EVALUATION OF SWEET POTATO (*IPOMEA BATATAS*, L.) CULTIVARS AND ADVANCED BREEDING LINES FOR RESISTANCE TO TWO ROOT-KNOT NEMATODE SPECIES (*M. INCOGNITA* & *M. JAVANICA*)

by

Conrad K. Bonsi

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THESIS APPROVED BY:

Major Professor

Dean of School

Dean of Graduate Programs

FOR:

Conrad K. Bonsi
Student

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Title of Thesis

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Conrad K. Bonsi

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ABSTRACT

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Conrad K. Bonsi

Several sweet potato cultivars and advanced breeding lines were screened in both the greenhouse and a heavily nematode infested field for resistance to root-knot nematode species (Meloidogyne incognita and Meloidogyne javanica). Two greenhouse methods, "The Bed Method" and "The Improved Method" were used for indoor investigations. A heavily nematode infested field was used for outdoor investigations. The infestation in the field had been built up over a period of three years. Plants in all investigations were evaluated on a scale of 1-5 based on the percentage number of roots infested using both gall and egg mass indices.

Several breeding lines, namely, FH-7-72, TI-1892, L3-186, TI-158-76, TI-152-76 and TI-184-76 were resistant to M. incognita; however only FH-7-72, TI-1892 and L3-186 were comparable to 'Jewel' in their resistance. 'Carver' and 'Rojo Blanco', two newly released cultivars from Tuskegee Institute were intermediate in resistance and susceptibility respectively when inoculated with M. incognita.

When plants were screened for resistance to M. javanica, TI-1892, 'Carver', FH-7-72, TI-1895, TI-164-76, TI-152-76,

TI-186-76, TI-62-76, TI-174-76 and TI-184-76 were found to be resistant, with TI-1892, TI-152-76 and TI-174-76 showing the highest resistance levels.

TI-1892 and TI-152-76 were higher in their resistance levels than other breeding lines when plants were inoculated with a mixed population of M. incognita and M. javanica. Although FH-7-72, TI-184-76 and TI-174-76 were resistant to both of these species in pure cultures, they were intermediate in resistance when tested in a mixed population. This indicated that plants which are resistant to either of the species in pure cultures may become susceptible in a mixed species population.

Plants evaluated in the field study indicated that FH-7-72 and TI-1892 were comparable to 'Jewel' in resistance, while 'Carver' was intermediate in resistance and 'Rojo Blanco' was susceptible. TI-263-76 and TI-1895 showed high tolerance levels to nematode population densities at levels below 1,000 larvae/pint of soil. Although cracking and rotting of storage roots were observed in all cultivars, it is believed that this might have been enhanced by root-knot nematode infestations.

The Improved Method allowed plants to be evaluated within the shortest period of time when all the three tests were compared. It also allowed periodic root observations without physically damaging the plants. All three methods produced comparable results.

INTRODUCTION

Plant parasitic nematodes are serious pests of many commercial crops. The United States losses in yield due to these microscopic eel-worms have been estimated as high as 10% with root-knot nematodes alone accounting for 4% (54).

Root-knot nematodes (Meloidogyne spp) infestations of sweet potatoes (Ipomea batatas) cause cracking and deformity of the root (64, 82, 84, 93). This reduces the grade and results in decreased yields and poor quality. The interaction of root-knot nematodes with other disease causing organisms such as bacteria and fungi further increases crop losses. The use of healthy plant material combined with soil fumigation has been shown to be effective in reducing initial nematode population density below a level that causes economic loss, however this can be expensive (82, 64). Breeding resistant cultivars is a more economical, desirable and effective method of control.

The objective of this study was to evaluate selected sweet potato cultivars and breeding lines possessing desirable horticultural characters for resistance to root-knot nematodes (Meloidogyne spp). Cultivars found to possess a high level of resistance to one or more of these root-knot nematode species may be used as breeding parents or continued in the breeding program and eventually released as new cultivars.

LITERATURE REVIEW

Sweet potato (Ipomea batatas. L) is a very important crop in tropical and subtropical countries. It is believed to have originated from tropical America where it spread to other parts of the world. The sweet potato belongs to the Convolvulaceae or morning glory family (93). The sweet potato is primarily used for human food but may also be used for animal food, for starch production and for various other industrial purposes (84, 93). Sweet potatoes are damaged by a number of important fungi, virus and bacteria diseases, and nematodes (84). The sweet potato was recorded as a host of root-knot nematodes in 1911 by Bessey (6).

