CROP PROTECTION PROGRAMME

Identification of resistance to major nematode pests of yams (*Dioscorea* spp.) in West Africa

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FINAL TECHNICAL REPORT

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[R6694 Crop Protection Programme]

EXECUTIVE SUMMARY

This DFID, CPP project was a collaboration between CABI Bioscience and the Tuber and Root improvement programme of the International Institute of Tropical Agriculture in Nigeria. The project sought to identify sources of resistance to the principal nematode pests of yams *(Scutellonema bradys* and *Meloidogyne incognita)* which cause dry rot and galling of yam tubers in West Africa and are a priority for yam breeders at IITA. The project focused on development of yam nematode resistance screening techniques for field and screenhouse and carried out extensive screening of germplasm from West Africa. An important aim was to achieve a better understanding of the genetic and environmental components of variability in the host: parasite interaction of yams and yam nematodes through strategic research. The project involved survey work, which examined the distribution of nematodes in Ghana and assessed farmer's perceptions of nematode losses. It also involved field, screenhouse and glasshouse trials in Nigeria, Ghana and UK.

Yam nematodes are widespread in Ghana, where they are well known to farmers and where attempts to control nematodes using fallow and selecting good planting material are commonplace. Farmers in Ghana consider losses from *S. bradys* to be more important than those from *M. incognita*. Farmers grow a large number of varieties and whilst they might be willing to test new, potentially resistant, varieties, it is important that such should fit into this diverse background.

Experiments on precision established that Latin square field designs are more favourable than an Alpha array, but neither dealt satisfactorily with the heterogeneity of natural nematode populations and thus screening protocols which used artificial inoculum (nematode infected yam peelings) were more reliable. Five or more replications are recommended in order to approach meaningful separation of quantitative variants. Data from experiments using young yam seedlings should be interpreted with care since this work identified discrepancies between the results of such experiments and expression in the field.

Most of the yam species and accessions screened have been found to be susceptible to nematodes. There was variation in susceptibility within *Dioscorea rotundata*, but the functional importance of this variation in terms of increased yield and reduced storage losses requires more work. *Dioscorea dumetorum* has resistance to both *S. bradys* and *M. incognita*, but barriers to interspecific crosses to *D. rotundata* preclude the exploitation of this resistance at present.

Monoxenic culture techniques for the mass rearing of *S. bradys* have successfully been developed, which can assist further detailed pot experimentation.

Pratylenchus coffeae which is widespread in Ghana on *Musa* spp. can multiply in roots of a number of species of *Dioscorea*, namely *D. alata, D. rotundata, D. cayenensis, D. esculenta, D. dumetorum, D. bulbifera*, but does not multiply readily in yam tubers and hence is not a threat to yam production. *P. coffeae* in Ghana appears to be a *Musa* host race.

BACKGROUND

Yams, *Dioscorea* spp. are important economic crops grown mainly in tropical countries especially, in the yam belt or yam zone of West Africa. Many farm-families depend on the tubers for food, cash, local food security and other traditional uses. The tubers provide a substantial intake of vitamins (thiamine and vitamin C) and iron and also protein. Yam peels and over matured tubers are used to feed domestic animals such as pigs, goats and chickens. It is gradually being realised as an important non-traditional crop for export. However, yams are severely damaged by plant parasitic nematodes reducing yield, food quality, and market value. At least three potential nematode pest species namely *Scutellonema bradys*, *Meloidogyne* spp. and *Pratylenchus coffeae* are known to exist. Reduction of 20-30% in tuber weight at harvest has been reported. Also, nematode infection contributes to long term storage losses, which have been estimated as 50%, and loss can be total.

Chemicals, cultural methods such as hot water treatment of seed yams, crop rotation, biological control, the use of resistant varieties and integrated management, can control plant-parasitic nematodes. Most of the management options are limited in use due to high costs, time, feasibility and adverse effects on the environment and mammalian toxicity. Most plant-parasitic nematodes by their nature and habitat are restricted in their movement from field to field and area to area and new physiological races that break resistance probably would be slow. Yam cultivars with resistance to nematodes would provide an attractive nematode management option appropriate to smallholder farm families. There is therefore the need to begin to search for nematode resistance in yams.

PROJECT PURPOSE

The main project purpose was to identify sources of resistance to yam nematodes for use in Yam Improvement Programmes aimed at reducing the yield and storage losses in yam caused by nematodes. This addressed the DFID Crop Protection Programme's Forest/Agriculture Interface, Purpose 1, output of improved methods of managing the major nematode pests of root and tuber crops. The project aimed to achieve a better understanding of the genetic and environmental
components of variability in the host: parasite interaction of yams and yam nematodes through strategic research. The project focused on development of yam nematode resistance screening techniques and screening of yam germplasm for nematode resistance then examined the correlation between nematode host status and other plant characteristics. The findings should provide recommendations for plant breeders.

DETAILS OF COMPLETED RESEARCH ACTIVITIES

OUTPUT 1. TECHNIQUES FOR SCREENING YAMS FOR RESISTANCE TO NEMATODES REFINED

MONOXENIC CULTURE OF THE YAM NEMATODE, *S. BRADYS*

Yam nematodes have not previously been cultured under monoxenic conditions, but with careful maintenance, monoxenic cultures of migratory nematodes can provide a reliable supply of inoculum of consistent quantity and quality as are required for screening. In this work, the suitability of excised tuber tissues as a tissue substrate for *S. bradys* was investigated. White yam tuber was washed and cut into pieces with skin intact and then dipped in Bio- Supercarb for 15 min. The pieces were air dry and then cut into slices of about 3-6 g each with skin intact. The skin of each slice was removed and then sterilised in sodium hypochlorite (1 % available chlorine) for 15 min. The slices were rinsed six times with sterilised distilled water and then dabbed dry on filter paper. The sterilised yam slices were plated on 1 % water agar medium in Petri dishes. The plates had been put in a drying cabinet at 30°C for 10 min to dry off excess water. The plates were kept in the culture room at 25°C for about three weeks to callus before inoculated with *S. bradys. S. bradys* was sterilised with 5 drops of 0.1 % malachite green (technical grade) for 5 min and then rinsed 10 times with sterilised distilled water. Each plate containing the callus yam slice was inoculated with 20 or 30 active juvenile and adult stages of *S. bradys*. The plates were sealed with insulating tape and kept in the culture room at 25°C.*S. bradys* were then extracted from both the yam tissue and agar of the plates by a modified Baermann funnel method after five months.

A means to suppress contaminating fungi in yam tissue callus was needed and Bio-Supercarb, a systematic fungicide, which contains carbendazin, was used. The mortality of the fungicide was tested on *S. bradys*. Three levels of concentration of the fungicide, 0.5, 1.1, and 2.2 and litres of water were used and water as the control. About 5 ml of the various fungicide concentrations and water were separately dispensed into sterilised watch glasses. Twenty active stages of *S. bradys* were put in each watch glass; there were three replicates. *S. bradys* was obtained from yam bin cultures at International Institute of Parasitology (IIP), UK. The nematodes were observed daily for three days and the effect of treatment on them assessed by recording the number of live and dead nematodes. A nematode was considered alive when active.

REFINEMENT OF A PROTOCOL FOR SCORING SYMPTOMS OF NEMATODE INJURY AND QUANTIFYING NEMATODE DENSITIES

Experiments were done to examine the rate of emergence of *S. bradys* from chopped yam tissues into water using a Baermann funnel, in order to establish optimum period of incubation with regard to nematode recovery and the deterioration of yam tissue. A novel method for scoring nematode symptoms on yam tubers was also devised and tested. Although not critically evaluated experimentally, different methods were operated

concurrently in the same laboratory at IITA allowing full discussion of the practical elements of each.

The novel method began with a random selection of tubers from each accession. Symptoms of dry rot, galling as well as tissue softness and cracks were then recorded for each tuber (0-3) based on the Table 1.1.

Table 1.1 Description of infection types and scores for yam nematodes

Infection score	Softened yam Tuber tissue (%)	Root/tuber galling	Dry/wet rot	Tuber Cracking	Root Necrosis (%)
0	0	None	None	None	None
1	< 25	Light	Light	Light	Light
2	26 – 50	Moderate	Moderate	Moderate	Moderate
3	> 50	Severe	Severe	Severe	Severe

Based on the scoring, the selected tubers of each accession were grouped according to symptom types. A sub-sample of one to four tubers for each accession was selected from the groupings. Each of the selected tubers was separately peeled (strip) from the proximal to the distal end at three places of about equal distance from one another. The peelings of each tuber were bulked, chopped to about 3-4 mm width and 2 cm length and thoroughly hand-mixed. A 5 g sub-sample was taken for nematode extraction by a modified Baermann funnel method. The nematodes were identified and numbers were counted. Sub-samples of 3 g in muslin bags were taken to assess the population density of *Meloidogyne* species. The tissues in muslin bags were boiled in acid fuchsin stain for 15 min. and each muslin bag was macerated for 20s at low speed. Stained *Meloidogyne* species in juvenile stages and adults were counted.

