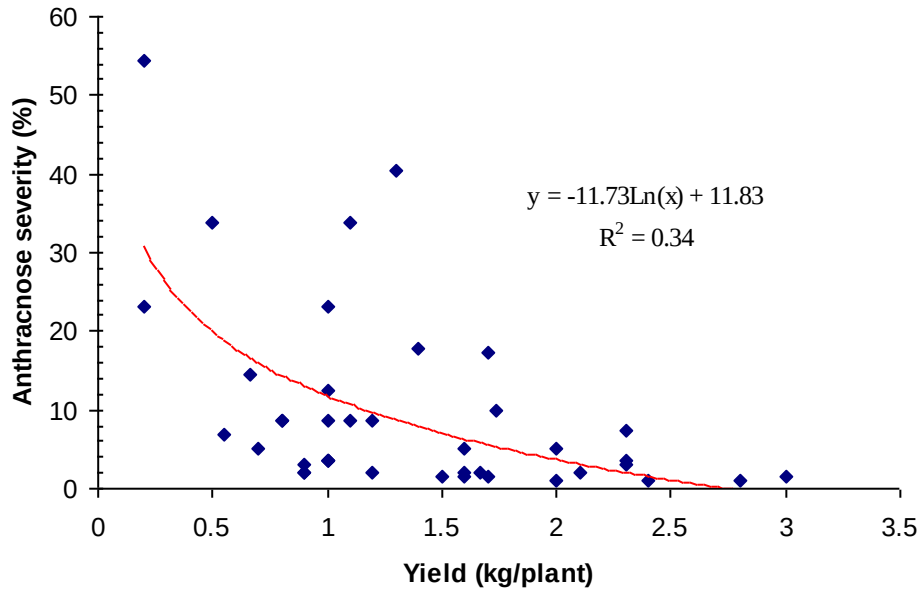

Figure 4.2 Yield (kg/plant, mean of two adjacent plants) of *D. rotundata* var Puna plotted against anthracnose severity (mean of four adjacent untreated plants). Data collected on untreated SARI plots during August 1997. [5]

[4] Estimated from the SARI 1997-98 field trial. See Fig 4.2 for regression where yield is correlated against anthracnose severity (each data point represents the mean of four adjacent plants). The correlation is not absolute because other factors (such as nematode infestation and virus infection) might also be influencing yield.

[5] This regression will vary with the scaling of disease severity and when disease occurred in relation to the growth stage of the crop, amongst other factors.

4.1.2.3 Sources of pathogen inoculum

Yam anthracnose was found in almost all the yam fields during mid-season (July/August) and was found in all yam fields by late season (September). The amount of anthracnose present on a crop varied considerably between farms. Variation in anthracnose severity might be related to climate variation between locations but this is unlikely to explain the differences seen (adjacent farms were found to have varying amounts of anthracnose on the same varieties). Interestingly, a positive correlation was found when anthracnose severity on *D. rotundata* cv Labreko is plotted against severity on the same variety and farm in the following season, provided that seed planted in 1998 had been derived from the previous crop (Fig 4.3). However, correlation does not necessarily imply causation. So although Fig 4.3 strongly suggests that planting material might be the most important source of pathogen inoculum, other site-specific factors (such as intercropping practices on each particular farm) could also account for the observed pattern. Interestingly, although *C. gloeosporioides*, pathogenic on yam, were isolated from many non-yam hosts in Barbados (Peters, 1996), there was no obvious association between the pathogen on yam and intercrops in Ghana.

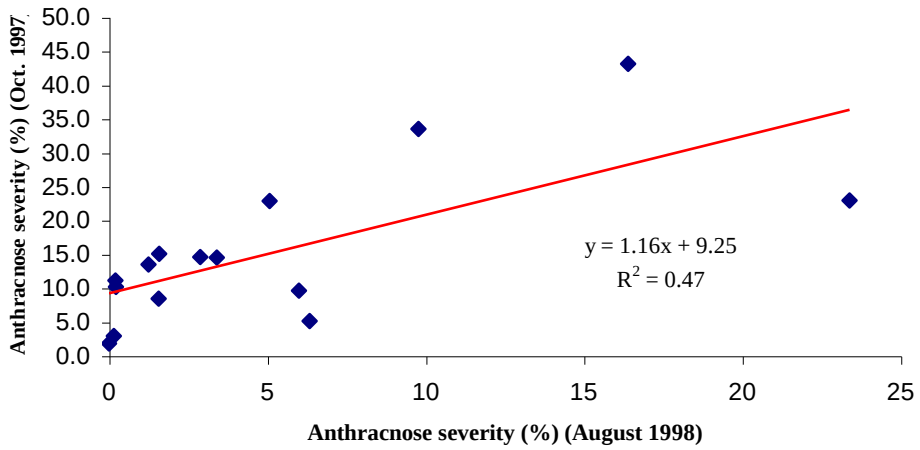

Figure 4.3 Anthracnose severity on white yam (*D. rotundata* var Labreko) during August 1998 plotted against anthracnose severity during July 1997. Farms were only considered if the planting material used in the 1998 crop was derived from the 1997 crop.

4.1.3 *Viruses (Authors L Kenyon & J Hughes) (See Full Report, Annex, Section 7)*

An initial analysis of the results of the virology component of the project was presented as an MSc thesis (Olatunde, 1999).

4.1.3.1 1998 survey results

The survey results for 1998 were analysed and presented as a poster at the ISTRC-AB meeting in Benin Republic 11-17 October 1998 (see Annex, Section 7)

4.1.3.2 1999 *D. rotundata* survey results

During the field surveys, ten distinct symptom types of a virus-like nature were identified in different plants (Table 4.9), and some plants presented with a combination of symptoms.

Table 4.9. Virus-like symptoms observed in yam plants in Ghana

	Symptom code	Symptom detail
1	-	No symptoms
2	(ck)	Leaf crinkle
3	(dgvb)	Dark green vein banding
4	(lc)	Leaf chlorosis
5	(ld)	Leaf distortion
6	(lvc)	Leaf vein clearing/chlorosis
7	(mos)	Mosaic
8	(mot)	Mottle
9	(shst)	Shoe-string distortion
10	(stu)	Stunting
11	(ys)	Yellow spots

In 1999, a total of 769 *D. rotundata* plants were assessed for virus-like symptoms in locations across Ghana. Mosaic was the most common symptom being observed in 351 (45.6%) of the plants, though this proportion was not the same in all regions surveyed (Table 4.10). A further 288 plants had a variety of other symptoms of a virus-like nature; a number of plants exhibited more than one symptom type and the second most common single symptom type was a general leaf chlorosis (130 plants). The range and incidence of symptom types and combinations of symptoms was location specific, though there was less variation within regions. For example, a high proportion of the plants assessed in the Northern region had leaf chlorosis without any other symptom, while in Brong Ahafo mosaic tended to predominate (Table 4.10). From the whole sample, only 130 plants (16.9%) showed no virus-like symptoms at all (4.11).

Table 4.10. Distribution of symptom types seen on plants of *D. rotundata* in different regions of Ghana in 1999

Symptoms[a]	Brong-Ahafo	Central & Accra	Eastern	Northern	Ashanti	All
(mos)(ck)	2 (1)[b]	4 (2)	1	9	1 (1)	**17 (4)**
(mos)(ck)(dgvb)(stu)	7 (3)					**7 (3)**
(mos)(ck)(ld)				10 (1)		**10 (1)**
(mos)(ck)(lvc)			1			**1**
(mos)(ld)	4 (3)			2 (2)		**6 (5)**
(mos)(lvc)		1				**1**
(mos)(lvc)(ys)		1				**1**
(mos)(shst)	4			1 (1)		**5 (1)**
(mos)(stu)	14 (3)			4 (1)		**18 (4)**
(mos)-	137 (20)	42 (11)	51 (14)	35 (15)	20 (17)	**285 (77)**
(ck)		4 (1)		3	1	**8 (1)**
(lc)				130 (5)		**130 (5)**
(ld)				2		**2**
(lvc)	10 (3)		2	11		**23 (3)**
(mot)	15 (7)	6 (2)	14 (2)	5 (2)	7 (7)	**47 (20)**
(mot)(shst)	1 (1)					**1 (1)**
(shst)				1		**1**
(ys)	14	13	26 (1)	23		**76 (1)**
No virus-like symptoms	27 (1)	29	30	41	3	**130 (1)**
	235 (42)	**100 (16)**	**125 (17)**	**277 (27)**	**32 (25)**	**769 (127)**

[a] See 4.7 for key to symptom types

[b] Figures in brackets are the number of plants testing positive for YMV by ELISA

Table 4.11. Distribution of virus-like symptoms across the different *D. rotundata* cultivars

Symptoms[1]	Asana	Asobayere	Asua	Bipa	Blass	Chenchito	Dorbai	Kpasi	Labreko	Lili	Ntoto	Puna	Punakwa	Tila	Yorubas	Total
(mos)(ck)					3		2		1		1	5	5			**17**
(mos)(ck)(dgvb)(stu)							7									**7**
(mos)(ck)(ld)												4	6			**10**
(mos)(ck)(lvc)									1							**1**
(mos)(ld)							1		1	1		3				**6**
(mos)(lvc)					1											**1**
(mos)(lvc)(ys)					1											**1**
(mos)(shst)		3								1		1				**5**
(mos)(stu)		13							1	1		3				**18**
(mos)-	8	50	20	4	11		30	2	31	5	31	81	1	10	1	**285**
(ck)					4							2	2			**8**
(lc)									43			75	12			**130**
(ld)						1						1				**2**
(lvc)	1		1						7	2		12				**23**
(mot)	1				3		7	4	5	3	3	20	1			**47**
(mot)(shst)										1						**1**
(shst)						1										**1**
(ys)	17		2		11	4	3	1	10		2	22	1	3		**76**
No virus-like symptoms	23	1	2		16		19	2	15	5	13	31	1	2		**130**
Total	**50**	**67**	**25**	**4**	**50**	**6**	**69**	**9**	**115**	**19**	**50**	**260**	**29**	**15**	**1**	**769**

[1] See 4.9 for key to symptom codes.