Effects of Nematode Damage on Plants and Their Control

Nielson and Saser (64) obtained greater yields in infested soils treated with 1, 2-dibromoethane or with D-D (1, 3-dichloropropane; 1, 2-dichloropane) than non treated soil. Weimer and Harter (96) showed that nematodes caused considerable loss of sprouts of sweet potatoes in seed beds, but losses in the field were not serious. Southards et al (82) showed that "Dasnit" was effective in controlling nematodes associated with sweet potatoes resulting in increased yield and better root quality. Burk and Tennyson (14) obtained root-knot free sweet potato roots for bedding by a hot water dip of

116°F. for 65 minutes. Martin (61) used hot air at 122°F. for four to eight hours and obtained good control without adversely affecting the vitality of 'Goldrush' roots. Thomason et al (92) also used dry heat at 113°F. for 36 hours and eliminated M. incognita and M. incognita acrita in the cultivar 'Velvet'.

Nematocide treatments as shown by Harrison (45) can affect nematode populations in general either by direct action on the nematode or by indirect action on the host. He also showed that the effect of population in either case was not always apparent from a short term observation.

Crop rotation used for nematode population management as stated by Nusbaum and Ferris (65) caused reduction of the initial or preplant population densities of nematodes to levels that allowed the subsequent crop to become established and to complete its early growth before being heavily attacked and to preserve competitive antagonistic and predaceous nematodes at population densities effective in buffering the pathogenic species. Sauer and Giles (76) observed that fallowing reduced root-knot nematode infestation on tomato when applied for a number of years.

One way to avoid nematode damage to plants is to grow cultivars with tolerance limits higher than densities of a damaging nematode population actually occurring in the field (4, 78). Breeding and selection of such cultivars require experiments in which this tolerance limit is determined.

Seinhorst (78) in his work observed the relationship between the density of populations of root infesting nematodes and the yield of attacked plants and postulated an equation which expressed two phenomena; (a) a certain density up to which yield is not affected, and (b) a certain minimum yield which remained unaffected even at the higher densities.

The fundamental quantitative relationships between plant parasitic nematodes and growth and yield of annual crops are primarily a function of preplant densities (4, 7, 94). Barker and Olthof (4) showed that the expression of resistance or tolerance to nematodes was influenced immensely by host age. They also showed that the initial density required to cause significant plant damage and yield losses varied with different nematode species. They further observed that crop damage could be limited by planting crops at times which allowed satisfactory growth but inhibited nematode activity.

Elliot (29), and Poole and Schmit (71) observed independently that sweet potato yields were curtailed by root-knot nematode.

Wallace (95) showed that in some species of plants, top growth was stimulated following invasion by lavae of M. javanica at low numbers; in a second group of plant species there was a decrease in top weight as number of nematodes increased while in a third group he showed that there was no effect on the plant species as the density of the nematodes increased.

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Olthof and Potter (66) showed that commercial losses of certain vegetables affected by M. hapla were as high as 46-64% at the highest nematode densities. Hanounik et al (39) found yields of tobacco to decrease sharply until a minimum yield was approached as the density of M. incognita on tobacco increased beyond tolerance levels. Baker et al (3) showed that yields of tomato were suppressed up to 85% and 50% when infected by M. incognita and M. hapla respectively at high population levels.

Several specific names have been applied to root-knot nematodes and many workers on root-knot nematodes have noted conflicting evidence as to the behavior and range of host as pointed out by Chitwood (15). He also found that members of the genus Heloidogyne were extremely adaptable and their morphological character showed considerable variation.

Streu (86) observed greater population densities of plant parasitic nematodes on the root hair zone and active feeding was observed on root tips and on root hair zones. Bird (9) observed active feeding and rapid growth in a young adult of M. javanica after the nineteenth day from hatching when molting was completed.

Riggs and Winstead (73) found that root-knot nematode larvae entered root tips of both resistant and susceptible tomato cultivars in large amounts. Three infection courts were evident as shown by Krusburg et al (57). These included (a) young root tips, (b) lateral root raptures and (c) surface of cracks.