COMPARISON OF FIELD EXPERIMENTAL DESIGNS

Two field experiments were set up at IITA research farm, Ibadan, to compare the efficiency of Latin square arrangement and Alpha array experimental designs for screening for yam nematode resistance. The experiments were established with alternating allocations of naturally infested soil and naturally infested soil plus artificial infestation with *S. bradys* infected yam tuber peelings. The naturally infested field had been cropped to yam for three consecutive seasons.

STUDIES ON THE INVASION AND POPULATION DYNAMICS OF *S.BRADYS* IN YAM TUBERS.

A study of the population dynamics of yam nematode in tubers was done to examine the role of both the rate of nematode infection and multiplication on observed differences in susceptibility. This field trial studied the invasion and population dynamics of *S. bradys* in resistant and susceptible yam tubers at IITA.

INVESTIGATION OF THE INOCULUM TYPE AND SIZE OF S. BRADYS

A range of nematode delivery systems are available for inoculating nematodes. This work was done to optimise the delivery and quantity of inoculated nematodes in yam nematode

screening protocols. Two types and three sizes of inoculum were used in this study in the screenhouse at IITA. The types of inoculum are nematode in water suspension and chopped yam peelings. The inoculum sizes were 1 g, 25 g and 100 g of chopped *S. bradys* infected yam peelings and 120, 2,800 and 10,000 *S. bradys* active stages representing the number of nematodes in the peelings respectively. Two contrasting IITA *D. alata* accessions, TDa 294 and TDa 92-2 were used. The plants were potted in about 800 ml heat-sterilised 2:1 topsoil-cocopeat mix and then were inoculated after two weeks. A simple line screening design with five replicates was used. The plants were assessed 9 weeks after inoculation by determining any visual nematode damage and reproduction in roots and tubers of all entries in the screen.

INFLUENCE OF REPLICATION ON PRECISION IN ESTIMATING QUANTITATIVE DIFFERENCES IN SUSCEPTIBILITY OF YAM TO NEMATODES

There are currently no good sources of resistance in *Disoscorea rotundata* to yam nematode, although work, to date, suggests that quantitative variation might play a role. This work was done to examine the level of replication that might be required to enable selection of quantitative variants. A set of 21 potted tissue culture plants of two contrasting *D. rotundata* accessions, TDr 87/00571 and TDr 87/00211 were used in this trial in the screenhouse at IITA. The plants were potted in steam sterilised soil-cocopeat mix. The established plants were inoculated with about 1,700 active stages of *S. bradys* (35 g infected yam peelings) per pot. The simple line design was used. Entries were assessed eight weeks after inoculation by recording any visual nematode injury and the number of *S. bradys* in roots or tubers. The plants were randomly harvested as groups of 3, 5 and 13 representing the number of replicates for each entry.

OUTPUT 2 YAM GERMPLASM SCREENED FOR RESISTANCE TO NEMATODES

PRELIMINARY SCREENING FOR NEMATODE RESISTANCE OF IITA YAM GERMPLASM

At the outset of this research project an assessment of nematode resistance in stored yam tubers at IITA was made. This was a collection of germplasm which had not been exposed experimentally to nematode infection. For this reason any potentially resistant tubers identified, had to be treated with caution. A total of 306 *D. rotundata* and 18 *D. alata* accessions were screened at International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The tubers were harvested in 1996 from the research farm at IITA headquarters, Ibadan, Nigeria. The plots were planted with cassava or yam in 1994 and mucuna fallow in 1995. The harvested accessions were either stored in a storeroom maintained at 19°C or kept in an open-air yam barn under ambient conditions for about three months. Each accession was randomly selected and symptoms of dry rot, galling and tissue softness as well as cracking of each tuber were scored (0-3). Based on the scoring, the selected tubers of each accession were grouped according to symptom types. A sub-sample of one to four tubers for each accession was selected from the groupings. Each of the selected tubers was separately peeled (strip) from the proximal to the distal end at three places of about equal distance from one another. The peelings of each tuber were bulked, chopped to about 3-4 mm width and 2 cm length and thoroughly mixed. A 5g sub-sample was taken for nematode extraction by a modified Baermann funnel method. The nematodes were

identified and numbers were counted. Sub-samples of 3 g in muslin bags were taken to assess the population density of *Meloidogyne* species. The tissues in muslin bags were boiled in acid fuchsin stain for 15 min. and each muslin bag was macerated for 20 s at low speed. Stained *Meloidogyne* species in juvenile stages and adults were counted.

SCREENHOUSE SCREENING OF SELECTED GENOTYPES OF IITA YAM ACCESSIONS, NIGERIA.

Based on the preliminary assessment of nematode infestation in yams of the IITA yam breeding programme, 23 genotypes of *D. rotundata* and 17 wild and domesticated *Dioscorea* species were selected for screening in pots. The wild and some domesticated yams were collected from Cameroon, Benin Republic, Republic of Guinea, Cote d'Ivoire, and Burkina Faso all in West Africa by the Biotechnology Research Unit of IITA. Uniform plants from yam minisetts pre-sprouted in sterilised moist coco-peat (shredded coconut husk) were used for screening for resistance to *S. bradys* and *Meloidogyne* spp. A randomised complete block design with eight replicates was used. Established plants in the pots were inoculated with about 360 active stages of *S. bradys* per pot and 500 juveniles of *Meloidogyne* species per pot for each experiment. All entries were assessed five months after inoculation by recording visual nematode damage and the number of nematodes in roots or tubers.

FIELD SCREENING OF GHANAIAN LANDRACES FOR RESISTANCE TO *S. BRADYS* AND *MELOIDOGYNE* SPECIES

Forty Ghanaian yam landraces identified by farmers during the Farmer participatory appraisal (See output 3) were screened for resistance at Crops Research Institute in Kumasi.

GLASSHOUSE INVESTIGATION OF THE VARIATION IN SUSCEPTIBILITY OF YAM SPECIES TO *S. BRADYS*, UK.

This experiment was set up at IIP, UK in the glasshouse. The yam plants were obtained from yam vines except *D. dumetorum* that was from seeds. They were screened in vacapots containing about 200 ml sterilised soil-sand mix. The established plants were inoculated with about 500 active stages of *S. bradys*. All the plants in the screen were assessed 9 weeks after inoculation by recording any apparent nematode damage and reproduction of the nematodes in the roots or tubers.

FIELD SCREENING OF OPEN-POLLINATED YAM SEEDLING POPULATION FOR *S. BRADYS* RESISTANCE.

The open-pollinated yam seedlings were obtained from accession TDr 95/05576 (female) and suspected male, *D. rotundata* var. Puna. The seeds were sown in moistened peat pellets in the glasshouse at IITA. The seedlings were transplanted to the field at 2 to 3 leaf stage (5–6 weeks old) in ridges at 1 m x 0.25 m and then a shed was raised over them. 16-16-16 NPK fertiliser was applied using the ring method. The seedlings were staked immediately they started to crawl. Six weeks after transplanting, the seedlings were

inoculated with about 1,700 *S. bradys* (25 g yam peelings). All the plants in the screen were assessed seven months after inoculation by recording any apparent nematode damage and reproduction of the nematodes in tubers. Each seedling was considered genotypically different and there was no replication.

SCREENHOUSE SCREENING OF YAM PARENTAL LINES FOR RESISTANCE TO *S. BRADYS*

Yam parental lines of the Cellular and Molecular Technologies Laboratories, IITA were tested in a pot experiment in the screenhouse for their reaction to *S. bradys.* Tissue culture plants of ten parental lines (five each of *D. alata* and *D. rotundata*) were screened. The tissue culture plants were potted in steam sterilised soil-cocopeat mix. The established plants were inoculated with about1,700 active stages of *S. bradys* (35 g chopped *S. bradys* infected yam peelings) per pot.

SCREENHOUSE SCREENING OF PARENTS AND PROGENIES OF INTRASPECIFIC HYBRIDISATIONS FOR RESISTANCE TO NEMATODES

Intraspecific hybrids of TDr 87/00211 (male) and TDr 87/00571 (female) were screened in pot experiments in the screenhouse for their reaction to *S. bradys and Meloidogyne incognita* at IITA, Nigeria. Fifty-nine genotypes of intraspecific hybrids (Tissue culture plants) and their parents were screened for their reaction to *S. bradys* and twenty-five for *Meloidogyne incognita*. The tissue culture plants were potted in sterilised soil-cocopeat mix. The established plants were inoculated with about 780 active stages of *S. bradys (*25 g *S. bradys* infected yam peelings) per pot. For the *Meloidogyne* species trial, each pot was inoculated with 400 juveniles of *Meloidogyne* species. The plants were assessed eight weeks after inoculation by recording visual nematode injury and the number of nematodes in roots or tubers.