4.1.3.3 Plants surveyed in 1999

Samples from 211 of the plants were tested by TAS-ELISA for YMV. Of these, 127 (60%) gave a positive reaction, and a high proportion of these positive reactions were for plants exhibiting either mosaic (95 plants) or mottle (21 plants). Mosaic and mottle were difficult to distinguish between and hence were never seen together in the same plant (4.12). Chi-square analysis was used to test the association between symptoms and infection with YMV as determined by ELISA. There were strong positive associations between mosaic, mosaic and other virus-like symptoms, mottle, or mottle and other virus-like symptoms, and infection. Only one plant out of 22 with no virus-like symptoms tested positive for YMV, and similarly, only five of 27 plants with generalised leaf chlorosis (lc) tested positive; a negative association. Generally, yellow leaf spots (ys) or leaf vein chlorosis/clearing (lvc) were observed on leaves that did not exhibit any other symptom; either these symptoms are masked by the other symptoms, or their cause is inhibited by the causes of the other symptoms. These symptoms also exhibited a negative association with YMV infection. Leaf crinkle (ck) usually occurred in combination with mosaic, but was not associated with YMV infection. There were too few plants with shoe-string (shst) or dark-green-vein-banding (dgvb), stunting (stu), or leaf distortion (ld) tested to show any association between these symptoms and any of the other symptoms or positive ELISA reactions.

Three *D. rotundata* cv "Puna" plants were positive for DAV by ELISA, though these were all plants in trials at Crops Research Institute, Kumasi, and the original setts had been brought in from elsewhere.

Table 4.12. Association between symptom types in *D. rotundata* and infection with YMV as determined by ELISA

	Number of plants					
			Tested by ELISA			
Symptoms[a]	Total with symptom	Not tested	YMV positive (+)	YMV negative (-)	% YMV +	χ^2 probability[b]
(mos)(ck)	17	10	4	3	57.14	
(mos)(ck)(dgvb)(stu)	7	4	3	0	100	
(mos)(ck)(ld)	10	7	1	2	33.33	
(mos)(ck)(lvc)	1	0	0	1	0	
(mos)(ld)	6	1	5	0	100	
(mos)(lvc)	1	0	0	1	0	
(mos)(lvc)(ys)	1	1	0	0		
(mos)(shst)	5	2	1	2	33.33	
(mos)(stu)	18	14	4	0	100	
(mos)	285	194	77	14	84.61	2.76E-10
(mos)+	351	233	95	23	80.50	1.11E-11
(ck)	8	5	1	2	33.33	
(ck)+	43	26	9	8	52.94	0.524
(lc)	130	103	5	22	18.51	neg
(ld)	2	1	0	1	0	
(lvc)	23	14	3	6	33.33	neg
(lvc)+	26	15	3	8	27.27	neg
(mot)	47	27	20	0	100	+++
(mot)(shst)	1	0	1	0	100	
(mot)+	48	27	21	0	100	+++
(shst)	1	1	0	0		
(ys)	76	66	1	9	10	neg
No virus-like symptoms	130	108	1	21	4.54	
Total	769	558	127	84	60.19	

[a] See 4.9 for key to symptoms (where a symptom type is followed by "+" the plants had that symptom in combination with any other virus-like symptom)

[b] Chi-squared probability that the observed ratio of YMV positive to YMV negative plants in the symptom group is the same as for the whole sample (the smaller this number is, the more likely it is that the ratio is different compared to the whole sample; "neg" is used where the observed ratio is the reverse of the expected, +++ positive but chi test not applicable since 100% of plants test positive.).

When severity of mosaic symptoms was considered, it was found that all of the plants tested by ELISA that were scored very severe (vs) for mosaic had detectable YMV (Table 4.11).

Table 4.13. Association of very severe mosaic symptoms with infection with YMV as determined by ELISA

mosaic severity	Total assessed	Not tested	YMV+ (by ELISA)	YMV- (by ELISA)
Mild (m)	61	41	12	8
Severe (s)	221	138	68	15
Very severe (vs)	69	54	15	0
Mottle (no mosaic)	48	27	21	0
No mosaic	370	298	11	61

Only 11 of the 639 *D. rotundata* plants assessed to have virus-like symptoms did not have symptoms on the older leaves. Infection in these plants is more likely to have taken place through the activity of a vector.

Twenty-nine plants of *D. rotundata* and 13 *D. alata* with virus-like symptoms were tested for YMV by IC-RT-PCR, TAS-ELISA and DTBI. IC-RT-PCR was as sensitive as TAS-ELISA and DTBI for detecting YMV in 25 of the *D. rotundata* plants. It also detected YMV in one plant of *D. alata* that was not detected by either ELISA or DTBI.

4.1.3.4 1999 *Dioscorea alata* results

Over 470 *D. alata* plants were assessed in 1999, and approximately half of these had virus-like symptoms similar to those observed in *D. rotundata* plants (Table 4.13). As with *D. rotundata*, mottle and mosaic were difficult to distinguish between and so were never seen together in the same plant. Mosaic was the most common virus-like symptom. Since only eight out of 86 plants tested positive for DAV by ELISA (Table 4.14, last column) few statistically valid inferences can be made. However, all the plants that tested positive for DAV came from Eastern Region, had either mosaic or mottle symptoms and were either cv Akaba or Seidu-bile.

Table 4.14. Distribution of symptom types seen on plants of *D. alata* in different regions of Ghana in 1999

Symptom[a]	Ashanti	Brong-Ahafo	Central Accra	Eastern	Northern	Total	DAV ELISA[b]
(mos)(ck)		2		15 (2)	2	19	2/8
(mos)(ck)(stu)		1				1	
(mos)(ck)(lvc)	1					0	0/1
(mos)(ld)		1				1	
(mos)(lvc)				2	1	3	0/1
(mos)-		49	22	59 (4)	22	152	4/43
(mos)+	1	53	22	76 (6)	25	176	6/53
(ck)				3	1	4	0/2
(ck)(ys)	1					0	0/1
(ck)+	2	3	0	18 (2)	3	26	2/12
(dgvb)		2	7	1		10	0/5
(lc)			6		4	10	0/3
(lvc)	3	4	11		13	28	0/6
(mlo)		1				1	0/1
(mot)				4 (2)		4	2/2
(ys)	1	5		1	2	8	0/3
-	4	60	4	65	104	233	0/18
Total	10	125	50	150 (8)	149	474	8/86

[a] See 4.9 for key to symptom types
[b] Number of samples testing positive for DAV by ELISA over number of samples tested

4.1.3.5 Conclusions and discussion

The virology component of the project was associated primarily with outputs 1 and 2.
The observed high proportion of plants bearing virus-like symptoms, but not testing positive for virus by serology is probably because of one or a combination of the following:

- some of the symptoms are not caused by a virus (the great number of *D. rotundata* in Northern region having leaf chlorosis may have more to do with water/nutrient/temperature stress than virus)
- the virus is present at too low a titre in the field collected leaf material to be reliable detected by the homologous antiserum (the antiserum against DaBV was raised against a West African strain of DaBV, but at best only gives weak signals when used in ELISA on glasshouse-grown DaBV-infected plants, similarly, YMV was detected in one plant of *D. alata* by IC-RT-PCR but not by TAS-ELISA)
- the symptoms are caused by different strains of the viruses to which the available antisera do not react (current studies in other parts of the world indicate that there is greater genetic diversity within the potyviruses infecting yam than previously appreciated)
- the symptoms are caused by other virus genera to which antisera were not available (*Dioscorea mottle virus* (DMoV), genus Carmovirus, is common in Nigeria, but no antiserum suitable for use in ELISA was available at the time of the study (Hughes, IITA pers. com.)

4.2 Improved knowledge of the etiology and epidemiology of Scutellonema bradys *and* Fusarium solani *under Ghanaian conditions (Output 2). (Authors J Peters & A Missah)*

4.2.1 Interaction of Scutellonema bradys *and* Fusarium solani *in artificially inoculated micropropagated plants*

Table 4.15 shows the slopes of the regression lines representing the weekly tuber weight changes over an 8-week storage period (6th to 13th weeks after harvest). The tubers were harvested from yams that had been treated with single and combined inoculations of *S. bradys* and *F. solani*. An ANOVA of the slopes splits the treatments into two groups: 1. control and *F. solani*-inoculation; and 2. all treatments involving *S. bradys*. The rates of weight loss within the 8-week storage period were significantly higher (p=0.002) in all treatments involving *S. bradys* compared to *F. solani* alone and control treatments. Although the differences among the three treatments involving the yam nematode were not statistically different, *F. solani* in association with *S. bradys* caused a greater weight loss than *S. bradys* acting alone. There was no difference between the rate of weight loss in the control and *F. solani* treatments.

Table 4.15. Mean rate of weight loss (regression slope) of yam tubers during an 8-week storage period. Plants had been inoculated with combinations of *Scutellonema bradys* and *Fusarium solani*.

