CHAPTER 2

SCREENING OF BAMBARA GROUNDNUT (*VIGNA SUBTERRANEA*) LANDRACES FOR RESISTANCE/TOLERANCE TO *MELOIDOGYNE INCOGNITA* RACE 2.

ABSTRACT

Greenhouse studies were conducted to evaluate fifty bambara groundnut (*Vigna subterranea* (L). Verdc.) landraces obtained from Botswana and South Africa for resistance/tolerance to *Meloidogyne incognita* race 2. Each landrace was inoculated with 5000 *M. incognita* eggs and evaluated for galls and egg masses eight weeks later. Host suitability was determined using Canto-Saenz's host suitability designations. None of the landraces was resistant to *M. incognita* race 2. However, landraces HVA 38-3, SB 4-4C, CLRDE and Swazi V4 showed slight tolerance to the nematode. The nematode reduced growth and yield of all landraces.

2.1 Introduction

The root-knot nematode, *M. incognita* is a serious problem in many crop-production areas throughout the world. The nematode affects all cultivated crops including bambara groundnut (*Vigna subterranea*). Although there is very little information regarding M. *incognita* on bambara groundnut, there are indications that the nematode can severely affect the crop and result in significant yield losses (Ogbuji, 1979). This is especially a problem in small-scale-farmer situations where the crop ranks third in importance after cowpea and groundnut as a main source of food and income. Control of *M. incognita* on bambara groundnut in small-scale-farming systems can best be achieved by the use of resistant varieties. Ogbuji (1979) concluded that both resistance and tolerance are lacking in the Nigerian bambara groundnut genotypes screened against M. *incognita* and *M. javanica.* Mc Donald & De Waele (1989) made similar observations with *M. javanica* on bambara groundnut although they suggested that tolerance might exist in some genotypes. The objective of the present study was therefore to evaluate bambara groundnut landraces from Botswana and South Africa for resistance and/or tolerance to *M. incognita* race 2 which is the predominant host race in these two countries.

2.2 Materials and Methods

The study was conducted at two locations, the Botswana College of Agriculture (BCA) and the University of Pretoria (UP) experimental farm over a two-year period using germplasm from Botswana and South Africa (Fig 2.1).

Experiments at Botswana College of Agriculture

Two experiments were conducted at BCA between February and July 1996 in a greenhouse at temperatures maintained between 20 and 30 °C. The soil used in both experiments was a sandy loam (75 % sand, 5 % silt, 20 % clay and pH 6.0). The topsoil was mixed with river sand at a ratio of 2:1 and fumigated with methyl bromide prior to use. Fifteen bambara groundnut landraces were used in experiment 1 and five landraces in experiment 2 (Table 2.2a and 2.2b). Thirty-five centimeter diameter plastic pots were filled with soil and arranged on benches in a completely randomised design. To ensure optimum nitrogen fixation seeds were treated with a cowpea group inoculant, *Bradyrhizobium* spp. (*Vigna*) obtained from Stimuplant (P.O. Box 2013, Swavelpoort, Pretoria 0036) before planting. For each landrace both *M. incognita*-inoculated and non-inoculated (control) plants were included using 5 replicated pots per treatment with three seeds planted in each pot. Pots were watered daily with tap water. Seedlings were thinned to one per pot six weeks after emergence and fertilised weekly with a solution of Multifeed $P_{43}^{®}$ fertiliser applied at 100 g /liter of water (Plaaskem (Pty) Ltd, P.O.Box 87005, Houghton, 2041).

Nematode inoculum was obtained from BCA from heavily galled spinach roots. Identification of the species and race were done using the North Carolina Differential Host Test (Sasser & Triantaphyllou, 1977) and was confirmed by Dr. K. Kleynhans (Agricultural Research Council, Plant Protection Research Institute, Pretoria) by means of morphological studies. Five thousand *M. incognita* race 2 eggs were extracted from heavily galled spinach roots using the NaOCl technique described by Hussey & Barker (1973). A 5 ml suspension containing 5000 eggs was applied to each plant. The suspension was pipetted into depressions made around the crown of each seedling. After inoculation, plants were allowed to grow for ten weeks to enable the nematodes to complete two life cycles and the crop to reach maturity. Plants were sprayed with cypermethrin applied at the rate of 150 ml/ha to control aphids. Powdery mildew was controlled with a foliar spray of triforine applied at the rate of 1 ml/liter of water.

The plants were harvested ten weeks after inoculation. Tops (shoots) were cut from each plant, the fresh mass determined and then dried to measure dry mass. Roots were gently washed free of soil and their fresh weight determined. Each root sample was stained in 0.15 g/liter aqueous solution of Phloxine B (Hussey & Barker, 1973) for 15 minutes before being evaluated for galls and egg masses. Galls and egg masses were rated using a 0-5 root gall or egg mass index (Taylor & Sasser, 1978) where 0 = 0 galls or egg masses, 1 = 1 - 2, 2 = 3 - 10, 3 = 11 – 30, 4 = 31 -100 and 5 ≥ 100 galls or egg masses per root system. To obtain the final population (Pf), eggs were extracted from roots using the NaOCl technique of Hussey & Barker, (1973). The reproduction factor (R factor) of each landrace was calculated by dividing the final population with the initial population (Pi). Canto-Saenz (1985) host suitability designations were assigned to determine resistance or tolerance.