OUTPUT 3 NEMATODE VARIABILITY ON YAM KNOWN

PARTICIPATORY RURAL APPRAISAL: NEMATODE PESTS PROBLEMS OF YAM IN GHANA

A farmer participatory appraisal of pests and diseases in stored yams was made in Ghana in 1998 to examine farmers' perceptions of nematode disease problems on yams. A total of 17 districts and farmers from 32 towns and villages were considered. The surveyed area is within the Forest-transitional and Guinea-Savannah agroecological zones. The farmers provided information on the type of varieties they grow, cropping system, planting material, storage methods, and pests' problems of yams and control. A total of 243 respondents (farmers) contributed. Dry rot and galling of tubers were identified. Nematode infected yam tubers from all the sites visited were collected. Local and traditional yam varieties were also collected for controlled nematode resistance screening.

IDENTIFICATION AND DISTRIBUTION OF YAM NEMATODES IN GHANA

Nematode populations in yam tissues collected during the rural appraisal were extracted and identified to species level.

HOST RACE STATUS OF *PRATYLENCHUS COFFEAE* ON YAM IN GHANA

Pratylenchus coffeae is widespread in Ghana, where it is a pest of *Musa*, but it was not found infecting yam although, it is known to be a pest of yam in Pacific rim countries and central America. This experiment was done to examine race specific variation in *P. coffeae* in Ghana.

This trial was set up in the screenhouse at UST, Kumasi. Plants from yam minisetts and tissue culture plants of Musa species were potted in sterilised soil-cocopeat mix. The established plants were inoculated with about 800 active stages of *P. coffeae (*45 g infected roots and corms of *Musa*). The plants were assessed eight weeks after inoculation by recording visual nematode injury and the number of nematodes in roots or tubers. Concurrently glasshouse experiments were done in the UK comparing the multiplication of populations of *P. coffeae* from Belize and Ghana on *Musa* cv Grande Naine, *Dioscorea rotundata* and *D. togoensis*.

RESEARCH RESULTS

OUTPUT 1. TECHNIQUES FOR SCREENING YAMS FOR RESISTANCE TO NEMATODES REFINED

MONOXENIC CULTURE OF THE YAM NEMATODE, *S. BRADYS*

S. bradys populations in the inoculated yam tuber slices after treatment increased by *ca* 100 to 247 and 340 to 820 fold for 20 or 30 *S. bradys* after five months respectively (Table 1.2). Mean reproduction increased by 196 fold for 20 *S. bradys* and 600 fold for 30 *S. bradys* inoculated (Table 1.2). The outer surfaces of the yam slices were darkened. This may be due to necrosis of invaded tissues, whereas the inner parts had fresh tissues. All the culture plates were free from contaminating microorganisms. Dry rot symptoms characteristic of *S. bradys* infection in yam tissues were not observed. This is probably because of the humid condition in the Petri plates. Also, nematodes are known to behave differently in callus plant tissues. In previous work at IITA culturing of *Scutellonema bradys* in the greenhouse was successful on sweet potato and cowpea, but not on sprouting yam tuber pieces. However, this technique using sterilised yam slices on water agar medium in Petri dishes can support high reproduction of *S. bradys* and constitutes a suitable method for mass-production of the nematodes for screening for host plant resistance. It is impossible to track the fate of inoculated nematodes, but it is always the case that a proportion of nematodes are not potent. These results suggest that raising the inoculum level from 20–30 dramatically improved the multiplication of nematodes in the time frame of the experiment.

Table 1.2. *S. bradys* reproduction in yam tuber slices five months after inoculation

Plate no.	Weight of yam Slices/ g	Initial *S. bradys* Population (Pi)	Mean no. *S. bradys* (Pf)	Pf/Pi
1	3.0	20.0	2040.0	102.0
2	5.0	20.0	5230.0	261.5
3	3.0	20.0	3454.0	172.7
4	4.0	20.0	4930.0	246.5
5	6.0	30.0	24600.0	820.0
6	6.0	30.0	22800.0	760.0
7	3.0	30.0	10250.0	341.7
8	4.0	30.0	14400.0	480.0

Table 1.3. Effect of Bio-Supercarb concentration on *S. bradys* with initial inoculation of 20 nematodes

Dosage	*Mean no. *S. bradys* alive	Mean no. *S. bradys* dead	% Live nematodes	% Dead Nematodes
Recommended (1.1)	19.0	1.0	95.0	5.0
Low (0.5)	20.0	0.0	100.0	0.0
High (2.2)	20.0	0.0	100.0	0.0
Tap water (control)	20.0	0.0	100.0	0.0

*Mean of three replicates

No death was observed in the low, high and control treatments after three days however, one death was observed in the recommended dosage (Table 1.3). Analysis of variance showed that there were no significant differences between treatments. It is very difficult to axenise yam tissues for monoxenic culture, but Bio-Supercarb can be used to treat yam slices for the suppression of fungi growth during the monoxenic culture of *S. bradys.*

REFINEMENT OF A PROTOCOL FOR SCORING SYMPTOMS OF NEMATODE INJURY AND QUANTIFYING NEMATODE DENSITIES

The 0-3 rating of dry rot symptoms (Table 1.1) worked well as a means of assessment and it was not thought that the creation of further divisions of symptom severity would lead to increased accuracy. Peeling yam tissue from the proximal to the distal end reduces bias in selecting areas of tissue for nematode population estimates, but smaller samples of peel taken systematically over the tuber would probably work just as well.

Results from Baermann funnel extracts in water showed that most nematodes escaped from macerated yam peelings, within two days of setting up the incubation at ambient

temperatures. Incubated tissues rapidly deteriorated after 2 days, but the extra work required for daily removal and replenishment of extracts, which does increase their longevity, did not recover significantly more nematodes and did not justify the extra work involved. This method would in any case be impossible within very large screening trials.

COMPARISON OF FIELD EXPERIMENTAL DESIGNS

The dry rot scores and nematode counts for the tested accessions are given in Tables 1.4 &1.5. The consistency and reliability of field screening was greatly improved by artificial inoculation of nematodes and such methods, i.e. which do not rely on natural infection, are recommended. Neither design eliminated the occurrence of false negative (resistant) reactions as a result of 'escapes' from natural nematode infection. Such escapes can occur because of the heterogeneous distribution of nematodes in the soil. Generally, the Latin square arrangement recorded more consistent dry rot rating and high nematode counts than the Alpha array and gave small (4%) improvements in efficiency over the Alpha array. Latin square which also benefits from being relatively simple to use can be recommended.

Table 1.4. Effect of a Latin square design on the reaction of ten IITA yam parental lines to *S. bradys* eight weeks after storage (Inoculated with ca 2,500 *S. bradys* [50 g infected yam peelings])

	*Mean dry rot index		Mean no. *S. bradys*/ 5 g tuber peelings					
	Naturally	[d]Artificially	Naturally infested soil			Artificially infested Soil		
Yam Accession	Infested Soil	Infested Soil	No.	[k]Trans-formed	s.e	No.	Trans-Formed	s.e
TDr 131[a]	0.3	3.0	80.0	5.7	6.8	1481.4	37.9	3.5
TDr 89/01438[b]	3.0	3.0	845.7	23.7	8.0	800.6	26.4	3.5
TDr 93-28[a]	1.6	3.0	367.0	16.1	6.0	716.2	25.1	3.5
TDr 93-72[a]	2.6	3.0	741.6	25.2	6.0	395.6	19.1	3.5
TDr 89/02677[b]	2.6	3.0	1101.6	31.2	6.0	849.0	27.0	3.5
TDr 93-82[a]	2.5	3.0	521.3	19.7	6.8	447.5	20.6	3.9
TDr 93-1[a]	1.8	3.0	724.0	23.5	6.0	146.0	11.8	3.5
TDr 93-31[a]	2.5	3.0	641.3	22.6	6.8	147.7	11.9	4.6
TDr 93-83[a]	1.0	3.0	431.3	17.5	6.8	86.3	8.0	3.5
TDr 93-2[a]	2.2	3.0	954.0	26.4	6.0	435.0	19.5	3.5
CV	50.9	0.0		62.7			36.3	
[c]Root MSE	1.0	0.0		13.5			7.8	

*Average of 5 replicates, s.e: Standard error. TDr: *Dioscorea rotundata*, [a]landrace, [b]Breeder's line [k]Square root (Mean + 0.5) and SAS adjusted for missing data. [C]Root mean square error. [d]Naturally infested soil plus chopped *S. bradys* infested yam peelings.