Effects of parasitic action of root-knot nematodes and nematodes in general as pointed out by Hollis (47) include mechanical damage, extraction of cellular protoplasm and nutrients, and reduction of absorptive and conductive root areas. He also observed that nematode effects on plants involved a direct action (feeding activities) and an indirect activity (chemical excretions from the nematode body). Krusberg and Nielson (57) observed that giant cell formation was associated with nematode feeding and the tissues in which these cells formed indicated those tissues fed upon by the nematode. Other atypical tissues as "abnormal xylem," hyperplastic parenchyma and cork were also associated with the nematode feeding. Larvae of Heterodera marioni as shown by Linford (59) fed repeatedly from epidermal cells before entering the root and they continued feeding as they entered into and migrated within it. He also observed young epidermal or dermatogen cells at the point of entry of the nematode to have been killed not by feeding but by entry of the larva after the cell had been weakened by the stylet.

Christie (17) and Endo (30) showed that morphological development in the root leading to giant cell formation was due to the stimulating action of some secretion expelled through the mouth of the nematode. Paulson and Webster (68) in their microscopic studies of giant cell formation showed that giant cells acted as nutrient sources for the developing root-knot

nematodes and that the giant cells degenerated shortly after the maturation of the female nematode.

Bird (10) from his work on M. javanica infestation of tomato and beans showed that giant cell development and maintenance depended on a continuous stimulus from the nematode. Once the stimulus from the nematode was removed, the cytoplasm of the giant cell became nonfunctional and broke down.

Root-knot nematodes as shown by Krusberg (58) can cause quite different morphological and anatomical responses in different plants and even in various parts of a particular plant and different species can cause different responses in the same plants. Meloidogyne species in general produce characteristic galls on the roots of susceptible plants and where seeds are sown in heavily infested soil, seedlings occasionally develop galls on their aerial parts (38, 85). Aerial galls were shown to have been induced by inoculating buds or young leaves of susceptible plants with root-knot nematode larvae (59, 72). Taylor (88) showed that Meloidogyne spp produced galls on the above ground parts of certain Hibiscus spp but penetration of the larvae occurred while the hypocotyl was still below the soil level. Wong and Willetts (98) found no differences in the type, number and tissue, or origin of the giant cells formed in the aerial parts and roots of susceptible tomato and French bean plants.

Effects of Environmental Factors on the Nematodes.

It has been shown that soil environmental factors affect nematode activity in the soil (12, 13, 17, 50, 52, 90). Wong and Mai (99) showed that temperature was an important factor in growth, development and reproduction of M. hapla in lettuce. They also showed that lack of O_2 or its limited supply was responsible for the decline of nematode activity in water logged soils.

Temperature as pointed out by Taylor and Buhrer (89) may be an important factor in determining the geographical distribution of Meloidogyne species. M. hapla as they observed occurred more frequently in cooler climates; M. incognita and M. javanica were more prevalent in the hotter climates. Griffin and Jorgenson (36) observed that potato tuber infection by M. hapla was increased as temperature increased from 20-30°C and that infection was higher at a high field moisture level.

Dropkin (24) in his studies on 18 resistant plant species and cultivars to Meloidogyne spp indicated that resistance was dependent on temperature in some plants and not in others. Barker and Olthof (4) pointed out that, some of the more serious crop failures due to nematodes resulted from lowering of the tolerance level of plant to the nematode by environmental stress. Griffin and Hung (37) showed that there was a direct correlation between galling of resistant alfalfa seedlings inoculated with root-knot nematode and temperature.

They showed that as the temperature increased, galling of the seedlings increased. Jatala and Russel (51) in their studies found that penetration, rate of development and total population of M. incognita in roots of susceptible Allgold and resistant Nemagold sweet potatoes increased with temperature between 24-32 C.

Bird and Wallace (13) in their experiments on the influence of a range of temperatures on hatching, mobility, invasion and growth on root-knot nematodes indicated that M. hapla had a thermal optimum of 25 C for hatching, 20 C for mobility and 15 C for invasion and grew well at 20 C. M. javanica had a thermal optimum of 30 C for hatching, 25 C for mobility, a wide range for invasion, and a thermal optimum of 25 C for growth.

Kinlock and Allen (53) showed that a soil temperature of 20 C was equally suitable for the invasion and development of M. hapla and M. javanica in tomatoes. However, M. javanica predominated in a mixed species infection at this temperature. Peacock (69) observed that the life cycle of root-knot nematode was completed in 28 days on tomato and cowpea at soil temperatures of 26-31 C and 33 days on maize, soja and tobacco.