Experiments at the University of Pretoria

Five experiments were conducted in a greenhouse at UP between February 1996 and April 1997. Greenhouse temperatures between 20 and 30 °C were maintained throughout. The procedures followed in all experiments were the same as for experiments conducted at the BCA except where specified.

The soil used was a 2:1 mixture of topsoil and river sand with 80 % sand, 4 % silt, 14 % clay and a pH of 5.4. The soil was steam-pasteurised at 100 °C for 1 hour before being used. Artificial light was provided by means of 250 watt mercury vapour lights for 2 hours after sunset from April to end of July to increase day length since bambara groundnut is sensitive to photoperiod (Linneman, 1994). Most of the germplasm used in the experiments was obtained from South Africa. Germplasm used in experiment 6 was a mixture of germplasm from Botswana and South Africa selected on the basis of their performance in previous experiments (Table 2.2c-g).

Harvesting of experiments 1 to 4 was done twelve to fourteen weeks after inoculation. Experiment 5 was harvested six weeks after inoculation. No yield data was collected for experiment 3.

All data were analysed by ANOVA and where necessary means were separated by Duncan's multiple-range test (SAS, BMDP Statistical Software, Los Angeles, CA). Gall and egg mass index values were ranked before they were analysed statistically. Where ranked gall index and egg mass index values were identical, only gall index values were presented.

2.3 Results

Expriments at Botswana College of Agriculture

All the landraces tested in experiment 1 did not differ significantly with regard to gall index and egg mass index. Landrace OM1 was significantly different from the other landraces in final population and R factor (Table 2.3a). *M. incognita* race 2 reduced plant growth (fresh weight of roots and dry mass of shoots) although there was no significant difference between landraces. Landraces Goo B differed significantly from Gab C, JB Pop 2, JB Pop 5, JB Pop 10, JB Pop 11 and Jac C with regard to reduction in yield (number of pods). However, there was no significant difference between landraces in the reduction of the dry mass of pods (Table 2.3b).

In experiment 2 some of the five landraces tested were significantly different from the other in gall and egg mass index. WS 52 had the highest gall and egg mass index and was significantly different from SB 4-4E and S10, which had the lowest indices. There were no significant differences between landraces in terms of the final population and R factor. All landraces were susceptible to the nematode (Table 2.3c). The highest reduction in dry mass of shoots was recorded for S13 and this was significantly different from S10 and SB 4-4E. S13 and WS 52 had the highest reduction in dry weight of pods compared with other landraces. There was no significant difference between landraces in terms of the reduction in fresh weight of roots and number of pods (Table 2.3d).

Experiments at the University of Pretoria.

All landraces tested in experiment 1 were susceptible to *M. incogita* race 2. Landrace K1 was significantly different from CLDRE in terms of the final population and R factor (Table 2.3e). SB 8-1 had the highest gall index value of 22.80 and was significantly different from V4 S1 and CLDRE with gall index values of 11.20 and 10.40 respectively. K1 had the highest egg mass index value of 22.90 and was significantly different from CLDRE with an egg mass index value of 7.90 (Table 2.3e). Swazi V4 and V4 S1 were significantly different from K1 in the reduction in dry weight of shoots (Table 2.3f). Swazi V4 was significantly different from SB-81 in terms of reduction in number of pods. There were no significant differences between landraces in the reduction of dry weight of pods and fresh weight of roots (Table 2.3f).

In experiment 2, Potgietersrus and Marabastad differed significantly from HVA 38-3 in terms of gall and egg mass indices. SB 4-4C was significantly different from Potgietersrus and Marabastad in terms of gall index but not in egg mass indices. SB 4-4C and HVA 38-3 did not differ significantly in both gall and egg mass index. No significant differences occurred between landraces in the final population and R factor values (Table 2.3g). The highest reduction in dry weight of shoots was recorded for M4 while Groblersdal and SB 4-4C had the lowest values. No significant differences occurred between landraces in terms of reduction in fresh weight of roots, number of pods and fresh weight of pods (Table 2.3h).

In experiment 3, there were no significant differences between the eight landraces in gall and egg mass index, final population and R factor values. All the landraces were susceptible to the nematode (Table 2.3i). Landraces did not differ significantly with regard to the reduction in growth (Table 2.3j).

The six landraces tested in experiment 4 did not differ significantly from each other in gall index, egg mass index, final population, and R factor values (Table 2.3k). Landraces differed significantly in the reduction in fresh weight of roots. There were no significant differences between landraces with regard to the reduction in dry mass of shoots and number of pods (Table 2.3*l*).