Table 1.5. Effect of an Alpha array design on the reaction of ten IITA yam parental lines to *S. bradys* eight weeks after storage (Inoculated with ca 2,500 *S. bradys* [50 g infected yam peelings])

			Mean no. *S. bradys*/ 5 g tuber peelings					
	*Mean dry rot index		Naturally infested soil			Artificially infested soil		
Yam Accession	Naturally infested soil	[d]Artificially infested soil	No.	[k]Trans-formed	s.e	No.	Trans-formed	s.e
TDr 131[a]	1.6	3.0	375.8	16.7	5.6	1198.3	26.6	7.9
TDr89/01438[b]	1.9	3.0	460.4	16.9	4.7	470.0	20.1	7.9
TDr 93-28[a]	1.3	3.0	288.3	15.4	7.5	898.7	25.4	5.0
TDr 93-72[a]	2.1	2.3	759.3	23.9	4.7	178.3	11.8	8.0
TDr 89/ 02677[b]	2.3	2.7	739.3	26.6	5.1	329.0	18.0	8.0
TDr 93-82[a]	1.5	3.0	590.0	17.6	9.3	570.6	22.1	4.6
TDr 93-1[a]	2.3	2.3	137.3	10.3	7.6	164.7	10.5	5.4
TDr 93-31[a]	1.3	3.0	251.7	11.7	7.5	265.0	14.8	5.5
TDr 93-83[a]	0.9	2.3	147.4	8.8	4.4	393.3	19.0	8.0
TDr 93-2[a]	0.0	2.3	20.0	3.1	7.6	318.5	16.4	6.8
CV	70.6	29.6		72.9			67.5	
[c]Root MSE	1.1	0.8		11.8			12.6	

*Average of 10 replicates, s.e: Standard error. TDr: *Dioscorea rotundata*, [a]Landrace, [b]Breeder's line. [k] Square root (Mean + 0.5) and SAS adjusted for missing data. [C]Root mean square error. [d]Naturally infested soil plus chopped *S. bradys* infested yam peelings.

STUDIES ON THE INVASION AND POPULATION DYNAMICS OF *S.BRADYS* IN YAM TUBERS.

Nematode population at harvest and subsequent dry rot symptoms ranged from 0 to 2.8 and 0 to 560 respectively. At 8 weeks after harvest, the range was 0 to 3 for dry rot and 0 to 800 for number of nematodes. Generally, symptoms and nematode population density increased with time in the susceptible yam accessions, except in TK106 which had little or no living tissue left for invasion. There was no change in dry rot symptom expression and invasion in the resistant yam accession, *D. dumetorum* (Table 1.6). In susceptible yam tubers the *S. bradys* had invaded at harvest and continued to reproduce in storage. This work cannot detail the mechanism of resistance in *D. dumetorum*, but it is likely that post-infectional characteristics in the yam tuber, confer resistance. It is less likely that nematodes are completely prevented from entering the *D. dumetorum* tuber.

Table 1.6. Invasion and population dynamics of *S. bradys* in yam tubers
(Means of 6 replicates and inoculated with *ca* 2,500 S. bradys [50 g yam peelings])

Yam accession (all *D. rotundata* except otherwise stated)	Dry rot score		Mean no. *S. bradys*/5 g tuber peelings	
	Harvest	After 8 wk	Harvest	After 8 wk
TDr 89/01438	1.7	1.8	210.0	490.0
CR1/0051	2.8	3.0	180.0	800.0
D. dumetorum	0.0	0.0	0.0	0.0
TDr 131	2.2	2.4	60.0	680.0
TK 106	2.0	2.7	560.0	60.0

INVESTIGATION OF THE INOCULUM TYPE AND SIZE OF S. BRADYS

In most cases, the *S. bradys* infected yam peelings recorded higher nematode numbers than with the nematode in water suspension (Table 1.7). There was no significant difference between the inoculum size in peelings however, nematode numbers increased from the lowest weight of 1g to the highest of 100 g peelings. Nematode suspensions did not give consistent reproduction of *S. bradys* in both yam accessions. The coefficient of variation (CV) was high for suspension, for example, 68.8 and 80.2 for number of *S. bradys* in roots and tubers as against 46.4 to 67.8 for peelings respectively. Based on the results, *S. bradys* infected peelings are a better source of inoculum, if available, for screening for nematode resistance in yam.

Table 1.7. Efficiency of inoculum type and size of *S. bradys* in resistance screening

Yam accession	Inoculum		Mean tuber Cracking Index	Mean no. *S. bradys*/ 5 g tissue			
						Tuber	
	Type	Size		Roots	Range	peelings	Range
TDa 294	Peels	1.0 g	0.5 (0.6)	306.0	65.0-675.0	213.0	0.0-820.0
TDa 294	Suspension	120.0	1.0 (0.0)	9.0	0.0-35.0	0.0	0.0-0.0
TDa 294	Peels	25.0 g	0.0 (0.0)	429.0	150.0-707.0	85.0	60.0-100.0
TDa 294	Suspension	2800.0	0.3 (0.6)	119.0	15.0-220.0	11.0	0.0-30.0
TDa 294	Peels	100.0 g	0.7 (0.6)	461.0	287.0-635.0	368.0	55.0-680.0
TDa 294	Suspension	10000.0	1.0 (0.0)	132.0	0.0-215.0	34.0	0.0-90.0
TDa 92-2	Peels	1.0 g	1.0 (0.0)	136.0	15.0-310.0	95.0	30.0-245.0
TDa 92-2	Suspension	120.0	1.5 (0.6)	3.0	0.0-10.0	16.0	10.0-25.0
TDa 92-2	Peels	25.0 g	0.1 (0.4)	421.0	116.0-1160.0	430.0	80.0-1413.0
TDa 92-2	Suspension	2800.0	1.0 (0.0)	30.0	0.0-105.0	32.0	0.0-85.0
TDa 92-2	Peels	100.0 g	0.3 (0.5)	437.0	0.0-1080.0	518.0	20.0-890.0
TDa 92-2	Suspension	10000.0	0.7 (0.6)	55.0	0.0-155.0	71.0	0.0-190.0

Standard deviation in parentheses. Mean of 5 replicates.

INFLUENCE OF REPLICATION ON PRECISION IN ESTIMATING QUANTITATIVE DIFFERENCES IN SUSCEPTIBILITY OF YAM TO NEMATODES

The number of *S. bradys*/5g tissue ranged from 135 to 929 for roots and 1 to 55 for tubers for TDr 87/00571 and 265 to 1889 for roots and 4 to 40 for tubers for TDr 87/00211 (Table 1.8), with significant differences (P=0.05) between the replications. Increasing replication improves the precision of quantitative differences in susceptibility. In practice, practical considerations will govern the level of replication, but the results suggest that greater than 5 replicates give better separation of quantitative differences in susceptibility in yam to *S. bradys*.

Table 1.8. Influence of replication on quantitative difference in susceptibility of yam to *S. bradys* (Inoculated with 1700 *S. bradys*)

Replicate number	Yam accession	Mean tuber cracking index	s.e	Mean no. *S. bradys*/ 5 g tissue			
				Roots	s.e	Tuber peelings	s.e
3	TDr 87/00211	1.0 (0.0)	0.3	135.0 (82.9)	6.8	2.0 (4.0)	27.5
5	TDr 87/00211	1.4 (0.6)	0.2	343.0 (164.9)	5.2	1.0 (0.6)	21.3
13	TDr 87/00211	0.5 (0.5)	0.1	929.0 (642.3)	3.3	55.0 (58.4)	13.2
3	TDr 87/00571	1.0 (0.0)	0.4	265.0 (243.0)	12.2	4.0 (4.9)	1.9
5	TDr 87/00571	2.3 (1.2)	0.3	956.0 (484.5)	9.4	27.0 (23.1)	1.5
13	TDr 87/00571	2.0 (0.8)	0.2	1889.0 (1715.3)	7.0	40.0 (38.6)	0.9

Standard deviation in parenthesis. s.e : standard error

OUTPUT 2 YAM GERMPLASM SCREENED FOR RESISTANCE TO NEMATODES

PRELIMINARY SCREENING FOR NEMATODE RESISTANCE OF IITA YAM

The highest number of nematodes recorded was 4,500/5 g for *S. bradys* and 250/5 g for *Meloidogyne* species. *S. bradys* was the most prevalent nematode occurring in 46% of accessions. 10.2 % and 0.3 % of the accessions were infested with *Meloidogyne* and *Pratylenchus* species respectively. No linear relationship was observed between symptom ratings and nematode population densities in tubers for either nematode. Based on the number of nematodes per unit tissue selection criteria, the following number of accessions were placed in each reaction category: 0-10 = Resistant (R), 11-25 = Partially resistant (PR), 26–50 = Moderately susceptible (MS), > 50 = Susceptible (S) and Sensitive = severe symptom and low nematode density.

Table 2.1. IITA yam accessions grouped under reaction categories

	No. of accessions for nematodes reactions				
	S. bradys		*Meloidogyne* species		*Pratylenchus*
Reaction category	*D. rotundata*	*D. alata*	*D. rotundata*	*D. alata*	Yams
R	160.0	13.0	202.0	18.0	0.0
PR	43.0	2.0	43.0	0.0	0.0
MS	48.0	0.0	24.0	0.0	2.0
S	52.0	3.0	9.0	0.0	6.0
Sensitive	3.0	0.0	28.0	0.0	0.0

SCREENING OF SELECTED GENOTYPES OF IITA YAM ACCESSIONS FOR RESISTANCE TO *S. BRADYS* AND *MELOIDOGYNE INCOGNITA*, NIGERIA.