An important consequence of parasitic as well as pathogenic action of root-knot nematodes might be the disturbance of metabolism of the host or an impairment of the ability of the host plants in the uptake of water and nutrients from the

soil (47). Such effects are sometimes reflected in the accumulation or depletion of a particular constituent in the tissues causing symptoms of deficiency or toxicity of these materials in the plants (11, 47). Goswamin et al (35) found that there was an increase of Ca in the roots but not in the shoots when tomato plants were infected with M. incognita. Mg was found to decrease in the shoots but it increased in the roots. Otiefa (67) found that egg mass production by M. incognita considerably increased when the level of K changed from low to medium but there was little effect with additional increases of K in the plant. He also found that M. incognita developed more slowly on lima beans with low K and faster on those with high K. He also observed that infected plants had less N, P, K and Ca and Mg than uninfected plants. Maung and Jenkins (62) found an increase in levels of N, P, and K in roots on infected tomatoes with a heavy infestation of M. incognita acrita, but no significant changes with light infection.

Meloidogyne javanica parasitising tomato plants deficient in a single major element was found by Bird (11, 9) to respond in most cases by growing more quickly than when fed on plants obtaining a full nutrient balance. He also observed that this response was most noticeable when N was absent and was less noticeable when Mg, Fe, or K was absent.

Nature of Resistance.

Changes in host growth regulatory substances are probably part of many root-knot nematode infections (23, 26). Dropkin (24) observed that the ability of certain growth regulators and temperature to alter the course of infection in genetically resistant plants is the result of subtle metabolic differences between cultivars. Bird (12) in his studies found that plants responded to root-knot nematode infection by reduction in their photosynthetic rate, growth and yield, which might have resulted from the interference with the synthesis and translocation of growth hormones produced in the roots.

Wingard (97) defined resistance as the ability of a plant to withstand, oppose, lessen or overcome the attack of a pathogen. However, some other plant nematologists tend to place emphasis on the development of nematode populations with only secondary attention to host injury (3, 39, 75, 101). Rohde (74) gave a more generally accepted definition of a resistant plant as one on which nematodes reproduce poorly, and a tolerant plant as one that shows little injury even under attack by large populations of nematodes.

Peacock (70) in his studies postulated several ways in which unknown chemicals might have been responsible for resistance of a plant to nematode attack. These included: (a) masking the attractant substance in the root, or by actively repelling the nematode; (b) killing the nematode on entry

or retarding its development; (c) neutralizing the effect of nematode saliva on giant cell formation; (d) changing the composition of the cell wall so that the cell wall is impenetrable to the nematode stylet; and (e) upsetting the sex ratio of the nematode either physiologically or by eliminating the females. Peacock (69) earlier observed that the life cycle of root-knot nematode was never completed, because larvae died before or shortly after completing the final molt on two species of Crotalaria. Huijsman (46) in his studies on resistance of potato root to eelworm observed that all resistant plants produced a root diffusate containing the hatching factor and when the potatoes were grown in infested soil, numerous larvae invaded the roots but failed to develop further.

Wallace (95) considered the difference in the response of certain plants to infection by M. javanica as being the result of the interaction between inhibitory and stimulatory processes in the plant and that there appeared to be a kind of balance or homeostasis between the nematode and the plant, in which there was a feedback between the feeding process and the plant cell. Although many plants are highly resistant to various nematode species, Krusberg (57) observed that inhibitory chemicals have been isolated from only two plants, a terthienyl compound isolated from tagetes, and a glucoside isolated from asparagus. It has been suggested by some workers (26) that the level of growth hormones may determine the host's response to root-knot nematodes and that higher levels of auxins and kinins in plants

favor susceptibility.

Sawhney and Webster (77) showed that IAA and Kinins in a combination but not separately increased the susceptibility of susceptible tomatoes but when resistant plants were treated with the same combination, they produced galls. However only a few larvae developed to maturity which suggested that resistance was not completely broken and further suggested that plant growth hormones were not the only factors which determined the host responses to M. incognita infection. Mjuge and Viglierchio (63) showed that IAA applied in drench form to tomato plants allowed for normal top growth while producing a threefold increase in root growth and a fivefold increase in gall number in a field infested with M. incognita.

Investigations carried out by Giebel and Jackowiacki (33) showed that the activity of tryptophan decarboxylase in roots of susceptible potato after their invasion by H. rostochiensis larvae generally increase about two times as compared with healthy roots whereas it did not change distinctly in roots of resistant plants. Singh and Choudhury (79) found that phenolic content as well as phosphorous was directly related to root-knot nematode resistance being highest in immune cultivars followed by resistant, tolerant and susceptible cultivars.