In experiment 5, no significant differences occurred between landraces with regard to the gall index, final population and R factor values. However, SB 20–2A differed significantly from Goo B in terms of egg mass index (Table 2.3m). The reduction in dry mass of shoots ranged from 5.26 to 2.32. The highest reduction occurred in S9 and this was significantly different from SB 20-2A that had the lowest value. There were no significant differences between landraces in terms of the reduction in fresh weight of roots. SB 20-2A had the highest reduction in number of pods and was significantly different from S9, Goo B and DIPC whereas SB 20-2A, JB Pop 11 and CLDRE did not differ significantly (Table 2.3n).

2.4 Discussion

All landraces tested at BCA in experiment 1 were susceptible to *M. incognita* race 2 according to Canto-Saenz's (1985) host suitability designations. The R factors for all landraces were above 1.00 and gall indices above 2.00. Canto-Saenz's designations are based jointly on host efficiency (nematode reproduction on host) and damage to the plant (gall index) and is a better way of categorising resistance in plants than using gall index or egg mass index only. The same landraces are susceptible even when other evaluation methods are used (Taylor & Sasser, 1978; Hadisoeganda & Sasser, 1982). There were no significant differences between landraces in terms of the reduction in plant mass (dry weight of shoots and fresh weight of roots). This shows that all the fifteen landraces responded in a similar way to infection by *M. incognita* race 2. Landraces differed significantly in yield reduction (number of pods) due to infection. However, a significant reduction in dry mass of pods was only recorded in one experiment (Table 2.3d). This could be attributed to the fact that pod formation did not occur at the same time for all landraces. Some landraces formed pods late and at the time of harvest some of the pods were still immature. This is a common phenomenon in bambara groundnut especially when pod formation coincides with reduced day-length (Linneman, 1994) as it was the case in this experiment. Most of the landraces showing smaller reductions in yield due to *M. incognita* race 2 infection were the JB populations obtained from the Department of Agricultural Research, Botswana. It is possible that these landraces are of similar origin with differences between them being due more to genetic drift in small isolated populations rather than any conscious selection (Wigglesworth, 1996). Interestingly, all landraces from BCA collection except one (Gab C) had greater yield reductions as a result of infection by *M. incognita* race 2. Again this may be an indication of a similarity in origin of these landraces since they were collected from farmers within the same region. It is possible that seed could have been bought from outside Botswana and that selection of larger light coloured seed for planting took place. This is a common practice by small-scale farmers in Botswana.

In experiment 2, the five landraces from the Potchefstroom collection showed significant differences in gall and egg mass indices. Coincidentally, the gall index and egg mass index values were identical and all landraces were susceptible according to Canto-Saenz's designations. The landraces were also significantly different in terms of the reductions in plant mass (dry weight of shoots) and yield (dry weight of pods). There was a positive correlation between gall index (plant damage) and the reduction in plant mass and yield due to infection by the nematode. Landraces with high gall indices showed greater reduction in growth, due to *M. incognita* infection than those with low gall indices. This shows that *M. incognita* had an effect on all five landraces tested in this experiment.

Of the landraces evaluated in experiment 1 at the University of Pretoria, CLDRE was a marginal case. Although it is susceptible according to Canto-Saenz's designations, it had a low R factor and a low gall index (1.10 and 2.24 respectively). V4 S1 and Swazi V4 showed the lowest reduction in dry weight of shoots due to *M. incognita* infection. These three landraces were susceptible to M. *incognita* according to Canto-Saenz's interpretation but they could otherwise be considered tolerant because they were able to withstand the attack by the nematode and produce higher yields than the other landraces.

In experiment 2, HVA 38-3 performed better than others and had the lowest gall indices and R factor values. However, this landrace is susceptible because its gall index is greater than 2. Potgietersrus and Marabastad had high gall indices that correlated positively with the reduction in plant mass. All landraces tested in experiments 3 and 4 were susceptible and no significant differences occurred between landraces. Although there were reductions in plant mass as well as in yield, landraces did not differ significantly

The six landraces tested in experiment 5 did not differ from each other in gall index, final population and R factor values. Goo B had the lowest egg mass index and differed significantly from SB 20-2A. This verified results from earlier experiments where the same landrace reacted in a similar way when compared to others except that the gall index and egg mass index values were lower. This could be due to a number of factors including among others the time when the experiment started, different soils used at BCA and UP, and differences in greenhouse temperatures.

The results of this study confirm earlier reports that bambara groundnut is susceptible to *M. incognita* (Ogbuji.1979). Other reports of susceptibility of bambara groundnut to root-knot nematodes involved studies with *M. javanica*. Although (Mc Donald & De Waele, 1989) suggested a possibility that tolerant bambara groundnut landraces may exist, their results were based on *M. javanica*. *M. incognita* race 2 reduced growth and yield of all landraces evaluated. No previous studies have been done involving *M. incognita* race 2 on bambara groundnut. The results of this study have therefore shown that this nematode is a serious problem on bambara groundnut, and that no significant resistance or tolerance exsist in the landraces screened. Consequently, other measures will have to be explored for control of this nematode on bambara groundnut.