In field screening all genotypes selected were susceptible to *S. bradys*, but there were significant differences (P<0.01) between accessions. There was a strong linear relationship between dry rot symptoms and *S. bradys* population. The number of *S. bradys*/5 g ranged from 0 to 1,825. In most cases, higher dry rot scores were associated with higher the numbers of *S. bradys* (Table 2.2).

Table 2.2. Selected IITA yam accessions and their reaction to *S. bradys*
(Mean of unequal number of replicates (3-12) and inoculated with about 800 *S. bradys* (50g infected yam peels)

	Dry rot index (0-3)		
Yam accession	Harvest	After 8 weeks	No. *S. bradys*/5 g after 8 weeks
TDa 92-2	1.0	2.9	1825.0
TDa 95-92	1.6	3.0	1167.0
TDr 93-91	0.8	2.2	1086.0
TDa 96-12	1.3	2.8	1048.0
TDa 297	1.0	2.8	840.0
TDr 93-22	2.0	2.3	529.0
IN94R-23	0.5	2.2	488.0
TDr 131	1.0	2.6	427.0
TDa 93-36	1.8	2.9	408.0
TDa 96-5	1.3	2.5	393.0
TDr 93-49	1.2	2.3	327.0
TDr 93-82	0.7	2.7	285.0
IN94R-5	0.5	2 0	260.0
TDr 93-74	1.2	2.2	211.0
TDa 95-27	2.0	2.5	209.0
TDr 93-9	3.0	3.0	160.0
TDr 93-72	2.0	3.0	128.0
TDr 93-1	1.0	3.0	105.0
TDr 93-39	0.0	0.0	0.0

In general, *D. alata* (TDa) had higher population densities of *S. bradys* than *D. rotundata* (TDr) ranging from 209 to 1825 and 0 to 1086 respectively**.** All IITA *D. alata* and *D. rotundata* accessions screened are susceptible to *S. bradys*.

Table 2.3. Reaction of IITA yam accessions to *Meloidogyne incognita* in pot trials
(Means of 8 replicates and inoculated with about 400 *Meloidogyne* juveniles [J2])

Yam accession (all D. rotundata except otherwise specified)	Tuber galling (0-3)	Root galling (0-3)	*Meloidogyne* J2/5 g tissue Roots	Tuber
1010	1.0	0.4	22.0	23.0
D. mangenotiana (Guinea forest)	0.1	0.6	268.0	13.0
TDr 93-82	0.5	0.9	5.0	6.0
TDr 179	0.4	0.3	4.0	4.0
TDr 89/02565	0.4	0.4	12.0	3. 0
KK102	1.0	0.8	15.0	3.0
TDr 131	0.4	0.4	3.0	2.0
TDr 89/02677	0.8	0.3	47.0	2.0
TDr 93-25	0.5	0.6	16.0	1.0
2008	0.4	0.6	13.0	0.0
1024	0.3	0.1	3.0	0.0
1020	0.5	0.8	2.0	0.0
1009Tm101	0.1	0.3	0.0	0.0
BP 129	0.1	0.3	3.0	0.0
Ka 120	0.1	1.0	8.0	0.0
Yb 114	0.1	1.0	0.0	0.0
KP 106	0.0	0.0	9.0	0.0
NF 104	0.3	0.6	3.0	0.0
TDr 93-1	0.1	0.9	2.0	0.0
TDr 93-28	0.3	0.5	3.0	0.0
TDr 93-31	0.0	0.3	0.0	0.0
TDr 93-47	0.0	0.3	0.0	0.0
TDr 93-72	0.4	0.3	3.0	0.0
TDr 93-74	0.4	0.4	0.0	0.0
TDr 95-78	0.1	0.5	5.0	0.0
TDr 93-79	0.3	0.4	8.0	0.0
TDr 95-83	0.3	0.6	53.0	0.0
TDr 93-89	0.1	0.0	2.0	0.0
TDr 87/00158	0.1	0.9	0.0	0.0
TDr 89/01438	0.0	0.1	0.0	0.0
TDr 89/02461	0.8	0.1	0.0	0.0
TDr 89/02494	0.4	0.8	10.0	0.0
IN94R-5	0.0	0.4	0.0	0.0
TDr 95-158	0.3	0.8	0.0	0.0
IN94R-102	0.0	0.4	1.0	0.0
D. praehensilis (Moyenne in Guinea)	0.1	0.8	0.0	0.0
BP128	0.3	0.6	7.0	0.0
Baniakpa	0.0	0.1	0.0	0.0
D. praehensilis (Guinea forest)	0.0	0.3	0.0	0.0
D. Praehensilis (Benin Republic)	0.3	0.4	0.0	0.0
Standard deviation	0.6	0.5	0.9	0.1

Analysis of variance showed highly significant differences (P = 0.01) between yam accesssions. The mean number of *Meloidogyne incognita* ranged from 0 to 268/ 5g roots and 0 to 23/5 g tuber (Table 2.3). There was no apparent correlation between galling in roots and tubers and numbers of nematodes in root and tubers. There was no linear relationship between susceptibility in roots and tubers. These are results are difficult to interpret especially regarding classification because of the poor reaction of the yams to *M.*

incognita. This is probably because of the high temperatures recorded in the glasshouse resulting in killing of the nematodes or making them impotent.

SCREENING OF GHANAIAN LANDRACES FOR RESISTANCE TO *S. BRADYS* AND *MELOIDOGYNE* SPECIES

Based on the farmer participatory appraisal, 40 Ghanaian yam landraces were screened. There were highly significant differences (P = 0.01) between yam varieties. There was weight reduction in the stored yam tubers, and dry rot scores also increased within the storage period. There was a linear relationship between the weight reduction in tubers infected with *S. bradys* and the increased dry rot symptoms. It is noteworthy that the severity of both dry rot and root knot nematode galls increased during storage. This implies that both species continue to multiply in storage. Gall scores did not correlate with tuber weight loss and confirm farmer perceptions that root knot nematode is a less important nematode in terms of crop loss. Dry rot and *S. bradys* population density revealed a strong negative correlation (r =0.42, P = 0.01). *S. bradys* counts at four weeks ranged from 0 to 951/5 g and from 0 to 675/5 g at 11 weeks after harvest (Table 2.4). Again, severely infected yam tubers recorded high nematode populations. However, some severely infected tubers had low *S. bradys* population probably because these tubers were either dried out or completely destroyed by dry and wet rot with very little or no living tissue remaining. Ten contrasting varieties were selected for further studies and results confirmed that *D. dumentorum* var. *nkanfo* and *D. cayenensis* var. *Afun* are resistant to *S. bradys*. *D. dumentorum* var. *nkanfo* is also resistant to *Meloidogyne incognita*.

Table 2.4. Ghanaian landraces reaction to *S. bradys* resistance, Crops Research Institute.

(Field trial, 4 replicates and inoculated with about 6,000 *S. bradys* (50 g infected yam peelings)