Treatment	Slope
Scutellonema bradys	-9.93**
Fusarium solani	-3.66
S. bradys+F. solani	-11.80**
S. bradys+F. solani (2 weeks after nematode inoculation)	-10.37**
Control	-3.16
SED	-2.12
P	0.002

**Significantly different from the control (P<0.01)

Infestation of *S. bradys* increased the colonisation of tubers by *F. solani*. The percentage re-isolation of *F. solani* from yam tubers and pieces of tuber tissues plated on PDA is presented in Fig 4.4. When *S. bradys* and *F. solani* had been inoculated together, the incidence of *F. solani* colonising sub-samples of tuber periderm, was increased when compared to plants inoculated with F. solani alone (p=0.009). Also, the incidence of tubers colonised by *F. solani* was increased from 58% (in those plants inoculated with *F. solani* alone) to 100% (in those inoculated with both *F. solani* and *S. bradys*) (p=0.081). *Fusarium solani* was not isolated from control tubers.

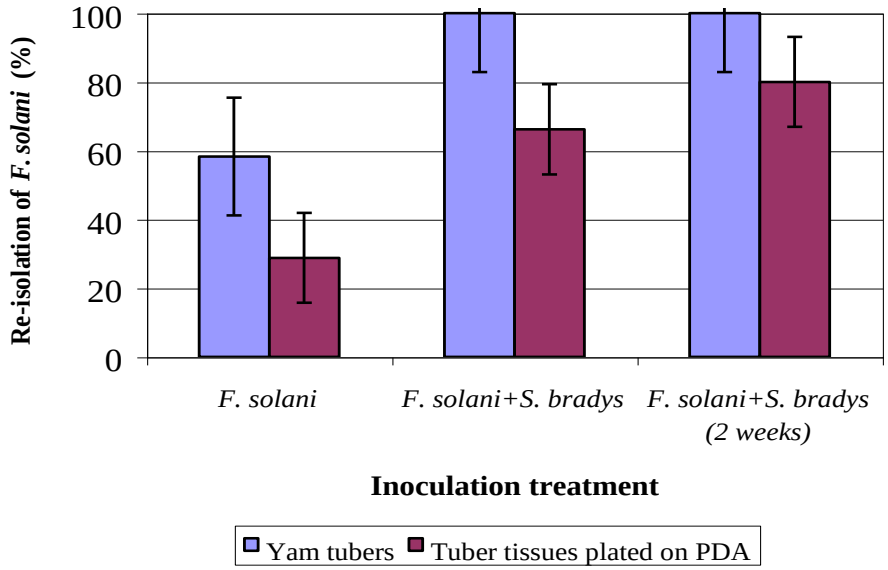

Figure 4.4 Percent re-isolation of *F. solani* from tubers and tuber tissues of yam inoculated with *F. solani* separately, and together with *S. bradys* (bars represent standard errors at p=0.05)

4.2.2 The migration of Scutellonema bradys *from okra to yam*

The incidence of *S. bradys* in samples of soil around yam and okra plants, and in yam tubers and okra roots are presented in Table 4.16. The incidence of *S. bradys* was higher in soils around yam tubers when nematode-infested okra was transplanted onto mounds next to the yam roots (p=0.022): *S. bradys* was recovered from 45% of soils around tubers when infested okra was in the furrows and from 80% of soils around tubers when infested okra was in the mound. Correspondingly, a higher number of tubers became infested with *S. bradys* when infested okra was planted on the mound than when the intercrop was in the furrows (p=0.004). Thus, okra is a host for, and source of, *Scutellonema* spp. that are pathogenic on yams. The incidence of *S. bradys* in okra roots and soil around them was not affected by planting position (p=0.311 and 1.0 respectively).

Table 4.16. Chi-square and T-tests of the influence of position of nematode-infested okra on okra roots and soils yam tubers and okra

Parameter	Position of infested okra		P-value
	Furrow	Mound	
Chi-square test of incidence of *S. bradys*	Counts		
Soils around yam	9	16	0.022
Soils around okra	18	18	1.000
Yam tubers	4	13	0.004
Okra plants	5	8	0.311
	Means		
T-test of population of *S. bradys* (Square-root transformed)			
Soil around yam (/100 ml)	2.6	1.9	0.589
Soil around okra (/100 ml)	1.1	2.8	0.942
Per infested okra roots (5 g)	1.3	1.2	0.74

4.3 Efficacy of methods for producing clean yam planting material and for reducing the rate of re-infection in the field tested under Ghanaian conditions. (Outputs 3 & 4.)

4.3.1 Yields after a three year cycle of planting clean or non-clean seed

Following a three year cycle of planting 'clean' seed (ie seed tubers collected from parent plants that had been relatively free from foliar disease and nematode infestation compared to 'non-clean' seed, see Table 3.2), yields (kg/mound) in *Dioscorea alata* cv Matches were increased by 28% (p=0.01) and in *D. rotundata* var Puna by 61% (p=0.02) compared to 'non-clean' controls (Fig 4.5). It is also important to note that this effect does not interact significantly either with site or chemical treatment (Annex, Section 3). Thus clean seed will significantly increase yield regardless of the effect of location or treatment.

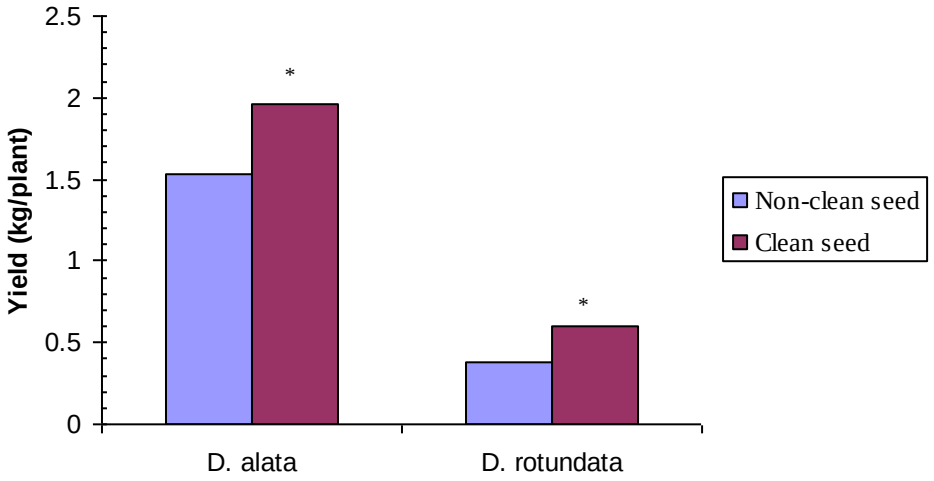

Figure 4.5 Effect on yield (kg/mound) of planting clean (low disease status) and non-clean (high disease status) seed tubers of yam (*Dioscorea alata* and *D. rotundata*). * indicates differences between adjacent bars at the 5% significance level (SED=0.144; df=60).

Attempts to improve yields by applying a fungicide (Benlate) and a nematicide (Furadan) were only consistently successful when applied to *D. alata*: yields were increased by 23%

(Fig 4.6) ($p<0.05$) (by comparison of the aggregate clean/non-clean seed treatments). In *D. rotundata*, the fungicide and nematicide treatment reduced yield at Site 2 (SARI) by 50% (Fig 4.7). There are many explanations for this. For example, soaking the seed tubers in fungicide emulsion might have exacerbated tuber rotting if the tubers had not been allowed to air-dry prior to planting. Anecdotal evidence in Ghana suggests that *D. rotundata* cultivars (particularly 'Puna' and 'Labreko') are more susceptible to rotting than *D. alata* cultivars.

It is interesting that there is a significant interaction between site and yam species ($p=0.011$) (Annex. Section 3). *D. rotundata* produced higher yields when grown in Site 2 (SARI) (Fig 4.7). SARI is situated in the Guinea savanna agro-ecological zone where the majority of *D. rotundata* is grown in West Africa (approximately 87% of the yams grown in this area are *D. rotundata* varieties whilst 13% are *D. alata* varieties) (Annex, Section 8 5, Kindness *et al*, 1999). *D. alata* performed equally well at both sites (CRI in the Northern Region; and CRI in the Brong-Ahafo Region which is in the forest-margin zone). In the Brong-Ahafo Region, approximately 49% of the yams grown are *D. rotundata* cultivars and 47% are *D. alata* cultivars (Kindness *et al*, 1999; Annex, Section 8).

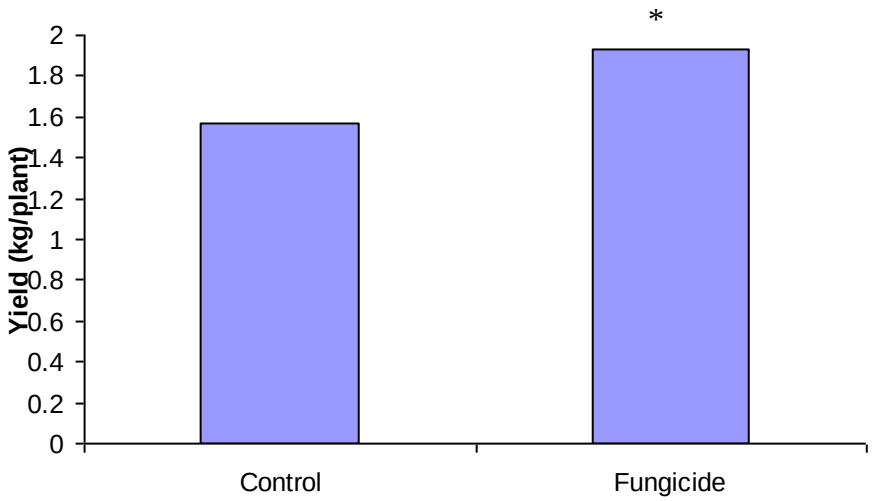

Figure 4.6 Fungicide (Benlate) and nematicide (Furadan) treatment increases yield (kg/mound) of *Dioscorea alata* by 23% (p=0.034).