2.5 REFERENCES

Canto-Saenz, M. 1985. The nature of resistance to *Meloidogyne incognita*. Pp. 225-217 In: An Advanced Treatise on *Meloidogyne* Vol.1: Biology and Control. J. N. Sasser and C. C. Carter (eds). North Carolina State University Graphics, Raleigh.

Hadisoeganda, W. W. & Sasser, J. N. 1982. Resistance of tomato, bean, southern pea, and garden pea cultivars to root knot nematodes based on host suitability. *Plant Disease* 66: 145-150.

Hussey, R. S. & Barker, K. R. 1973. A comparison of methods of collecting inocula of *Meloidogyne* species including a new technique. *Plant Disease Reporter* 57: 1925-1928.

Linneman, A. R. 1994. Photothermal regulation of phenological development and growth in bambara groundnut (*Vigna subterranea* (L.) Verdc.). PhD Thesis, Wageningen, 123pp.

Mc Donald, A. H. & Waele, D. D. 1989. Effect of *Meloidogyne javanica* on bambara groundnut (*Voandezeia subterranea*) in South Africa. *Phytophylactica* 21: 429-431.

Ogbuji, R. O. 1979. Effect of two *Meloidogyne* species on growth and reproduction of bambara groundnut (*Voandezeia subterranea*) in Nigeria. *Tropenlandwirt* 80: 47-51

Sasser J. N. & Triantaphyllou, A. C. 1977. Identification of *Meloidogyne* species and races. *Journal Nematology* 9 (abs.): 2283.

Taylor, A. L. & Sasser, J. N. 1978. Biology, identification and control of root-knot nematodes (*Meloidogyne* spp.). Cooperate Publication of Department of Plant Pathology, North Carolina State University and U. S. Agency for International Development. Raleigh, N. C. 111 pp.

Wigglesworth, D. J. 1996. The potential for genetic improvement of bambara groundnut (*Vigna subterranea* (L.) Verdc.). Pp. 181-191 In: Proceedings of the International Bambara Groundnut Symposium. University of Nottingham, UK. 23-25 July 1996.

Table 2.2a: *Vigna subterranea* landraces used in Experiment 1 at Botswana College of Agriculture.

Landrace	Source
DIPC	Botswana College of Agriculture
OM 1	Botswana College of Agriculture
OM 6	Botswana College of Agriculture
Gab C	Botswana College of Agriculture
JB Pop 2	Department of Agricultural Research, Botswana
JB Pop 3	Department of Agricultural Research, Botswana
JB Pop 4	Department of Agricultural Research, Botswana
JB Pop 5	Department of Agricultural Research, Botswana
JB Pop 10	Department of Agricultural Research, Botswana
JB Pop 11	Department of Agricultural Research, Botswana
NTSR	National Seed Testing Centre, Zimbabwe
Ram R	Botswana College of Agriculture
Gac C	Botswana College of Agriculture
Jac C	Botswana College of Agriculture
Goo B	Botswana College of Agriculture