Yam varieties	Dry rot index (0-3)			No. *S. bradys*/5 g tuber peelings	
	Harvest	4 wk	11 wk	4 wk	11 wk
Yeremma	1.5 (1.0)	1.5 (0.6)	2.3 (0.5)	1073.0	1050.0
Saabiri	0.5 (0.6)	1.3 (1.0)	1.8 (0.5)	405.0	988.0
Sante	0.5 (1.0)	1.3 (0.5)	2.0 (0.8)	870.0	880.0
Matches	1.5 (0.6)	2.0 (0.0)	2.3 (0.5)	518.0	869.0
Afi	0.7 (1.2)	2.0 (0.0)	2.3 (0.6)	646.0	863.0
Mmrefi	0.5 (0.6)	0.8 (1.0)	1.3 (1.0)	430.0	817.0
Nigeria	1.0 (0.8)	1.5 (0.6)	2.0 (0.0)	1004.0	804.0
Afasie-Kwandwo	0.5 (0.6)	1.0 (0.0)	2.0 (0.0)	398.0	749.0
Datordi	1.8 (0.5)	2 .0 (0.0)	2.5 (0.6)	933.0	709.0
Accra	2.0 (0.0	2.0 (0.0)	2.3 (0.5)	821.0	504.0
Tempe	1.3 (1.0)	1.8 (0.6)	2.0 (0.8)	470.0	468.0
Nsoadansi	1.0 (0.0	1.5 (0.6)	2.0 (0.0)	1125.0	419.0
Puna	2.3 (0.5)	2.3 (0.5)	2.5 (0.6)	371.0	416.0
Abrewa nwo	1.0 (1.2)*	2.3 (0.5)	2.5 (0.6)	598.0	396.0
Kyemogo	0.8 (0.1)	1.0 (0.0)	2.3 (0.5)	327.0	379.0
Sanyata	2.3 (1.0)	2.3 (1.0)	2.8 (0.5)	541.0	331.0
Kpirindwo	2.3 (0.6)	1.7 (0.6)	2.3 (0.6)	482.0	322.0
Akaba	1.8 (1.3)	2.5 (0.6)	2.5 (1.0)	780.0	320.0
Zong	1.5 (0.6)	2.0 (0.0)	2.8 (0.8)	761.0	308.0
Ziglangbo	0.8 (1.0)	1.8 (0.5)	1.5 (0.6)	525.0	275.0
Kwaa-Asamoah	1.3 (1.0)	2.0 (0.8)	2.0 (0.8)	132.0	255.0
Serwaah	2.3 (0.6)	2.3 (0.6)	3.0 (0.0)	525.0	232.0
Dakpam	1.3 (1.0)	1.0 (1.2)	1.5 (1.3)	194.0	229.0
Limor	2.3 (0.5)	2.5 (0.6)	2.8 (0.5)	478.0	171.0
Moninyoli	2.0 (0.8)	1.8 (0.5)	2.5 (1.0)	647.0	153.0
Dakorba	2.0 (0.8)	2.0 (0.0)	2.5 (0.6)	315.0	136.0
Lili	1.0 (0.0)	1.5 (1.0)	2.3 (1.0)	518.0	125.0
Muchumudu	2.0 (0.8)	1.8 (0.5)	2.8 (0.5)	516.0	109.0
Denteh	1.3 (1.0)	1.5 (0.6)	2.0 (1.2)	245.0	96.0
Kyire-Kumasi	1.3 (1.2)	1.7 (0.6)	2.0 (1.0)	368.0	95.0
Kpiringa	2.0 (0.0)	2.3 (0.5)	3.0 (0.0)	467.0	93.0
Chenchito	2.5 (0.5)	2.5 (0.5)	3.0 (0.0)	790.0	91.0
Agyaasi	1.3 (1.0)	1.5 (0.6)	2.3 (1.0)	250.0	86.0
Sono bayere	1.8 (1.0)	2.0 (0.0)	2.5 (0.6)	732.0	69.0
Labarko	2.0 (1.7)	2.3 (1.2)	2.7 (0.6)	71.0	68.0
Adi-amaaba	0.5 (0.6)	1.0 (0.0)	0.8 (0.5)	829.0	45.0
Fugla	1.5 (1.0)	1.5 (0.6)	2.8 (0.5)	226.0	38.0
Tela	0.8 (1.0)	1.3 (1.0)	1.3 (1.0)	380.0	28.0
Afun	0.3 (0.5)	0.3 (0.5)	0.3 (0.5)	3.0	5.0
Nkanfo	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0	0.0

*Standard deviation in parentheses.

Pot Screening of Ghanaian landraces for resistance to *S. bradys*

The number of *S. bradys*/5 g roots ranged from 180 to 1,569 and for *S. bradys*/ 5 g tubers from 5 to 274 (Table 2.5). There were highly significant differences (P = 0.01) between the yam varieties. There were more nematodes in roots than in tubers however, there was no linear correlation between them. There was also no correlation between dry rot and nematodes population in tubers. Cluster analysis and Duncan Multiple Range Test showed that *D. dumetorum* var. *Nkanfo* is resistant and this agreed with the field experiments.

Table 2.5. Reaction of selected Ghanaian landraces to *S. bradys* in pots
(Means of 4-6 replicates and inoculated with 1,400 *S. bradys* (55 g yam peels)

Yam varieties	Dry rot of tubers (0-3)	No. *S. bradys*/5 g tissue	
		Roots	Tuber
Chenchito	1.0	806.0	274.0
Lili	1.7	1281.0	261.0
Kyerekumasi	2.4	225.0	117.0
D. bulbifera	1.0	916.0	75.0
D. esculenta	0.0	1569.0	73.0
D. cayenensis var. Afun	1.6	182.0	7.1
D. dumetorum var. Nkanfo	0.5	180.0	5.0

Pot Screening of Ghanaian landraces for resistance to *Meloidogyne* species

The number of juveniles of *Meloidogyne incognita* /5 g roots ranged from 6 to 1104 and from 6 to 170/5 g tubers (Table 2.6). There were highly significant differences (P = 0.01) between the yam varieties. Nkanfo recorded the lowest number of nematodes in roots and tubers as well as coefficient of variation (CV). There was no linear correlation between tuber galling and population of J2. Not surprisingly there were several significant correlations, e.g. root galling and J2 population in roots (r = 0.53, P = 0.05); galling and number of eggs in tubers (r = 0.62, P = 0.01); tuber galling and J3 population in tubers (r = 0.49, P = 0.05) and tuber galling and number of females in tubers (r = 0.71, P = 0.01). Cluster analysis and Duncan Multiple Range Test revealed that *D. dumetorum* var. Nkanfo is resistant and *D. bulbifera* and *Chenchito*, highly susceptible. This result agreed with field data.

Table 2.6. Reaction of selected Ghanaian landraces to *Meloidogyne incognita* in pots
(Means of 4-6 replicates and inoculated with 10000 *Meloidogyne* J2 (10 g galled tomato roots)

Yam varieties	Tuber galling (0-3)	Root galling (0-3)	J2/5 g roots	Eggs/5 g tuber	J2/5 g tuber	J3/5 g tuber	Females/5 g tuber
Nkanfo	1.0	0.5	6.0	3.0	6.0	0.0	0.0
Afun	1.6	1.2	58.0	69.0	36.0	19.0	16.0
D. bulbifera	0.5	1.3	1104.0	1 0.0	170.0	0.0	3.0
Yeremma	1.6	2.0	821.0	55.0	13.0	10.0	8.0
Chenchito	2.4	2.4	634.0	322.0	99.0	162.0	60.0

GLASSHOUSE INVESTIGATION OF THE VARIATION IN SUSCEPTIBILITY OF YAM SPECIES TO *S. BRADYS*, UK.

Table 2.7. Reaction of *S. bradys* in roots and tubers of yam species
(Mean of 4 replicates and inoculated with 500 *S. bradys*)

	Mean no. *S. bradys*/5 g tissue	
Yam species	Roots	Tuber
D. dumetorum	10630.0	800.0
D. abyssinica	1035.0	625.0
D. rotundata 89/01892	950.0	255.0
D. rotundata 91/00658	295.0	225.0
D. preussii	140.0	5.0
D. togoensis	140.0	0.0

There were no significant differences between treatments. The mean number of *S. bradys* ranged from 140 to 10,630/5 g roots and 0 to 800/5 g tuber (Table 2.7). Again, there were more nematodes in the roots than tubers. None of the entries exhibited symptoms of nematode injury, furthermore there was no apparent relationship between susceptibility in roots and tubers, suggesting that susceptibility in roots of yams is not clearly linked to the susceptibility of tubers. *D. togoensis* and *D. preussii* were found to be potentially resistant and *D. dumetorum* and *D. abyssinica* were highly susceptible. The results of this test contrast sharply with others indicating that *D. dumetorum* has resistance to both *S. bradys* and *Meloidogyne incognita*. This appears to indicate that resistance to nematodes is not likely to be species specific.

FIELD SCREENING OF OPEN-POLLINATED SEEDLING POPULATION FOR *S. BRADYS* RESISTANCE.

The dry rot symptoms ranged between 0 to 3 while the number of *S. bradys* was between 0 to 1,985/ 5 g tuber. Cluster analysis and Duncan Multiple Range test for dry rot scores and the number of *S. bradys*/5 g tuber showed that 6 % of the genotypes are potentially resistant whilst 94 % are highly susceptible.

POT SCREENING OF YAM PARENTAL LINES FOR RESISTANCE TO *S. BRADYS*

All the parental lines were susceptible to *S. bradys* and there were no significant differences between them. The number of *S. bradys*/5 g roots ranged from 507 to 1,518 and for number of *S. bradys*/5 g from 9 to 138 (Table 2.8).

Table 2.8. Variation in susceptibility of yam parental lines to *S. bradys*
(Means of 4-7 replicates and inoculated with about 1,700 *S. bradys*)

	Tuber cracking	*S. bradys*/5 g tissue	
Yam parental lines	(0-3)	Roots	Tuber
TDr 93-1	1.1	1479.o	18.0
TDr 93-2	1.6	1225.0	104.0
TDa 92-2	0.7	792.0	42.0
TDa 95/00328	1.4	680.0	138.0
TDr 87/00571	1.6	1109.0	24.0
TDa 87/01091	1.0	716.0	13.0
TDa 95-310	1.0	507.0	9.0
TDa 85/00257	1.0	835.0	33.0
TDr 93-50	2.0	1518.0	59.0
TDr 87/00211	0.9	558.0	24.0

All the parental lines are susceptible in roots and tuber to *S. bradys*. However, variation in susceptibility among the lines was observed. There was no correlation between the number of *S. bradys* in roots and that in tubers.