Jatala and Russell (51) concluded from their studies that root-knot nematode resistance in sweet potato appeared to be based on root exudate repellent to the root-knot nematode

larvae and this could have inhibited or reduced larvae contact with the root. They further stated that resistance could have been due to failure of larvae to penetrate the plant, inability of the larvae to establish nutritive relationship with the plant due to hypersensitive plant interaction or nutrient deficiency and probable post infection production of inhibitory chemicals.

In the greenhouse and laboratory studies, Struble et al (87) demonstrated several relationships in root-knot nematode resistant sweet potatoes. These included: trace or less amounts of root galling; trace to severe root tip necrosis; few or no nematode developing to mature forms; little or no reproduction by nematodes; reduced number of egg mass in some cases where reproduction occurs and few or no giant cells were formed. Dean and Struble (21) observed that nematodes entering resistant sweet potato roots produced necrosis of host tissue several days after inoculation, however no necrosis was observed in roots of susceptible cultivars. Giamalva et al (32) suggested two types of resistance to root-knot nematodes in sweet potatoes; one associated with root necrosis and another type of resistance as exemplified by 'Heartgold', which is not associated with root necrosis.

Most nematode resistant cultivars of crop plants appear to have vertical resistance which shows up as hypersensitivity or necrosis controlled by one or two genes as observed by Rohde

(74). He also observed that plants with vertical resistance supported lower parasite populations and were often easy to recognize. This was mostly shown on root-knot nematode resistant plants. He also showed that horizontal resistance was polygenic and generally effective against all races of the pathogen.

Inheritance of Resistance to Root-Knot Nematodes.

There appear to be considerable disagreement on the inheritance of root-knot nematodes, with most agreeing that inheritance of resistance to nematodes in plants is controlled by one to three dominant genes (2, 18, 22, 40, 41, 44).

Hare (40, 41, 43) was probably the first to offer experimental proof of a single dominant gene for resistance to nematodes in plants inherited disomically. He showed that resistance of pepper to Meloidogyne spp was controlled by a single dominant gene or closely linked genes. Drolsom et al (22) described resistance of tobacco to M. incognita acrita as controlled by a single gene pair with resistance being dominant and the possibility of some modifiers. Gilbert and McGurrie (34) described resistance to severe galling by M. incognita on tomato as controlled by a single gene.

Barham and Winstead (2) stated that the resistance of certain tomato cultivars to four root-knot nematode species was controlled by one major gene specified as incompletely dominant. Thomason and Smith (91) confirmed that resistance

of tomato to M. incognita acrita and M. javanica was due to the same major gene. Hare (43) showed that resistance of cowpea to root-knot nematodes was controlled by a single gene pair with resistance being dominant. Smith (80) showed that resistance of cotton to root-knot nematode was recessive, possibly polygenic. Bain (1) found that the inheritance of resistance of both white and red clover to M. incognita and M. incognita acrita was dominant. Cordner et al (20) found that nematode resistance in sweet potato was a recessive factor and that its inheritance was relatively simple. Struble et al (87) however showed that resistance to root-knot nematode in sweet potato was not a simple inherited character but inherited as multiple factors. They extended the conclusions made by Hughes et al (49) on inheritance of resistance to stem rot in sweet potato as being subject to considerable environmental modification to include inheritance of resistance to root-knot nematode.

MATERIALS AND METHODS

Greenhouse and field experiments were conducted to evaluate sweet potato cultivars and breeding lines for resistance to root-knot nematode species.

Evaluation Procedures.

Both root gall and egg mass indices were used in the evaluation process. The following rating system reported by Dukes (28) were used for all nematode evaluations in this experiment.

Gall Index

1=No gall, root system healthy and free of galls
2=Light gall, 1-25% of root system galled
3=Moderate galling, 26-50% of root system galled
4=Heavy galling, 51-75% of root system galled
5=Severe galling, 76-100% of root system galled

Egg Mass Index

1=No egg masses evident over entire root system
2=Scattered egg masses covering only 1-25% of root system
3=Moderate number of egg masses covering 26-50% of root system
4=Numerous egg masses covering 51-75% of root system
5=Extremely large numbers of egg masses covering 76-100% of root system

Greenhouse Test I (Greenhouse-bed method)

Five beds were filled with sterilized soil of 1:1:1 mixture of top soil, old sawdust and sand respectively. The sterilization was done by fumigating the soil mixture with methyl bromide for 72 hours and then airing for 120 hours. Three of the beds were inoculated separately, each with a pure culture of one of the three species of Meloidogyne; (M. incognita, M. javanica, and M. hapla). The fourth bed was inoculated with a mixture of M. incognita and M. javanica and the fifth bed was inoculated with nematode infested soil from the field. The pure cultures were obtained from the USDA Nematology Laboratory at Beltsville, Maryland, and N. Y. Agriculture Experiment Station, Geneva, N. Y. All inoculations were done on September 27, 1976.