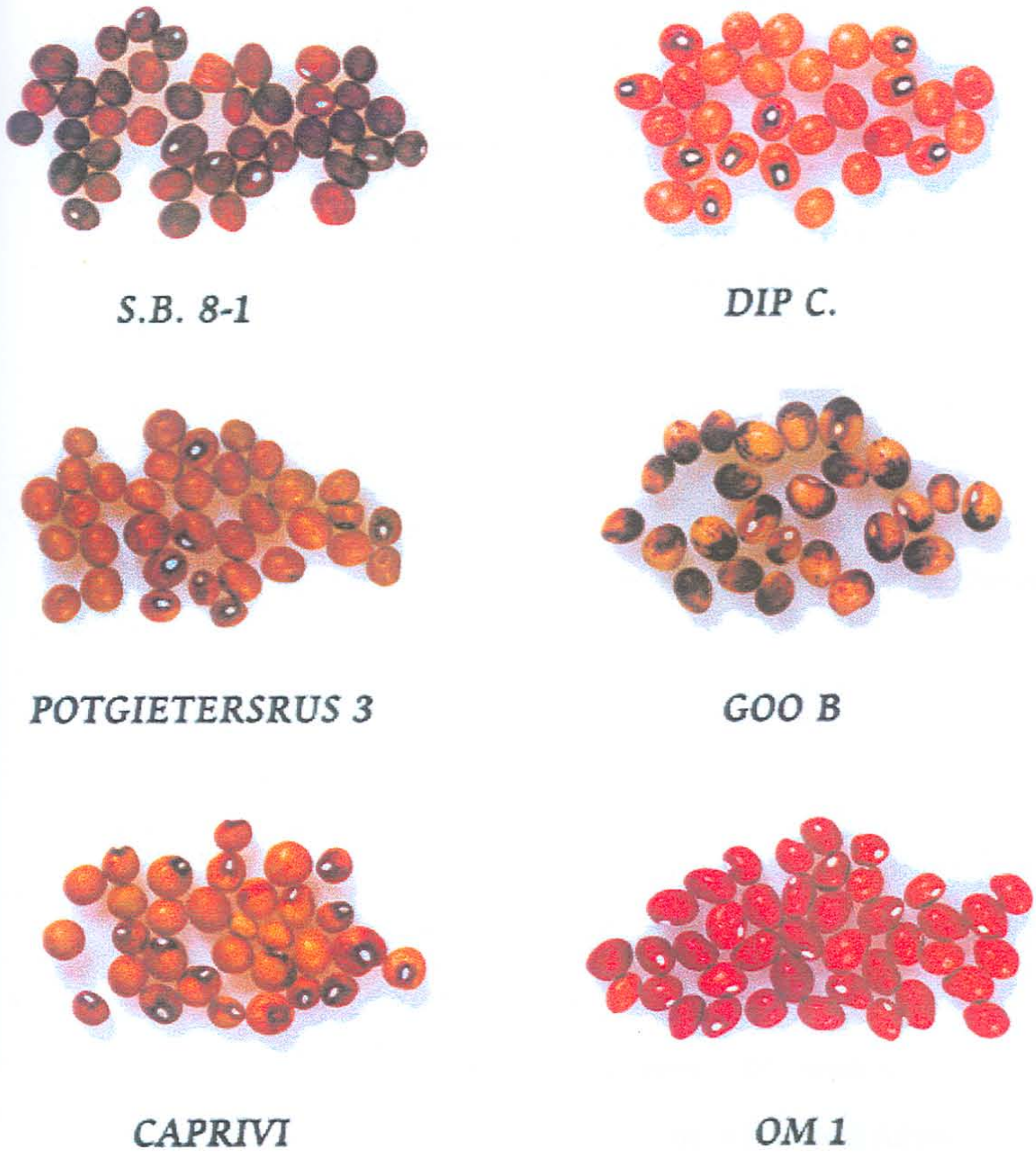

Fig 2.1: Bambara groundnut (*Vigna subterranea*) seeds – a selection of some examples of the landraces used in the present study.

Table 2.2b: *Vigna subterranea* landraces used in Experiment 2 at Botswana College of Agriculture.

Landrace	Source
SB 4-4E	Oil and Protein Seeds Centre, ARC*, Potchefstroom, South Africa
S13	Oil and Protein Seeds Centre, ARC, Potchefstroom, South Africa
S10	Oil and Protein Seeds Centre, ARC, Potchefstroom, South Africa
A57	Oil and Protein Seeds Centre, ARC, Potchefstroom, South Africa
WS 52	Oil and Protein Seeds Centre, ARC, Potchefstroom, South Africa

*Agricultural Research Council

Table 2.2c: *Vigna subrerranea* landraces used in experiment 1 at the University of Pretoria.

Landrace	Source
K1	Oil and Protein Seed Centre, ARC*, Potchefstroom
V4 S1	Plant Protection Research Institute, ARC, Pretoria, South Africa
CLDRE	Oil and Protein Seed Centre, ARC, South Africa
Swazi V4	Oil and Protein Seed Centre, ARC, South Africa
SB 8-1	Oil and Protein Seed Centre, ARC, South Africa
Caprivi	Oil and Protein Seed Centre, ARC, South Africa

*Agricultural Research Council

Table 2.2d: *Vigna subtrerranea* landraces used in experiment 2 at the University of Pretoria.

Landrace	Source
ETL-76469	Oil and Protein Seed Centre, ARC*, Potchefstroom
SB 4-4C	Oil and Protein Seed Centre, ARC, Potchefstroom
HVA 38-3	Oil and Protein Seed Centre, ARC, Potchefstroom
M4	Oil and Protein Seed Centre, ARC, Potchefstroom
Potgietersrus	Oil and Protein Seed Centre, ARC, Potchefstroom
Groblersdal	Oil and Protein Seed Centre, ARC, Potchefstroom
Marabastad	Oil ad Protein Seed Centre, ARC, Potchefstroom
A12	Oil and Protein Seed Centre, ARC, Potchefstroom

*Agricultural Research Council

Table 2.2e: *Vigna subterranea* landraces used in experiment 3 at the University of Pretoria.

Landrace	Source
Swazi V 4	Oil and Protein Seed Centre, ARC*, Potchefstroom
Caprivi Sel 1	Oil and Protein Seed Centre, ARC, Potchefstroom
MV 8817	Oil and Protein Seed Centre, ARC, Potchefstroom
ZB S2	Oil and ProtienSeed Centre, ARC, Potchefstroom
Sel van Potch. Mengel	Oil and Protein Seed Centre, ARC, Potchefstroom
WS 51	Oil and Protein Seed Centre, ARC, Potchefstroom
S9	Oil and Protein Seed Centre, ARC, Potchefstroom
SB 20-2 A	Oil and Protein Seed Centre, ARC, Potchefstroom

*Agricultural Research Council

Table 2.2f: *Vigna subterranea* landraces used in experiment 4 at the University of Pretoria.