POT SCREENING OF PARENTS AND PROGENIES OF INTRASPECIFIC HYBRIDISATIONS FOR RESISTANCE TO NEMATODES

There were no significant differences between the genotypes regarding the number of *S. bradys* in tubers. Again, no correlation was found between the numbers of nematodes in roots and that in tubers. All the hybrids and their parents in the screen were susceptible to *S. bradys* although there was quantitative variation in susceptibility. Selected contrasting hybrids screened on the field were all susceptible and agreed with the pot trial. This suggests that resistance of yam to *S. bradys* is not likely to be controlled by recessive genes. The number of *S. bradys*/5 g root ranged from 16 to 4935 and that of *S. bradys*/5g tuber from 0 to 259 (Table 2.9). Higher numbers of the nematodes were again found in roots than in tubers.

Table 2.9. Reaction of yam intraspecific hybrids to *S. bradys*

(Means of 4–8 replicates inoculated with about 780 *S. bradys*)

Parents and hybrids	Tuber cracking (0-3)	Mean no. *S. bradys*/5 g tissue	
		Roots	Tuber
CR1/0096	0.7	450.0	16.0
CR1/0051	0.8	1098.0	50.0
CR/002	1.0	1795.0	42.0
CR1/0036	1.3	222.0	17.0
CR1/0058	1.0	1590.0	123.0
CR1/00102	1.0	470.0	8.0
CR1/00192	1.5	1036.0	238.0
CR1/0027	2.1	4935.0	259.0
CR1/0020	0.6	132.0	1.0
CR1/0029	1.0	781.0	11.0
CR1/00193	0.5	583.0	3.0
CR1/OO92	1.0	1658.0	16.0
CR1/0022	0.4	210.0	12.0
CR1/00172	1.8	1464.0	116.0
CR1/0095	1.5	1301.0	25.0
CR1/001	3.0	1362.0	180.0
CR1/0034	1.0	222.0	21.0
CR1/0048	2.0	1491.0	186.0
CR1/0065	1.3	237.0	12.0
CR1/0098	1.8	959.0	107.0
CR1/0044	1.3	259.0	25.0
CR1/0039	1.4	67.0	18.0
CR1/0024	0.5	1742.0	25.0
CR1/0091	1.8	1293.0	107.0
CR1/00146	0.7	890.0	23.0
CR1/0046	2.8	662.0	66.0
CR1/0025	0.5	1297.0	8.0
CR1/0038	1.3	368.0	38.0
CR1/OO64	1.2	325.0	58.0
CRI/0041	1.0	1169.0	30.0
CR1/00113	1.4	936.0	134.0
CR1/00130	0.3	209.0	23.0
CR1/0075	1.3	282.0	34.0
CR1/00138	1.2	728.0	91.0
CR1/0056	0.3	904.0	7.0
CR1/0035	1.3	40.0.	38.0
CR1/00173	1.3	316.0	83.0
CR1/0069	1.3	979.0	29.0
CR1/00129	0.8	208.0	7.0
CR1/0054	1.0	4689.0	152.0
CR1/0016	1.0	1288.0	0.0
CR1/0053	1.4	1060.0	31.0
CR1/00101	1.0	55.0	68.0

Table 2.9 (cont.)

Parents and hybrids	Tuber cracking (0-3)	Mean no. *S. bradys*/5 g tissue	
		Roots	Tuber
CR1/0040	0.6	1217.0	13.0
CR1/0037	1.0	536.0	8.0
CR1/0052	1.0	1681.0	51.0
CR1/0028	0.3	650.0	30.0
CR1/00105	1.3	304.0	4.0
CR1/00143	3.0	771.0	50.0
CR1/00126	1.0	175.0	45.0
CR1/0074	1.5	1161.0	147.0
CR1/00106	1.0	624.0	26.0
CR1/0093	1.0	610.0	71.0
CR1/0011	0.8	1745.0	42.0
87/00571	2.0	1194.0	14.0
87/00211	0.7	735.0	22.0
CR1/00139	2.7	446.0	116.0
CR1/0030	1.8	2741.0	115.0
CR1/0088	1.0	16.0	130.0

The parent (TDr 87/00211) was highly susceptible to *Meloidogyne incognita* (Table 2.10). There was variation in susceptibility between hybrids, but very careful and precise screening and selection would be required to utilise this variation with confidence. Procedurally, it is appropriate to use all stages of *Meloidogyne* species for assessment of susceptibility in yam tubers as there were significant differences (P = 0.01) between egg, J3 and female counts in tubers.

Table 2.10. Reaction of yam intraspecific hybrids to *Meloidogyne incognita*

(Means of 4-8 replicates and inoculated with about 400 *Meloidogyne* J2s)

Yam hybrid and parent	Tuber galling (0-3)	Root Galling (0-3)	Root knot J2/5 g root	Root knot eggs/5 g tuber	Root knot J2/5 g tuber	Root knot J3/5 g tuber	Root knot female/5 g tuber
CR1/0090	2.0	1.7	1753.0	2042.0	94.0	131.0	388.0
TDr 87/00211	3.0	2.0	8808.0	0.0	74.0	124.0	173.0
CR1/0042	2.3	1.3	2423.0	280.0	93.0	25.0	141.0
CR1/0021	2.0	1.3	5404.0	84.0	33.0	31.0	132.0
CR1/00147	1.8	0.8	8780.0	89.0	31.0	56.0	128.0
CR1/00107	3.0	1.0	2896.0	38.0	8.0	13.0	96.0
CR1/00112	2.0	0.5	3994.0	83.0	24.0	13.0	65.0
CR1/0080	2.0	0.5	1108.0	0.0	4.0	17.0	56.0
CR1/0062	0.5	0.5	1172.0	15.0	11.0	12.0	49.0
CR1/0073	0.0	0.5	4621.0	65.0	0.0	16.0	49.0
CR1/0070	2.0	0.7	2436.0	15.0	2.0	7.0	46.0
CR1/0079	1.4	1.0	2263.0	15.0	0.0	20.0	42.0
CR1/0031	1.2	0.7	1321.0	39.0	17.0	3.0	32.0
CR1/0051	2.0	1.0	1033.0	0.0	3.0	3.0	24.0

Table 2.10 (cont.)

CR1/0033	1.0	0.2	1508.0	16.0	10.0	3.0	23.0
CR1/003	1.3	1.3	2710.0	12.0	4.0	7.0	20.0
CR1/00132	1.0	0.3	778.0	97.0	8.0	1.0	16.0
CR1/007	0.5	0.5	328.0	2.0	2.0	2.0	12.0
CR1/00118	1.5	0.5	674.0	9.0	21.0	15.0	12.0
CR1/0089	0.8	0.8	1293.0	37.0	15.0	2.0	10.0
CR1/00111	0.8	0.3	142.0	35.0	5.0	3.0	9.0
CR1/00123	1.8	0.3	690.0	15.0	10.0	0.0	8.0
CR1/00128	1.0	0.7	678.0	10.0	24.0	0.0	7.0
CR1/0077	1.0	1.0	1549.0	2.0	0.0	2.0	5.0
CR1/006	2.0	0.5	410.0	0.0	0.0	0.0	0.0

Field Screening of Cellular and Molecular technologies laboratory (IITA) accessions and interspecific hybrids for resistance to *S. bradys*

The population density of *S. bradys* ranged from 17 to 2,502/5 g yam peelings (Table 2.11). There were highly significant differences (P = 0.01) between the accessions. There was correlation (r= 0.39, P<0.01) between *S. bradys* population and dry rot symptom expression. There was also correlation between all the plant characteristics like softness, crack and population density. All the interspecific hybrids were highly susceptible to the nematode. The wild accession, *D. dumetorum* was found to be resistant to *S. bradys.*

Table 2.11. Reaction of yam interspecific hybrids and accessions to *S. bradys*
(Mean of 10 replicates after 8 weeks and inoculated with 2,500 *S. bradys* (50 g infected peels)

Yam accession	Tuber cracking (0-3)	Tuber softness (0-3)	Dry rot index (0-3)	Mean no. *S. bradys*/5 g tuber peelings
TDr 98/00216	2.9	1.1	3.0	2502.0
TDr 89/00217	2.8	1.0	3.0	1156.0
TDr 97/01316	3.0	0.5	3.0	1105.0
TDr 97/01314	2.5	0.7	2.5	1028.0
Kappe 138	2.3	0.6	2.6	827.0
TDr 97/01306	2.5	0.9	2.6	654.0
TDr 97/01275	2.4	0.4	2.9	189.0
BP 128	2.4	0.6	2.9	134.0
D. dumetorum	0.0	0.0	0.0	17.0

Field screening of yam intraspecific hybrids for resistance to *S. bradys*

S. bradys population ranged for 373 to 1,054/5 g yam peelings and dry rot ranged from 2.6 to 3 (Table 2.12). There were no significant differences between clones. This implies that all the clones are susceptible to *S. bradys*. The parents of the hybrids were also susceptible.