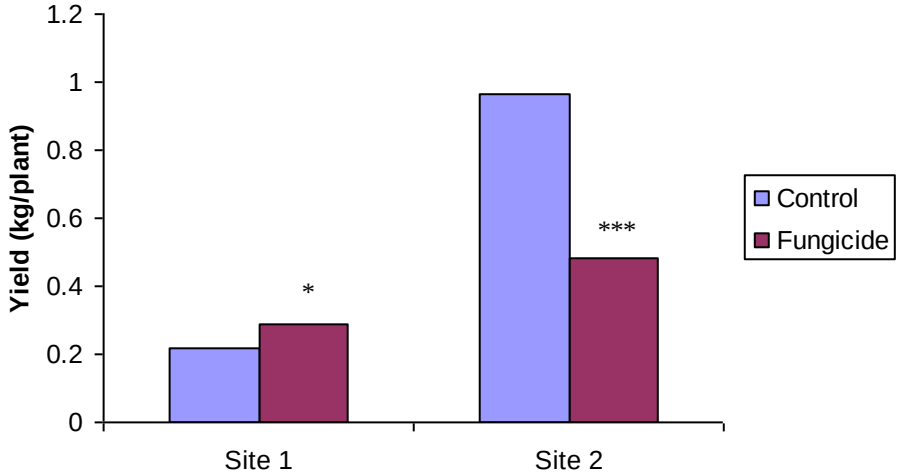

Figure 4.7 Interaction of site and chemical treatment (fungicide, Benlate, and nematicide, Furadan) on yield (kg/mound) of *Dioscorea rotundata*. (Site 1, CRI, Kumasi; Site 2, SARI, Tamale). *, * indicates differences between adjacent bars at 5 and 0.1% significance levels (SED=0.128; df=28).**

4.3.2 *Yield after first cycle of planting clean and non-clean seed*

Planting healthy, untreated, yam seed tubers increased tuber yields by 25% compared to untreated seed from unhealthy plants ($p<0.001$). Seed health was the second most important factor in determining tuber yield (after yam species, where *D. alata* produced 47% higher yields than *D. rotundata* ($p<0.001$)). However, secondary factors such as source of seed and geographical location of experimental site also affected yield to a lesser extent. Interactions due to these other factors have made it necessary to consider the complete table of means (Table 4.17). Planting seed tubers of water yam selected from healthy vines gave yield improvements of between 19% (seed selected from the Brong-Ahafo Region) and 22% (seed selected from the Northern Region) ($p=0.018$ and 0.023, respectively) compared to seed collected from unhealthy vines. Planting 'Puna' seed selected from healthy vines increased yields, over that found in non-clean plots, by 40% ($p=0.004$) when selected from the Northern Region but scarcely altered yield (-6%, $p=0.57$), compared to 'non-clean' seed, when seed was selected from Brong-Ahafo.

Treating seed with fungicide (Benlate) and nematicide (Furadan) increased yields by 14.2% over all combinations ($p=0.006$). However, although the fungicide and nematicide treatment generally gave increased tuber yields in most species/source combinations, the yield benefit from the treatment was inconsistent. The effect of chemical treatment on yield from each species (*D. alata* and *D. rotundata*) and seed health combination (averaged over source) are presented in Table 4.18. The fungicide and nematicide treatment increased yields in *D. alata* by 22% in non-clean seed and 17% in clean seed ($p=0.038$ and $p=0.016$ respectively). Chemical treatment also increased yields in *D. rotundata* by 19.3% in non-clean seed ($p=0.086$) but scarcely altered the yield of clean seed ($p=0.971$). In general, the highest yield gains were those where clean and treated seed were compared against non-clean and non-treated seed.

Table 4.17. Effect on yield of planting clean (low disease status) and non-clean (high disease status) seed tubers of yam (*Dioscorea alata* and *D. rotundata*).

	Field Trial Site/Yam species			
Treatment	**Northern *D. alata***	**Brong-Ahafo *D. alata***	**Northern *D. rotundata***	**Brong-Ahafo *D. rotundata***
Non-clean seed (kg/plant)	2.04	1.75	1.24	1.37
Clean seed (kg/plant)	2.47	2.08	1.74	1.29
% Improvement clean vs non-clean seed	21.5	19.2	39.7	-5.8
Significance level	0.023	0.018	0.004	0.571

Table 4.18. Effect of sanitation treatment (Benlate and Furadan) on yield of yam (*Dioscorea alata* and *D. rotundata*) grown from clean (low disease status) and non-clean (high disease status) seed tubers.

	Disease status/Yam species			
	Non-clean seed	Clean seed	Non-clean seed	Clean seed
Treatment	***D. alata***	***D. alata***	***D. rotundata***	***D. rotundata***
Control (kg/plant)	1.72	2.10	1.19	1.50
Fungicide/nematicide (kg/plant)	2.10	2.46	1.42	1.49
% Improvement treatment vs control	22.1	17.0	19.3	-0.7
Significance level	0.038	0.016	0.086	0.971

4.3.3 Determining the Causes of Yield Differences.

4.3.3.1 *Dioscorea rotundata*

Logistic curves were fitted to the anthracnose incidence data collected during the 1997 growing season in the SARI trial plots. Time to reach maximum disease increase (points of inflection, in weeks after emergence) were obtained from these curves and used as estimators of the extent of anthracnose disease levels. An ANOVA was calculated to compare anthracnose levels (i.e. points of inflection) in the different treatment plots. Table 4.19 shows that the disease epidemic had been delayed in the control clean seed plots compared to the control non-clean seed plots ($p<0.05$) when seed had been collected from the Northern Region. This supports the hypothesis that anthracnose is tuber-borne. There was a corresponding increase in yield ($p<0.01$). Clean seed from Brong-Ahafo had no appreciable yield increase compared with non-clean seed (despite a higher, but not significantly so, inflection). However, mean inflection, even in the non-clean seed from Brong-Ahafo, was comparable to the clean seed from the Northern Region. Therefore, anthracnose was not limiting yield in plots sown with seed from Brong-Ahafo at the SARI site.

In general, yield differences between treatments can be explained in terms of the differences in the incidence of anthracnose (or nematodes) between plots. In *D. rotundata* cv 'Puna' plots, there was a positive correlation between yield and point of inflection in control plots (Fig. 4.8, group 1). However, there was no correlation between yield and point of inflection in those plots where fungicide and nematicide treatments had been used (Fig. 4.8, group 2). It is likely that differences in yield between plots treated with fungicide and nematicide were due to factors other that anthracnose.

One of the effects of the fungicide and nematicide treatment was to decrease anthracnose inflection (i.e. exacerbate anthracnose levels) when compared to control plots ($p<0.001$) (Annex, Section 4). There was no corresponding decrease in yield possibly because the nematicide reduced nematode infestation levels. Nematodes were present in the trial seed. Indeed, the incidence of *Scutellonema bradys* on 'Puna' tubers (harvested at the end of the season) in the fungicide and nematicide treated plots was half that of the control plots (11.9% compared to 22.2%). It is interesting to note that there was no difference in nematode infestation between clean and non-clean seed (16.3% and 17.8% respectively). Therefore, differences in yields are likely to be attributed to differences in anthracnose levels in the control plots, and other, non-anthracnose, abiotic factors in the fungicide and nematicide treatment plots.

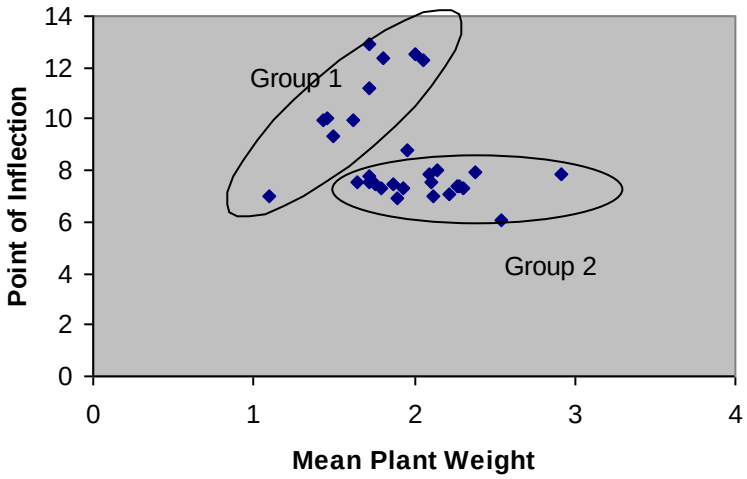

Figure 4.8 Inflection parameter values fitted to anthracnose incidence on *D. rotundata* var. Puna in the SARI field trials. Group 1 consists of mainly control plots (70%) where yields are correlated with point of inflection (weeks after emergence). Group 2 consists of mainly fungicide and nematicide-treated plots (70%) where yields are not correlated with point of inflection of anthracnose.

Table 4.19. Inflection parameter values fitted to anthracnose incidence on *D. rotundata* cv Puna in the 1997 SARI field trials.

	Point of Inflection (Weeks after emergence)/Difference in yield (kg/plant)			
	Northern		Brong-Ahafo	
	Control	Fungicide	Control	Fungicide
Non-clean seed	8.08	7.24	9.78	7.59
Clean seed	10.13	7.18	11.5	8.72
Differences in inflection	2.05*	-0.06	1.72	1.13
Differences in yield	0.53**	0.64**	0.08	-0.25

* Comparison of clean vs non-clean seed significantly different at 5% significance level

** Comparison of clean vs non-clean seed significantly different at 1% significance level

4.3.3.2 *Dioscorea alata*

An ANOVA was calculated to compare points of inflection fitted to anthracnose incidence data on *D. alata* collected during the 1997 growing season on the SARI trial plots (Annex , Section 4). The analysis shows that there was no difference in anthracnose incidence levels between 'clean' and 'non-clean' seed (p=0.587). However, seed purchased in the Brong-Ahafo Region (equal mixtures of 'Matches' and 'Guaa') had higher levels of infection (lower points of inflection) than those from the Northern Region ('Seidu bile')(p=0.037). Correspondingly, there was no difference in yield between clean and non-clean seed. But yields in Northern plots were higher that those in Brong-Ahafo plots (p=0.028). During surveys, 'Guaa' was found to be extremely susceptible to anthracnose and consequently disease severities on this cultivar might have reduced the plot average. In subsequent field trials, an equal mixture of 'Seidu bile' 'Guaa' and 'Matches' was used as planting material for all treatment plots.