Landrace	Source
ZB S1	Oil and Protein Seed Centre, ARC,* Potchefstroom, South Africa
MAD	Oil and Protein Seed Centre, ARC, Potchefstroom, South Africa
PGR 3	Oil and Protein Seed Centre, ARC, Potchefstroom, South Africa
Red Eye Ex.Zim	Oil and Protein Seed Centre, ARC, Potchefstroom, South Africa
V4 S4	Plant Protection Research Institute, ARC, Pretoria, South Africa
Gravelot	Plant Protection Research Institute, ARC, Pretoria, South Africa
Caprivi Sel 2	Plant Protection Research Institute, ARC, Pretoria, South Africa
WS 50	Plant Protection Research Institute, ARC, Pretoria, South Africa

*Agricultural Research Council

Table 2.2g: *Vigna subterranea* landraces used in experiment 5 at the University of Pretoria.

Landrace	Source
JB Pop 11	Department of Agricultural Research, Botswana
CLDRE	Oil and Protein Seed Centre, ARC*, Potchefstroom, South Africa
SB-20-2A	Oil and Protein Seed Centre, ARC, Potchefstroom, South Africa
S9	Oil and Protein Seed Centre, ARC, Potchefstroom, South Africa
Goo B	Botswana College of Agriculture
DIPC	Botswana College of Agriculture

*Agricultural Research Council

Table 2.3a: Reaction of *M. incognita* race 2 on fifteen *Vigna sub*terranea landraces in experiment 1 at Botswana College of Agriculture.

Landrace	Ranked GI *	Final Population**	R factor	Host Suitability Designation ***
JB Pop 4	47.00a	19730b	3.94b	Susceptible
Jac C	47.00a	13482b	4.08b	Susceptible
JB Pop 5	47.00a	16810b	3.36b	Susceptible
DIPC	40.30a	21380b	4.30b	Susceptible
JB Pop 3	40.30a	21690b	4.42b	Susceptible
JB Pop 11	40.30a	10830b	2.18b	Susceptible
Gac C	40.30a	21600b	4.32b	Susceptible
Gab C	40.30a	22550b	4.52b	Susceptible
Goo B	38.50a	10850b	2.18b	Susceptible
Ram R	38.50a	16300b	3.28b	Susceptible
OM 1	32.10a	55520a	11.10a	Susceptible
OM 6	31.30a	11310b	2.24b	Susceptible
JB Pop 10	31.30a	17660b	3.50b	Susceptible
NTSR	30.60a	22950b	4.56b	Susceptible
JB Pop 2	24.60a	15110b	3.00b	Susceptible

Each value is the mean of 5 replicates. Means in the same column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test.

GI = Gall index, R factor = Final population ÷ Initial population. *Taylor & Sasser (1978),

** Number of eggs per 20 g roots, **Canto-Saenz (1985).

Table 2.3b: Effect of *M. incognita* race 2 on plant mass and yield of fifteen *Vigna subterranea* landraces in experiment 1 at Botswana College of Agriculture.

Landrace	Reduction in dry wt. of shoots (g)*	Reduction in fresh wt. of roots (g)*	Reduction in number of pods*	Reduction in dry wt. of pods (g)*
Ram R	6.84a	18.60a	22.75ab	5.13a
Goo B	4.48a	19.32a	53.00a	3.98a
OM 1	5.60a	8.46a	23.60ab	5.46a
NTSR	2.74a	22.50a	17.20ab	5.02a
Gac C	2.44a	16.38a	16.75ab	4.60a
OM 6	5.86a	11.20a	24.40ab	4.00a
Gab C	3.14a	18.02a	11.60b	2.94a
B Pop 4	4.58a	22.00a	11.80b	4.26a
JB Pop 10	2.46a	40.52a	8.00b	2.36a
Jac C	3.36a	28.26a	8.60b	3.02a
JB Pop 5	3.02a	22.60a	10.00b	3.38a
JB Pop 3	3.50a	12.68a	14.60ab	2.68a
DIPC	2.28a	20.98a	15.60ab	4.88a
JB Pop 2	2.90a	27.20a	12.00b	1.88a
JB Pop 11	2.88a	16.66a	11.60b	6.12a

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test.

*Non-inoculated minus inoculated.

Table 2.3c: Reaction of *M. incognita* race 2 on five *Vigna subterranea* landraces in experiment 2 at Botswana College of Agriculture.

Landrace	**Ranked GI ***	**Final Population ****	**R factor**	**Host Suitability Designation*****
WS 52	19.00a	16690a	3.34a	Susceptible
S13	14.20ab	25930a	5.18a	Susceptible
A57	14.20ab	33220a	6.66a	Susceptible
SB 4 - 4E	9.40b	26180a	5.22a	Susceptible
S10	8.20b	25640a	5.12a	Susceptible

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test. GI = Gall index, R factor = Final population ÷ Initial population. * Taylor & Sasser (1978), ** Number of eggs per 20 g root, *** Canto-Saenz (1985).