Table 2.12 Reaction of intraspecific hybrids to *S. bradys* 8 weeks after harvest
(Mean of 10 replicates and inoculated with 2,500 *S. bradys* (50g infected yam peels)

Yam hybrids	Tuber cracking (0-3)	Tuber softness (0-3)	Dry rot (0-3)	Mean no. *S. bradys*/5g
CR1/0083	2.2	1.0	3.0	628.0
CR1/0074	2.1	0.9	2.9	696.0
CR1/0057	2.2	1.5	3.0	373.0
CR1/0024	2.1	1.1	3.0	746.0
CR1/0051	2.6	1.4	3.0	1054.0
CR1/0036	2.4	1.0	3.0	1023.0
CR1/0099	2.3	1.6	3.0	500.0
CR1/0075	1.5	1.2	2.6	973.0
CR1/0037	2.6	0.9	3.0	617.0
CR1/00143	2.7	1.0	3.0	472.0

OUTPUT 3 NEMATODE VARIABILITY ON YAM KNOWN

PARTICIPATORY RURAL APPRAISAL: NEMATODE PESTS PROBLEMS OF YAM IN GHANA

The symptoms of nematode injury were clearly identified by farmers. Most farmers were very familiar with the dry rot of tubers caused by migratory endoparasitic nematodes. In parts of the country, more than 90% of farmers had local names for the disease symptoms e.g. *nkronsa nkronsa* or *edwie* (rashes). Farmers could readily identify tubers with dry rot symptoms and these were rejected at planting or consumed early. Farmers estimated losses from dry rot to be 21% (0-100) in the Forest zone and 30% (2-100) in the Savannah. Losses from root knot nematode were estimated as 11% (0-40) in the forest and zero in the savannah (Table 3.1). The prevalence of the symptoms was 83% of sites in the forest zone and 100% in the savannah (Table 3.2). The dominant component crops are also shown. At all sites, dry rot symptoms were associated with *S. bradys* and galling with *Meloidogyne incognita.* In most years farmers grew 10-15 yam varieties mostly of *Dioscorea rotundata*, but also *D. alata*, *D. cayenensis*, *D. dumetorum* and D. *bulbifera*. All were thought by farmers to be susceptible to dry rot, but some varieties e.g. *D. rotundata* var. Lili and species of *D. alata* were said to store better. Traditional yam varieties were often described to be free of dry rot. There can be few cases where a nematode problem is culturally so important and so well understood by farmers. This suggests that farmers would adopt a resistant variety, if such is identified or developed. However, farmers grow a large number of yam varieties for different reasons like taste and yield, so any new variety should fit this background.

Table 3.1. Farmer's estimates of the proportion of tubers affected by dry rot and root knot nematode in Ghana

Agroecological zone	Dry rot disease (%)		Root knot galling (%)	
	Mean	Range	Mean	Range
Forest-transitional	21	0-100	11	0-40
Guinea-Savannah	30	2-100	0	0

Table 3.2 Prevalence of dry rot and root knot nematodes in Ghana

Agroecological zone	Dry rot (%)	RKN (%)	Dominant component crops
Forest-transitional	81	72	Cassava, chilli/maize
Guinea-Savannah	100	24	Millet, Cassava, maize/sorghum

IDENTIFICATION AND DISTRIBUTION OF YAM NEMATODES IN GHANA

The survey of stored tubers in Ghana revealed that the prevalence of nematode was high (>70% of sites) in both the forest and savannah agroecological zones. Root knot nematodes were found at all sites in the Savannah, but were less prevalent in the forest zone. *Meloidogyne incognita* was the species of root knot encountered and dry rot symptoms were entirely associated with *S. bradys*. No other migratory endoparasite was encountered.

HOST RACE STATUS OF *PRATYLENCHUS COFFEAE* ON YAM IN GHANA

The number of *P.coffeae*/5g roots ranged from 0 to 743 and from 0 to 14 / 5g tubers in the yam (Table 21). There was significant difference (P = 0.05) between the yam amd *Musa* varieties. The *Musa* species recorded the highest number of nematodes in roots however, *Musa* cv. Brodeyuo (true horn) was more susceptible. There was no correlation between per cent root necrosis and *P. coffeae* population. Trials on the pest status of *P. ccffeae* on yams in Ghana have been interesting.

Table 3.3 Host race status of *P. coffeae* on yam in Ghana

(Mean of 4-6 replicates and inoculated with 800 *P. coffeae*)

Yam and *Musa* varieties	%Root necrosis	Crack (0-3)	Tuber dry rot (0-3)	No. *P.coffeae*/5g root	No. P.*coffeae*/5g tuber
D. dumetorum cv. Nkanfo	44	0.2	0	5	0
D. cayenensis cv. Afun	43.3	0	0	35	0
D. bulbifera	62.5	0.3	0	73	0
D. alata cv. Yeremma	70	1	0	0	0
D. rotundata cv. Lili	67.5	1	0	27	10
D. esculenta	22.5	0	0	3	14
Musa cv. Asamienu	5	-	-	190	-
Musa cv. Brodeyuo	17.5	-	-	743	-

Table 3.4 Host race differentiation of *P. coffeae* from Ghana and Belize

Host species	*P. coffeae* ex Ghana (nematodes/g root)	*P. coffeae* ex Belize (nematodes/g root)
Dioscorea togoensis	3.0	30.0
Dioscorea rotundata	1.0	341.0
Musa cv Grande Naine	256.0	6.0

P. coffeae is known to be a pest of yams in the Caribbean, Pacific and Central America but nothing was known of its pest status on yam in Ghana, although it is widespread on plantain. *P. coffeae* can multiply in roots of a number of species of *Dioscorea* (Table 3.3). However, the nematode is unlikely to be a threat to yam production because tubers do not generally support nematode reproduction. Pot studies in the UK (Table 3.4) reveal a clear host preference between geographically distinct nematode isolates and shown that the Ghanaian population of *P. coffeae,* is a *Musa* host race and contrasts with Central American populations which do cause dry rot in yams. *Musa* varieties appear to differ in their susceptibility to Ghanaian populations of *P. coffeae;* Grande Naine is the least susceptible of the 3 varieties tested.

PROJECT PUBLICATIONS

Book chapter

Kwoseh, C.K., Plowright, R.A. and Bridge, J. (2001) *Scutellonema bradys* on *Dioscorea* spp. In: *Evaluating Plants for Resistance and Tolerance to Plant Parasitic Nematodes,* Starr, J.L, Cook,R. & Bridge, J. (Eds.). CAB International, Wallingford (In press)

Conference and Workshop Proceedings

Plowright, R.A. and Kwoseh, C.K. (1998) Farmers perceptions of nematode disease in yams in Ghana and the prevalence of endoparasitic nematodes in stored stored tubers. *Proceedings the 24 International Nematology symposium, 4-9 August 1998, Dundee.*

Kwoseh, C.K., Plowright, R. A., Stanfield, J. & Asiedu, R. (1998) Culturing *Scutellonema bradys* on yam tuber slices. In: *Proceeding of the 7th Triennial Symposium of the International Society for Tropical Root Crops - Africa Branch, Cotonou, Benin, 11 - 17 October 1998.* Poster.

Kwoseh, C.K., Plowright, R.A. and Bridge, J. (2000) Nematode pests of yams (*Dioscorea* spp.) in Ghana. *Proceeding of Workshop: Uptake by Farmers of Yam Research Recommendations, Kumasi, Ghana, 16 March 2000,* Natural Resources Institute, Greenwich University, UK.

PhD Thesis

Kwoseh, C.K. (2000) Identification of resistance to major nematode pests of yams (*Dioscorea* spp.) in West Africa. PhD thesis. Reading University. 200pp.

Internal Presentation

Kwoseh, C.K. 2000. The yam nematode (*Scutellonema bradys*) in West Africa and the potential for its control through resistance. Presentation at DFID's Crop Protection Programmes' Root Crops Cluster meeting, Natural Resources Institute, Greenwich University, 19 September, 2000.

Reports

Meerman, J.C., Speijer, P.R., Asiedu, R. (1999) Establishment of the geographic distribution of yam nematode pests in Nigeria, Ghana and the Republic of Benin. - in collaboration with C. Kwoseh, J. Mudiope, R. Plowright, T.E. Sangoyomi. *IITA annual report for 1999.*

Meerman, J.C., Speijer, P.R., Asiedu, R. (1999) Improvement of the methodologies for screening of yam host plant response to nematodes. – in collaboration with R. Plowright, C.Kwoseh. *IITA annual report for 1999.*

Meerman, J.C., Speijer, P.R., Asiedu, R. (1999) Screening for resistance in yam germplasm to nematodes affecting yam - in collaboration with R. Plowright, C.Kwoseh*, J. Mudiope. *IITA annual report for 1999.*

CONTRIBUTION OF OUTPUTS

This work has contributed greatly to the understanding of important pests of yams in West Africa. Good sources of resistance have been identified in *Dioscorea dumetorum* but barriers to interspecific hybridisation mean that this can not be exploited in the short term. Although quantitative variation in susceptibility has been identified, it would seem unlikely that useful nematode resistance will be found in *D. rotundata* itself. The development of novel cultural control methods with farmers, based around the issues of clean seed and crop rotation is likely to be more fruitful in the immediate future, particularly since farmers already utilise such methods.