4.4 Yam growers perceptions of yam diseases, and their responses to new or improved control measures. (Output 5). (Authors J Peters & H Kindness). **The full report is presented in Annex, Section 8.**

4.4.1 *Yam production and marketing problems*

Table 4.20 summarises the farmers groups' perceptions of different yam production and marketing problems (ranked in order of importance). In the Northern Region, 14 villages listed and ranked their constraints and in Brong-Ahafo the results are from 7 villages.

The results show that finance for labour and inputs was the most serious yam production constraint and was ranked 1st by all farmer groups in Brong-Ahafo region and 71% of farmer groups in the Northern region. Overall, pests and diseases were the second most important constraint in both the Northern and Brong-Ahafo regions, although 50% of the farmer groups in the Northern Region ranked pests and diseases as their third most important problem after drought (in 1998, the rains came unusually late).

Drought was an important constraint in the north, whereas it was not mentioned at all in Brong-Ahafo. Marketing was the next most important constraint to pests and diseases in Brong-Ahafo, and was the fourth most important in the north. Land acquisition was a constraint in Brong-Ahafo, but not a problem in the north. Associated with the problem of land shortage and land acquisition in Brong-Ahafo region is a problem of soil fertility, but it was not ranked as a constraint in the Northern region where there is not such a problem of land availability.

Poor quality and expensive tools were considered a big problem in some villages in the Northern region (in the villages where tools were mentioned they were ranked second) but in other villages they were not considered a problem at all (perhaps because this was considered under 'financial constraint'.

Table 4.20. Yam production and marketing problems

	Northern Region				Brong-Ahafo Region			
	Rank (% of farmer groups)				Rank (% of farmer groups)			
Constraint	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**
Drought	14.3	7.1	28.6	0.0	0.0	0.0	0.0	0.0
Finance (for labour and inputs)	71.4	14.3	7.1	0.0	100.0	0.0	0.0	0.0
High transport costs	0.0	7.1	0.0	14.3	0.0	0.0	0.0	0.0
Land acquisition	0.0	0.0	0.0	0.0	0.0	14.3	14.3	28.6
Low market prices	0.0	7.1	14.3	42.9	0.0	14.3	28.6	28.6
Pests & Diseases	14.3	14.3	50.0	14.3	0.0	57.1	28.6	14.3
Poor soils	0.0	0.0	0.0	0.0	0.0	14.3	0.0	28.6
Poor and expensive tools	0.0	35.7	0.0	0.0	0.0	0.0	0.0	0.0
Storage	0.0	0.0	0.0	21.4	0.0	14.3	14.3	14.3
Theft	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Key : Rank 1 is most serious, rank 2 is next most serious etc.
14.3% in the Northern Region is equivalent to 2 out of 14 groups
14.3% in the Brong-Ahafo region is equivalent to 1 out of 7 groups

4.4.2 Pests and diseases

Farmers were asked to discuss yam pests and diseases (ie describe their effects on the plants and tubers) and were asked to rank them in terms of importance[5]. Annex, Section 1 summarises the scientific, common English and local names of the various yam pests and diseases.

4.4.2.1 Importance ranking

Table 4.21 summarises the farmer groups' perceptions of pests and diseases affecting yams (ranked in order of importance). In the Northern Region, termites were ranked as the most important pest/disease, and mealybugs/scale insects were considered the second most important biotic constraint. Termites were also considered the most important pest in 1996 (Peters *et al*, 1997; Annex, Section 9). Interestingly, the farmers' perception that termites are the major constraint, compares favourably with direct observations of yam seed (Table 4.22): termites were the main cause of damage. However, in the Brong-Ahafo Region, scale insects and mealybugs were considered to be the major yam pest/disease problem overall. Termites were the second most important problem. In the Northern and Brong-Ahafo Regions, anthracnose and nematodes were both ranked third-equal most important constraint (In the Brong-Ahafo Region, viruses were also ranked in third place).

If we compare the order of importance given by farmers in 1996 and 1997, in the Northern Region, *S. bradys* and dieback increased in importance, whereas tuber beetle and wet rot decreased in importance. In 1997 in Brong-Ahafo Region, the two most important pests (mealybug/scale insects and termites) remained the same, viruses, anthracnose and nematodes increased in importance and tuber beetle and foliage beetles decreased in importance.

[5] The criteria used by farmers to rank pests and diseases were frequency and severity.

Table 4.21. Importance ranking of yam pests and diseases

Pest/disease	Relative importance (%)[1]	
	Northern	**Brong-Ahafo**
Termites	30	17
Mealybugs / scale insects[2]	17	31
Anthracnose	11	10
Nematodes (*Scutellonema bradys*)[2]	11	10
Die-back	9	0
Nematodes (Root knot)[2]	6	10
Virus	6	10
Wet rot	3	0
Foliage beetles	2	0
Dry rot	2	0
Tuber beetle	2	6
Millipede	1	7
Rodents	1	0
Centipede	0	0

[1] Based on totals perceptions of pest/disease being 1st, 2nd, 3rd and 4th most important constraint (totals were weighted 4, 3, 2 and 1 respectively).
[2]. Farmers in all but one village did not distinguish between mealybugs and scale insects, and so they have been treated as a single problem in the analysis. Nine out of the 14 villages could distinguish between the nematodes, *Scutellonema bradys* (tuber cracking) and *Meloidogyne* spp. (root and tuber knots), and so they have been treated separately.

Table 4.22. Assessment of Seed Tuber Health in the Northern Region, Ghana

	Incidence of tuber damage (%)[3]			
Mean (%)	*D. alata* 'Seidu bile' (SE)[4]		*D. rotundata* 'Puna' (SE)[4]	
('Seed')[1]	-		(45.2)	
Healthy	25.4	(6.3)	36.1	(3.5)
Termite/ant damage	6.4	(1.8)	17.9	(3.4)
Cutlass damage	19.9	(5.6)	15.4	(2.4)
Millipede damage	17.6	(7.2)	12.2	(2.9)
Surface fungal mycelium[2]	11.0	(3.7)	10.2	(2.5)
Internal rots	2.3	(1.2)	6.7	(2.0)
Rodent damage	0.4	(0.4)	6.2	(1.8)
Mealybug	0.0	(0.0)	5.7	(2.1)
Meloidogyne sp.	7.2	(4.7)	5.7	(3.5)
Scutellonema bradys	11.3	(7.6)	2.0	(0.9)
Scale insect	15.6	(9.7)	0.5	(0.4)
Sun/heat damage	0.4	(0.4)	0.3	(0.2)

[1] Proportion of tubers in storage grown for propagation purposes through double harvesting.
[2] Mainly *Sclerotinia/Rhizictonia* spp.
[3] Mean incidence in 10 tubers averaged over 21 & 11 farms for 'Puna' and 'Seidu bile' respectively.
[4] Standard errors of means ($p<0.05$) are given in brackets.

4.4.3 Sources of seed

In the Northern Region, most yam seed comes from the previous year's harvest. 77% of farmers said that they were increasing their farm sizes in 1998, and virtually all of them said that the additional seed was from their previous harvest. Farmers said that they buy seed either because they want to expand their farm, because they want new varieties or because they have insufficient seed from their previous harvest.

In some villages, the survey team questioned the groups further about the number of farmers who had bought seed. The response was that 18% of farmers in six of the survey villages had bought some seed in the last five years. In two of these villages, Sambu and

Demon-naya, a larger proportion of farmers (25% and 33% respectively) had bought seed this year because they are building-up their yam farms after a period of conflict, and said that prior to the conflict it was not common practice to buy seed. Of those that did buy seed, it is not known what quantity of seed was purchased. The farmers who had bought seed did so from other farmers in neighbouring villages, so the 'cleanliness' of the seed is unlikely to have been any better than seed from their own farms. Only four of the survey groups in the Northern Region were asked if they sell seed and, of these, only one farmer sold any seed last year.

In the Brong-Ahafo Region, again most seed comes from the previous year's harvest, but a higher proportion of farmers buy seed compared with the northern farmers. The proportion of those interviewed who bought yam seed in 1997 ranged from 14% to 50% in different villages, averaging 30% of the farmers. As in the north, most farmers did not indicate how much seed was purchased but two farmers said that they bought about 15% of their total yam seed. The reasons given for purchasing additional seed were shortage of seed, wanting to expand yam farms and an insufficient quantity of particular varieties. Farmers in six of the seven survey villages in Brong-Ahafo also sold seed. On average 16% of the farmers interviewed sold seed in 1997.

4.5 Transfer of new or improved control strategies to yam growers. (Output 6).

CSIR Scientists and MoFA officers used the field trial plots to demonstrate to farmers and extension agents the importance of planting healthy seed tubers that are free from pests and diseases (Plate 1) (Kenyon, 1999). Farmers were also shown laboratory demonstrations of nematodes under high magnification (using a light microscope) in order to reinforce the idea that seed tubers might harbour harmful pathogens without necessarily being visible to the naked eye. Farmers and extension agents were given a one page (double sided) information leaflet describing the most important yam diseases and offering control strategies (Peters *et al*, 1999; Annex, Section 5). Participants were also given the opportunity to comment on the recommendations of ZA0138) (i.e. not using tubers from infected, unhealthy plants as seed material as a means of producing healthier yams). In general, farmers were amenable to the recommendations. However, some farmers expressed concerns that in the event that they would be required to remove all the seed from their harvest, there would not be a reliable and affordable source of seed to replenish the stocks.