Table 2.3d: Effect of *M. incognita* on plant mass and yield of five *Vigna subterranea* landraces in experiment 2 at Botswana College of Agriculture.

Landrace	Reduction in dry wt. of shoots (g)*	Reduction in fresh wt. of roots (g)*	Reduction in number of pods*	Reduction in dry wt. of pods (g)*
S13	1.94a	18.80a	7.44a	6.04a
S10	0.48b	18.60a	4.92a	4.88ab
SB 4 – 4E	0.58b	18.36a	10.76a	1.76b
A57	1.16ab	16.10a	5.28a	1.32b
WS 52	1.02ab	16.80a	3.98a	6.46a

Each value is the mean of 5 replicates. Means in each column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test. * Non-inoculated minus inoculated.

Table 2.3e: Reaction of six *Vigna subterranea* landraces to *M. incognita* race 2 in experiment 1 at the University of Pretoria.

Landrace	Ranked G1*	Ranked EI*	Final Population **	R factor	Host Suitability Designation ***
SB 8 – 1	22.80a	12.10ab	9320ab	1.86ab	Susceptible
Swazi V4	18.00ab	18.20ab	8360ab	1.66ab	Susceptible
K1	18.00ab	22.90a	14300a	2.84a	Susceptible
Caprivi	12.60ab	18.30ab	8020ab	1.62ab	Susceptible
V4 S1	11.20b	13.60ab	11160ab	2.24ab	Susceptible
CLDRE	10.40b	7.90b	5580b	1.10b	Susceptible

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test. GI = Gall index, EI = Egg mass index, R factor = Final population ÷ Initial population. *Taylor & Sasser (1978), ** Number of eggs per 20 g roots, 8**Canto-Saenz (1985)

Table 2.3f: Effect of M. *incognita* race 2 on plant mass and yield of six *Vigna subterranea* landraces in experiment 1 at the University of Pretoria.

Landrace	Reduction in dry wt. of shoots (g)*	Reduction in fresh wt. of roots (g)*	Reduction in number of pods	Reduction in dry wt. of pods (g)*
K1	1.46a	11.80a	3.25ab	2.87a
SB 8 - 1	0.92ab	7.06a	1.50b	2.23a
Caprivi	0.74ab	6.76a	2.80ab	2.74a
CLDRE	0.98ab	5.42a	2.60ab	3.00a
Swazi V4	0.48b	4.86a	3.80a	3.46a
V4 S1	0.56b	4.82a	1.60ab	2.12a

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test.

*Non inoculated minus inoculated.

Table 2.3g: Reaction of *M. incognita* race 2 on eight *Vigna subterranea* landraces in experiment 2 at the University of Pretoria.

Landrace	Ranked GI *	Ranked EI *	Final Population **	R factor	Host suitability Designation ***
Potgietersrus	29.50a	28.40a	9540a	1.92a	Susceptible
Marabastad	26.50a	27.00a	7246a	1.44a	Susceptible
M4	24.50ab	25.80a	9580a	1.90a	Susceptible
Groblersdal	23.50ab	21.80a	7820a	1.56a	Susceptible
ETL – 76469	22.30ab	23.00a	6760a	1.36a	Susceptible
A12	18.50ab	18.00a	8380a	1.66a	Susceptible
SB 4 - 4C	13.90bc	15.20ab	6600a	1.34a	Susceptible
HVA 38 – 3	5.30c	4.80b	2500a	0.50a	Susceptible

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test.

GI = Gall index, EI = Egg mass index. R factor = Final population ÷ Initial population.

*Taylor & Sasser (1978), ** Number of eggs per 20 g roots, *** Canto-Saenz (1985).

Table 2.3h: Effect of *M. incognita* race 2 on plant mass and yield of eight *Vigna subterranea* landraces in experiment 2 at the University of Pretoria.

Landrace	Reduction in dry wt. of shoots (g)*	Reduction in fresh wt. of roots (g)*	Reduction in number of pods*	Reduction in fresh wt. of pods (g)*
Potgietersrus	0.58ab	6.22a	1.00a	1.80a
M4	0.88a	5.08a	1.00a	1.80a
Marabastad	0.46ab	2.74a	3.00a	2.78a
HVA 38 – 3	0.48ab	2.50a	0.50a	1.40a
Groblersdal	0.36b	4.58a	0.00a	0.70a
A12	0.44ab	4.50a	2.40a	3.80a
ETL – 76469	0.46ab	4.18a	3.00a	2.20a
SB 4 - 4C	0.26b	3.24a	4.50a	3.05a

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test. * Non-inoculated minus inoculated.

Table 2.3i: Reaction of *M. incognita* race 2 on eight *Vigna subterranea* landraces in experiment 3 at the University of Pretoria.