Plate 1. A MoFA officer demonstrating the importance of planting healthy, disease-free seed tubers to yam farmers during the farmers field visit to SARI, October 1999.

The Natural Resources Institute has been producing posters (Annex, Section 6), in collaboration with Reading University, MoFA and the Crops Research Institute for use as extension material. This material was produced following discussion with extension staff and farmers during a workshop to disseminate the research findings of ZA0138 (February 1999). An evaluation of the posters was done during the CPP Yam Uptake Study workshop. MoFA, Tamale has been given copies of the posters in order to translate the text into the local dialect of farmers in the Northern Region. The posters will be distributed to MoFA Extension Offices and farmers via MoFA (Sunyani and Tamale offices).

5 Contribution of Outputs

Outputs of the project include:

- Improved knowledge of improving yields in yam through producing clean seed
- Reports on farmers' perceptions of pests and diseases affecting yams
- Improved knowledge of the nature and distribution of yam diseases in Ghana

Planting material that was infected/infested with pathogenic fungi, nematodes and viruses is a major cause of yield losses throughout the main yam growing regions of Ghana. Conservative estimates suggest that 20-40% losses are realistic. Planting material can be sanitised to remove harmful organisms. However, ZA0138 showed that soils and roots of crops growing in association with yams, are also a source of nematodes and fungi pathogenic to yams. In addition, declining fallow periods due to population pressure has become a feature of agricultural production in much of Africa (Sekou, 1999). The result of such a decline may be a degradation in soil chemical and physical characteristics, as well as increased incidence of soil born pests, such as nematodes, and fungal pathogens. Further research is planned as a phase II of ZA0138, to address these issues using on-farm, on-station and laboratory investigations of the effectiveness of reducing, or eliminating, nematode and soil-borne fungal pathogen populations (for example by using leguminous cover crops, biocontrol agents and the use of nematicidal preparations derived from plants). In addition, work is planned to promote and encourage specialist growers who will produce clean planting material for local use. Outputs should be promoted to farmers via the extension services (Ghana) and DDS (Nigeria).

During the RRA, Project ZA0138 found that yam growers were extremely concerned about pests and diseases affecting yams. The focus of project R6691 was pathogenic fungi, viruses and nematodes. However, farmers were primarily worried about the more visible pests: termites, mealybugs and scale insects. Examination of yam seed stores confirmed that these pests are a major problem. Future research activities are needed to determine appropriate control strategies for these pests.

Project ZA0138 has shown that health of yam planting material affects subsequent yields: seed infected with pathogenic nematodes, viruses and fungi will produce poor yields. In collaboration with the SARI, CRI and MoFA, this message was presented to around 100 farmers and extension staff in the final year of the project in order to reinforce the importance of healthy planting material to farmers. In addition, growers and extensionists were trained to recognise nematode infestation in tubers. However, only a small minority of yam growers was reached. Ministry of Agriculture extension staff will distribute the message to farmers within their target villages but participants at the Farmers Field Visits (FFV) requested further FFVs be made available to the wider farming community.

Recommendations to Growers

•**Plant healthy seed tubers**. Nematodes, viruses and the fungus that causes anthracnose can survive in tubers after harvest. Therefore, to ensure that the yam crop is healthy, you must not use seed from plants that had visible signs of infection. Also, tubers with symptoms of nematode infestation must not be used as planting material.

•**Choose varieties carefully**. If you grow yams in an area where anthracnose is a problem, plant varieties that are resistant to the fungus (for example *Dioscorea alata* cv 'Seidu bile'). Extension agents can advise on which varieties to grow in your area.

•**Store the seed in structures that provide shade, ventilation and protection from rain**.

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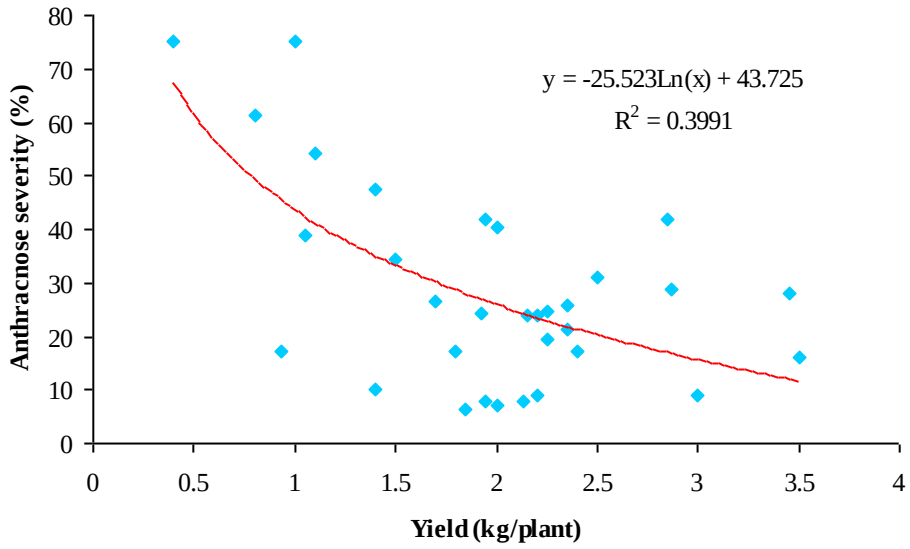
ANNEX

Section 1: English common, scientific and local names of yam pests and diseases
Section 2. Yield (kg/plant, mean of four adjacent plants) of *D. alata* plotted against anthracnose severity
Section 3. Anova of yield in the field trial.
Section 4. Anova of points of inflection in the sari field trial.
Section 5. Information leaflet: yam diseases in Ghana
Section 6. Information posters: yam pests and diseases
Section 7. Virus diseases of *Dioscorea* yams
Section 8. Farmers' perceptions of yam pests and diseases and management practices, particularly relating to yam seed, in the Northern and Brong-Ahafo Regions of Ghana.
Section 9. Report on yam field diseases in Ghana
Section 10. Report on dissemination workshop

Section 1: English common, scientific and local names of yam pests and diseases

English common name	Scientific name	Local names Northern region	Local names Brong-Ahafo region
Anthracnose	*Colletotrichum gloeosporioides*	Baloo, Kyeh, Wakon, Geylaa, Soraa, Bochai Bochaa, Nyu wang	
Die-back	Unknown possibly *Rhizoctonia solani* or *Fusarium solani.*	Yaba, Bochaa, Gbgani, Nyu kuum	
Dry rot	Numerous fungi including: *Fusarium* spp *Aspergillus* spp	Nyokugu, Kpiri kuuni, Kpiri ziegu	
Foliage Beetles	*Crioceris livida*	Nyebarimi, Nyikpera	
Mealybugs	Many including: *Phenacoccus gossypii*	Ninsaahi, Mamaree, Nyinsa kpala, Gbanpiela, Dayu puri	Fuo, Mfunemfu, Mfu
Nematode (cracked)	*Scutellonema bradys*	Nyugbana, Nyofieni, Fanni, Fanibu, Sanaa, Wa fama, Wafanni, Fariga, Gbani, Gbgani, Bochaa	Awurukuo, Kaba, Honoawu
Nematode (knobbly or root-knot)	*Meloidogyne* spp	Nyofieni, Toggi, Fanibu, Wa fama, Jamkpana, Samgbana, Jagaa, Bochaa	
Scale Insects	*Aspidiella hartii*	Furim, Nyinsa Kpala, Dunkasagabinnu, Nyirisi, Minaa, Poora Gbanpiela, Dayu puri	Fuo, Mfu, Mmoafufuo
Termites	*Amitermes evuncifer*	Tambiogu, Tambiegu, Digri, Yaba, Kpolow, Gumo, Chau, Tambe gunn, Tambe gunga	Mfotee, Nkanka, Nekye, Mmontro, Mmoanturo
Tuber Beetles	*Heteroligus* spp.	Wolingo, Bulinbugiri, Kpalinpor, Jalanboti	
Virus	Numerous including: yam potyvirus and badnavirus	Koga, Konkonga, Danduli, Lenlen, Nyukuong, Buguliheu, Nyu kooga, Nyukoga	Jabrija, Babaha, Nkufru, Asense
Wet rot	*Erwinia carotovora* and other bacteria	Nyoponu, Puonpielaa, Nyupuom, Hiipuo, Kpiri pieli, Kpiri mahili	

Section 2. Yield (kg/plant, mean of four adjacent plants) of *D. alata* var Matches plotted against anthracnose severity (mean of four adjacent untreated plants).



SECTION 3. ANOVA OF YIELD IN THE 1999 SARI FIELD TRIAL.

Variate: MEANWT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	4	3.0285	0.7571	3.66	
Block.*Units* stratum					
Site	1	0.8115	0.8115	3.92	0.052
Disease	1	2.1272	2.1272	10.29	0.002
Species	1	31.6670	31.6670	153.12	<.001
Treatmen	1	0.1195	0.1195	0.58	0.450
Site.Disease	1	0.3322	0.3322	1.61	0.210
Site.Species	1	1.4224	1.4224	6.88	0.011
Disease.Species	1	0.1921	0.1921	0.93	0.339
Site.Treatmen	1	0.1538	0.1538	0.74	0.392
Disease.Treatmen	1	0.0994	0.0994	0.48	0.491
Species.Treatmen	1	1.5870	1.5870	7.67	0.007
Site.Disease.Species	1	0.4322	0.4322	2.09	0.153
Site.Disease.Treatmen	1	0.1824	0.1824	0.88	0.351
Site.Species.Treatmen	1	0.6970	0.6970	3.37	0.071
Disease.Species.Treatmen	1	0.1324	0.1324	0.64	0.427
Site.Disease.Species.Treatmen	1	0.0139	0.0139	0.07	0.796
Residual	60	12.4089	0.2068		
Total	79	55.4075			

SECTION 4. ANOVA OF POINTS OF INFLECTION IN THE 1997 SARI FIELD TRIAL.

Dioscorea rotundata

***** Analysis of variance *****

Variate: vm3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	3	22.644	7.548	4.31	
BLOCK.*Units* stratum					
TREATMEN	1	38.677	38.677	22.07	<.001
LOCATION	1	12.408	12.408	7.08	0.015
DISEASE	1	10.386	10.386	5.93	0.024
TREATMEN.LOCATION	1	0.644	0.644	0.37	0.551
TREATMEN.DISEASE	1	4.424	4.424	2.52	0.127
LOCATION.DISEASE	1	0.650	0.650	0.37	0.549
TREATMEN.LOCATION.DISEASE	1	1.628	1.628	0.93	0.346
Residual	21	36.804	1.753		
Total	31	128.265			

D. alata

***** Analysis of variance *****

Variate: vm3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	3	5.304	1.768	0.97	
BLOCK.*Units* stratum					
TREATMEN	1	18.882	18.882	10.35	0.004
LOCATION	1	9.017	9.017	4.94	0.037
DISEASE	1	0.555	0.555	0.30	0.587
TREATMEN.LOCATION	1	2.941	2.941	1.61	0.218
TREATMEN.DISEASE	1	1.488	1.488	0.82	0.377
LOCATION.DISEASE	1	0.875	0.875	0.48	0.496
TREATMEN.LOCATION.DISEASE	1	5.263	5.263	2.88	0.104
Residual	21	38.312	1.824		
Total	31	82.637			

SECTION 5. INFORMATION LEAFLET: YAM DISEASES IN GHANA.

SECTION 6. INFORMATION POSTERS: YAM PESTS AND DISEASES

SECTION 7. VIRUS DISEASES OF *DIOSCOREA* YAMS.

SECTION 8. FARMERS' PERCEPTIONS OF YAM PESTS AND DISEASES AND MANAGEMENT PRACTICES, PARTICULARLY RELATING TO YAM SEED, IN THE NORTHERN AND BRONG-AHAFO REGIONS OF GHANA.

SECTION 9 REPORT ON FARMERS' PERCEPTIONS OF YAM FIELD DISEASES IN GHANA.

SECTION 10 REPORT ON DISSEMINATION WORKSHOP.

Yam Diseases Project Workshop - 8th February 1999

Ministry of Food and Agriculture conference hall, Bolgatanga road, Tamale.

Programme for opening ceremony

- Participants arrive
- Opening prayer
- Introduction of Chairman by Mr. A. Tabil
- Chairman's opening remarks - Dr OA Danquah (CRI)
- Welcome address by Mr JK Wumnaya, Regional Director (MoFA)

Programme for the day

- Project background - Dr JC Peters (UoR)
- Yam nematode diseases - Mr A Missah (CRI/UST)
- Plant materials in the management of yam nematodes - Mr A Tabil (University of Developmental Studies - UDS)
- Yam virus detection - Dr SK Offei (UGL) & Dr L Kenyon (NRI)
- Effects of viruses on yam - Dr J Lamptey (CRI) & Dr L Kenyon (NRI)
- Questions and discussion on talks
- Coffee/tea
- Yam diseases in Northern Ghana - Mr F Tsigbey (SARI)
- Impact and control of foliar diseases of yam - Dr JC Peters & Dr OA Danquah
- Post-harvest diseases - Mr D Crenstil (MoFA/NRI) & Mr E Cornelius (UGL)
- Questions and discussion on talks
- Close of morning session

- Lunch

- General discussion and planning - Chairman Mr AA Adjekum (International Fund for Agricultural Development -IFAD)
- Close of workshop
- Snacks
- Collaborators meeting
- Close of meeting

Rapporteurs: Mrs B Hemeng (UST) and Mrs E Tabil (SARI)

Background:
The yam diseases project (YDP) in Ghana is funded by the United Kingdom Department for International Development (DFID). It is managed through the University of Reading (UoR), UK, with collaboration from Ministry of Food and Agriculture (MoFA), Crops Research Institute (CRI), Savanna Agricultural Research Institute (SARI), University of Ghana at Legon (UGL), University of Science and Technology (UST) and Natural Resources Institute (NRI) UK.
The aim of the project has been to investigate the total pathology of yam in the field. The project is currently exploring sustainable methods for improving yam yields by reducing disease levels.

PROCEEDINGS (*Rapporteurs: Mrs B Hemeng (UST) and Mrs E Tabil (SARI)*

Opening Ceremony 9:25 A.M.
The meeting was started with a prayer then Mr A. Tabile introduced the Chairman, Dr. O. A. Danquah. The opening remarks was given by the Chairman stressing the importance of yam and its potential cash crop for poverty alleviation and a profitable crop with high productivity. The Chairman introduced the delegates from the Brong-Ahafo Region then invited the delegates to introduce themselves.

The Chairman welcomed the delegation then gave a short introduction of the importance of yams as an economical crop. The Export Promotion Council is now interested in exporting the commodity in large quantities. Dr Danquah continued that the Crops Research Institute (CRI) ranks yam as one of the most important crops as it accounts for 13% of the agricultural gross domestic production (AGDP). Cassava and cocoa accounts for 22% and 14% AGDP respectively.

9:45 am: Welcome Address (Mr. Wumnaya).
Mr. Wumnaya, Nothern Regional Director of the Ministry of Agriculture was invited by the Chairman to give the welcome address.

Mr. Wumnaya said that Tamale and the surrounding Districts were yam-growing districts where he himself comes from has plenty of land available but his people were very lazy. He said he has been told that the project which was started in July,1996 is being funded by DFID and managed by the UOR, UK., with NRI, the Universities in Ghana and MOFA as Collaborators. He said he was happy to note that participants have come from all walks of life, Researchers, Lecturers, MOFA Officials and farmers he hoped they will leave the place with better knowledge of yam diseases and pests, especially those associated with damage to post harvest crops.

Mr. Fuseini did the general interpretation into the local dialect for the farmers.

10.00 a.m.:General Background of Yam Disease Project (Dr. J. Peters).
Dr. Peters first thanked the MOFA Extension Officers and, in particular, the yam farmers for allowing the researchers to enter their farms to look at diseases and pests on yams. Over the next few hours, the scientists will present the results obtained from these farm visits.

The workers from UOR and NRI, DFID and the scientists working in Ghana appreciate the importance of yams. In addition, as the population of Africa increases, yams will become more important not only in the West but also in other regions of Africa where they can be grown. Therefore, there was a need to increase production and do so successfully would mean to remove the constraints of diseases and pests.

Dr. Peters described the objectives of the DFID-funded Yam Diseases project, which is to improve our understanding of the pests and diseases that attack. There was very little knowledge on yam health in Ghana before the project started. The first phase looked at the economic damage caused by pests and diseases; and phase two investigated control strategies for increasing yam production through reduction of pests and diseases.

Farmers in participatory studies had indicated that after financial concerns, pests and diseases were the most important constraint to yam production. Within this framework, farmers' perceived termites, in the North and Upper West Regions, and mealy bugs, in the Brong-Ahafo Region, as the most important pest and disease problems. Nematodes were ranked second in all locations. Slides of these problems such as termite attack, fungal diseases (anthracnose), tuber rot, nematode attack (lesion and root-knot), viruses (mosaic) were showed to farmers.

10.15 a.m. Yam Nematodes (presented in Twi by Mr Missah)
The speaker gave a general overview on the nematode problem in yams in Ghana. Over 50% of soil samples collected on yam farms had nematode species that were capable of causing damage to yams. The important nematodes, *Scutellonema*, *Meloidogyne*, and *Pratylenchus* spp., are found in yam planting material, soils associated with yam roots, and on the roots of many plants that are commonly intercropped with yams. The speaker concluded by saying that the nematode problem is likely to increase as rising populations cause increasing intensification on available arable land.

COFFEE BREAK

11.00 Natural Plant Products for the Control of Yam Nematodes (Mr. Tabile, UDS)
Various plant materials (Teak, *Icacinia senegalensis* and neem) were screened for activity against nematodes. The integration of the nematicide, Furidan, at half the recommended dose with powdered neem leaves increased yields in yam by nearly 100%, mainly by reducing *Meloidogyne* and *Scutellonema* infestation, when compared to yields in untreated plants. This was as effective in controlling nematodes as using Furidan at the full-recommended dose.

11.07 a.m.: Virus Diagnosis in Yams in Central Ghana (Dr. S. K. Offei, Univ of Ghana)
The objective was to assess the distribution and diversity of yam viruses in one of the major yam growing regions of Ghana. The study involved 600 plants of *Dioscorea rotundata*, *D. alata* and *D. cayensis*, which were propagated by tuber. Out of the study, 7 types of viruses were detected including *D. alata* badna virus, YMV, YMMV, *D. alata* potyvirus. Dr Offei described the symptoms associated with the most common viral diseases as vein banding, reduction of shoot string, dwarfing, reduced internodes, yellowing of leaves, mottling and chlorosis.