Landrace	Ranked GI*	Final Population **	R factor	Host Suitability Designation***
SB 20-2A	27.40a	5460a	1.10a	Susceptible
Swazi V5	25.50a	6080a	1.24a	Susceptible
ZB S2	22.40a	5840a	1.50a	Susceptible
MV 8817	19.30a	6980a	1.40a	Susceptible
S9	19.30a	2925a	0.60a	Susceptible
Caprivi Sel 1	19.30a	6260a	1.28a	Susceptible
Sel van Potch. Mengel	16.20a	6360a	1.28a	Susceptible
WS 51	14.60a	6040a	1.20a	Susceptible

Each value is the mean of 5 replicates. Means in each column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test. G.I.= gall index, R factor = Final population ÷ Initial population.

*Taylor & Sasser (1978), ** Number of eggs per 20 g roots, *** Canto-Saenz (1985).

Table 2.3j: Effect of *M. incognita* race 2 on plant mass of eight *Vigna subterranea* landraces in experiment 3 at the University of Pretoria.

Landraces	Reduction in dry wt. of shoots (g)*	Reduction in fresh wt. of roots (g)*
ZB S2	2.02a	8.70a
MV 8817	2.00a	7.30a
S9	1.64a	7.68a
Caprivi Sel 1	1.26a	6.00a
Swazi V5	1.36a	8.70a
WS 51	1.70a	11.20a
SB 20 - 2A	1.26a	8.38a
Sel van Potch. Mengel	1.18a	5.70a

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test.

* Non-inoculated minus inoculated.

Table 2.3k: Reaction of *M. incognita* race 2 on six *Vigna subterranea* landraces in experiment 4 at the University of Pretoria.

Landrace	Ranked GI *	Final Population **	R factor	Host Suitability Designation ***
Red Eye Ex. Zim.	22.30a	9074a	1.83a	Susceptible
Gravelot	18.50a	9560a	1.92a	Susceptible
MAD	14.70a	7404a	1.48a	Susceptible
V4 S4	13.30a	6460a	1.30a	Susceptible
Caprivi Sel 2	12.50a	7240a	1.46a	Susceptible
PGR 3	11.70a	8120a	1.64a	Susceptible

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at P≤ 0.05 according to Duncan's multiple range test. GI = Gall index, R factor = Final population ÷ Initial population.

*Taylor * Sasser (1978), ** Number of eggs per 20 g roots, ***Canto-Saenz (1985).

Table 2.3*l*: Effect of *M. incognita* race 2 on plant mass and yield of six *Vigna subterranea* landraces in experiment 4 at the University of Pretoria.

Landrace	**Reduction in dry wt. (g) of shoots***	**Reduction in fresh wt. (g) of roots***	**Reduction in number of pods**
PGR 3	1.86a	12.30a	4.00a
Gravelot	1.68a	4.30b	4.67a
MAD	1.42a	6.38ab	3.00a
V4 S4	1.16a	4.20b	4.00a
Caprivi Sel 2	1.08a	6.04ab	1.50a
Red Eye Ex. Zim.	0.92a	4.80ab	1.67a

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test.

* Non-inoculated minus inoculated.

Table 2.3m: Reaction of *M. incognita* race 2 on six *Vigna subterranea* landraces in experiment 5 at the University of Pretoria.

Landrace	**Ranked GI ***	**Ranked EI ***	**Final Population ****	**R factor**	**Host Susceptibility Designation *****
SB 20 - 2A	18.50a	22.10a	22800a	4.56a	Susceptible
CLDRE	18.50a	17.80ab	25140a	5.03a	Susceptible
S9	17.00a	16.20ab	19620a	3.92a	Susceptible
DIPC	17.00a	16.20ab	23200a	4.64a	Susceptible
JB Pop 11	14.00a	13.10ab	17660a	3.53a	Susceptible
Goo B	8.00a	7.60b	14950a	2.99a	Susceptible

Each value is the mean of replicates. Means in each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test. GI = Gall index, EI = Egg mass index, R factor = Final population ÷ Initial population.

* Taylor & Sasser (1978), ** Number of eggs per 20 g roots, ***Canto-Saenz (1985).

Table 2.3n: Effect of *M. incognita* race 2 on plant mass and yield of six *Vigna subterranea* landraces in experiment 5 at the University of Pretoria.

Landrace	Reduction in dry wt. of shoots (g)*	Reduction in fresh wt. ofroots (g)*	Reduction in number of pods*	Reduction in dry wt. of pods (g)*
	shoots (g)			
S9	5.26a	5.82a	6.00b	4.20a
DIPC	2.52ab	6.60a	8.60b	3.14a
SB 20 - 2A	2.32b	4.86a	21.60a	6.94a
JB Pop 11	3.12ab	6.22a	11.40ab	3.90a
CLDRE	4.34ab	7.14a	12.00ab	7.86a
Goo B	2.62ab	6.70a	4.8b	3.94a

Each value is the mean of 5 replicates. Means in each column followed by the same letter do not differ significantly at P≤ 0.05 according to Duncan's multiple range test. * Non-inoculated minus inoculated.