11:23 am The Impact of Yam Viruses (Dr. J. N. Lamptey).
Seeds of yam were collected from farmers' fields and grouped into high disease Demon-Naya, Gbungbalgba (North), Abi No 1 and Bamire (B/Afafo). Low disease areas were Boli and Komaoyili (North) Abi No. 3 and Diomankese (B/Ahafo). Yams of 200g pieces were cut and used for the research. Yam variety "Puna" from low disease area gave higher yield than one from higher disease area. The "Matches" also had the same trend. There was an appreciable gain in yield when planting materials from apparently healthy looking plants were used. Thus farmers should use planting materials from healthy plants.

11:35 a.m.: The floor was opened for Questions and Discussions.
A farmer from Sunyani mentioned his concern regarding mosaic and early senescence in his water yam. Dr Peters responded by saying that it is hoped, in the near future, measures

are going to be put in place to provide clean guaranteed seed for yam production provided farmers are willing to pay.

The work on possible use of wild yam as a natural nematicide was observed by a participant to be interesting. He continued that as the high expenditure and non-availability of synthetic nematicides were chronic problems in developing countries the work should be supported.

11.55 a.m.: Yam Disease Surveys (Mr. F. Tsigbey of SARI).
The speaker gave an overview of the major foliar diseases of yams. The most important were *Colletotrichum gloeoesporioides* and *Cercospora* spp.. Rot, caused by nematodes were also described.

12:05 p.m. Foliar fungal diseases of Yam: impact and control (Dr. J Peters).
The most important foliar disease of yam is anthracnose, caused by a fungus, *Colletotrichum gloeosporioides*. The speaker described how a recent survey of farmers' yam fields (where the amount of foliar disease on yams were monitored) was later used to identify seeds from farms that had high and low levels of anthracnose. The seed that had been collected from these farms then formed the basis for trials to assess the impact of seed-borne inoculum on plant health. The use of clean seed could increase yields by as much as 300%. However, yield increases in the region of 50% are not unrealistic. From these trials, the recommendation to farmers is to plant clean, healthy seed (that is, seed collected from plants that were collected from relatively disease-free plants). The speaker concluded that although anthracnose cannot be seen in planting material, black lesions and die-back symptoms on the parent plant along with small tubers are likely indicators of the disease.

12:15 p.m.:The Post Harvest Project (Dr. D. Crenstil).
The Post-harvest Yam Project was set up to determine and assess constraints and investigate technical solutions and opportunities for more effective handling and marketing of fresh yams within Ghana. This was assessed through PRAs with farmers, a monitoring survey, biological and quality assessment, route trials under which yams are transported and sold. The presence of tuber rots was monitored throughout the marketing chain. Tubers handled and stored in the traditional way were found to have substantial losses in terms of rots and sprouting. However, tubers that had been cured then stored in well-ventilated barns appeared to store well. Resin coating agents were tried in an effort to reduce post-harvest rots; but these proved ineffective.

12:25 p.m. Causes of Post Harvest Rots (Mr. E. Cornelius).
Rot-causing micro-organisms found on white yam include: *Aspergillus* spp., *Botryodiplodia theobromae, Erwinia carotovora, Fusarium* spp., *Penicillium* spp., *Rhizopus* sp., and *Scutellonema bradys*. 'Internal brown spots' were also commonly found in, otherwise healthy, tubers. This symptom is thought to be associated with a virus. The important role of secondary invaders was also noted. The symptoms of decayed consistency (dry rot, wet rot, soft rot); decayed tissue colour (brown, black, grey, purple cream) were discussed as well as the diagnostic symptoms produced by *A. niger, B. theobromae, P. brevi, R. stolonifer* and *S. bradys*. The control efforts including improved storage techniques, chemical, varietal selection, curing, waxing (resin solution) and irradiation were also mentioned.

12:35 p.m.

The floor was opened for discussion

A farmer asked if anyone had any knowledge of yam treatment before storage that would reduce post-harvest rots. Another farmer responded that lime prepared by oyster shell (80% lime paste) smeared on the wounded tubers performs better than the wood ash. The question on mealybugs and millipedes was deliberated upon and some farmers asserted that cow milk is used on the tubers, which attract ants, which then feed on the mealybugs hence controlling the infestation. Others also put the yams under shade already infested with ants for the ants to feed on the mealy bugs.

LUNCH BREAK

Mr Akwasi Adjei Adjekum chaired the afternoon session. There was an open discussion on problems surrounding yam cultivation.

General

a) One farmer said most of the rotting seeds in mounds were due to hot weather and variety of planting material. Those seed that had cuts and bruises should be planted in cool and wet weather whilst whole (smaller) or cured seed could be planted at any time. *The cool wet period corresponds to the main sprouting season, presumably damaged seed should be encouraged to sprout as quickly as possible.*
b) The Chairman asked about farmers' perceptions of diseases and its effect on yield. He wanted to know if there was any traditional method of control for the researchers to study.

The problem of nematodes of yam cultivation

c) A farmer from the Northern Region reported that nematodes were his greatest concern. He asked that perhaps, researchers could help look into that for them. Mr. Missah stressed that the farmers should be given indicators to nematode detection in order to discard them before planting. Indicators such as malformation, root-knots, narrow brown spots under skin when scraped (low infection), excess roots or "hairs", warts, etc.
d) One Extension Agent made the important point that soil infestation, even if good and healthy seeds are planted, should be considered. Farmers were advised to know the history of the land being cropped; check sources of inter-crops; soil testing and check roots of fallow crops and choice of planting materials before putting the land to yam cultivation.
e) It was realised that tubers harvested early have lower nematode infestations.
f) Bush yam was considered to be tolerant to nematodes, the most susceptible is Puna. Farmers contributed that there are four cultivar types (land races) of "Puna" and these included Laribriko which has broad leaves and Puna which has narrower leaves. Missah said his work showed "Puna" had all three of the major nematode species. The Chairman stressed the need for resistant varieties with resistance genes that can be isolated and incorporated into varieties with good agronomic qualities.

Clean Seed Production

g) A farmer suggested the idea of clean planting material, and so specialist seed growers for yam should be encouraged. Dr. Peters expressed the fear that farmers might not be prepared to buy clean healthy seed. The farmers responded they would be prepared to buy clean planting material.

h) A farmer also mentioned that the farmers should be encouraged to produce large number of planting material for their large farms through minisett technology. The Chairman elaborated on the reasons for the collapse of minisett technology – mainly because of the poor germination of the major *D. rotundata* vars. (i.e. Puna). (Germination rates in the region of 30% was common in Puna using the minisett method, compared to over 80% in D. alata var. Matches.) The Chairman encouraged volunteer farmers to experiment with this technology.

The use of fertilizers in yam cultivation

i) The Chairman advised researchers to identify indigenous methods of controlling yam diseases by farmers. There is somebody working on fertiliser use in increasing yield of yam, as there are misgivings about its use due to change in taste, texture, etc. The elimination of the use of single super phosphate in growing yam was alarming to a participant and wanted to know the reason. The farmers confirmed it saying there is early shedding of leaves.

j) A farmer has been practising chicken droppings (organic fertiliser) on selected mounds last year and had an increase yield of his yam when compared to the untreated mounds. The manure is put around the seed in the mound before covering with soil. The farmers prepare the land incorporating grasses (mulch) and that increase yield as well.

Pests

k) The Chairman wanted to know how farmers had been handling pests - mealybugs, millipedes, rodents, beetles, etc.,). One farmer said he sprinkles powdered hot pepper on yam seed to control mealybugs. Another farmer who uses powdered pepper on Puna variety confirmed this. Another method mentioned for mealy bug control was to use cows milk to attract ants which control mealybug. It was observed that some farmers dip yams into milk for this purpose.

l) The Chairman asked the participants how the early shedding of leaves takes place. A farmer said the leaves wither and die off. The Chairman explained the effect of fungi such as *S. rolfsii* (white mycelia at the base of the roots) in causing premature dying of the plant.

m) A destructive maggot was identified on one farmers' field at Afram plains where it consumes vegetation. It was believed to be the larval stage of the yam beetle.

Foliar Diseases

n) Using pictorial posters, Dr Danquah explained the presence of small yam tubers as a result of diseases. That is what the farmer uses to plant unlike the bigger tubers, which scored low infection of diseases, e.g. anthracnose. The Chairman advised farmers to tag infected yam plants when detected before they all sheds the leaves at maturity so as to ignore the infected tubers when harvesting to use for replanting. He went on to say that any plant that reduces its photosynthetic parts would definitely reduce the yield.

o) Another farmer wanted to know how virus infections could be controlled. Dr Lamptey said it could not be prevented but that in all cases it was the initial seed infection that produced severe symptoms

Workshop evaluation by the Participants

Demonstration farms.

A farmer expressed the view of setting demonstration farms in addressing the problems enumerated here to benefit wider Frontline Staff and farmers concerned with yam production.

Future Workshops

Many farmers said they would prefer the workshop to be held over a two day period to reduce the length of sitting in a day (farmers are not used to long hours of sitting). Mondays and Tuesdays are the most suitable days for workshops. The gathering agreed that around 50 delegates is a suitable size for a meeting but they were surprised no woman farmers were present. This was explained by Fuseini Andan that yam is mainly cropped by male farmers. One participant said that there should be an integration of stakeholders from different regions. Also, Subject Matter Specialists (SMS) from both locations should be invited to facilitate dissemination of workshop findings.

Request for Pictorial Disease Symptoms

The farmers and extension agents made a request for good photographic images of disease symptoms in order to enhance the information gained from the workshop. A trial version, in leaflet form, produced by J Peters was considered too small by the farmers who would rather have large posters.

5.25 pm. The Workshop came to a close with a prayer by Dr. J. N. Lamptey.
A group photograph was then taken to commemorate the occasion.