In a preliminary experiment, it was observed that some tomato cultivars were more easily infected than sweet potatoes. For this reason, susceptible tomato cultivars ('Homestead', 'Fireball' L262, and L445) were planted in each of the five beds to cause a more rapid increase in nematode infestations.

On the 10th of October 1976, a preliminary experiment was started with 21 sweet potato cultivars. Ten stem cuttings of each cultivar were planted in 10 cm rows in each of the 5 beds using a completely randomized design with 3 replications in each bed. Guard rows were planted with 'Centennial' sweet potatoes.

The plants were watered as necessary and were fertilized four weeks after planting with 30 ppm 20:20:20 NPK. The greenhouse was sprayed weekly with malathion, guthion, sevin and benlate alternately against insects and fungi. Soil samples from each bed were periodically sent to Auburn University Nematology Laboratory for nematode counts and purity evaluations (appendix 1).

On January 19, 1977 the plants were dug up and evaluated for nematode resistance due to frost damage in the greenhouse. Results of this study were not very meaningful as the infestation was too low and it was very difficult to maintain an optimum temperature in the beds without heating cables. The majority of the plants were killed during a hard freeze. This experiment did however provide some useful information, so that precautions could be taken in the planning of future experiments.

After removal of plant residue, the beds were reinfested with pure cultures of the same species obtained from the Beltsville USDA Laboratory containing about 1,000 - 2,000 larvae per pint of soil. Beds were replanted with 'Homestead' tomato seedling in the 1st and 2nd true leaf stage.

In July 1977, when the nematode population had reached 600 - 800 larvae per pint of soil in each of the beds except the 'hapla' bed, all above ground portions of tomato plants were removed and the soil in each bed was mixed thoroughly and

20 different cultivars and advanced breeding lines were planted as in the preliminary studies. 'Homestead' tomato seedlings were used for guard rows. Watering, fertilizer applications, and sprayings were done as in the preliminary studies.

No further experiments were conducted with M. hapla because the infestation was still too low to obtain any appreciable infection. The plants from the four remaining beds were dug and roots were washed and evaluated for root-knot nematode resistance on December 16, 1977.

Greenhouse Test II (The Improved Method)

This method was used in addition to the greenhouse-bed method. It was first developed and used in California by Gentile, et al (31). Cylinders 8 cms in diameter and 15 cm long were made by wrapping 15 x 20 cms sections of aluminum foil (0.003 mm) around an 8 x 15 cms tin can folding the extra foil at the lower end. The overlapping longitudinal ends were stapled together and the cylinders were filled with sterilized soil. The cylinders were arranged on thermostatically controlled heating cables in a bench with half their length in a moistened sandy soil. Sweet potato terminal cuttings were planted in each of the cylinders. After eight days, the cylinders were opened and the young roots were inoculated with the nematode species by placing 5-10 fragments of infested tomato roots with galls and egg masses containing about 1000 - 2000 eggs on the exposed rootlets in each cylinder. The

cylinders were then closed and placed back in their original positions. The temperature in the bed was maintained at 29 C and the plants were fertilized with 30 ppm of 20:20:20 NPK.

Twenty cultivars replicated five times were used in a completely randomized design. This method allowed a controlled inoculation of each plant and confined the root system and nematodes within a readily accessible area. It therefore permitted root observation and evaluation without severe injury to or loss of feeder roots. Because of the confinement of individual roots and high infestation levels, cultivars could be evaluated for root-knot nematode resistance after seven weeks rather than 10-12 weeks that are normally practiced in the greenhouse bench method and 14-20 weeks for field observations. This method was used for evaluation of sweet potato seedlings inoculated with M. incognita, M. javanica and nematode infested soil from the field which contained primarily M. incognita.

Field Experiment.

The field experiment was conducted on a heavily nematode infested field which had been previously planted with okra and vetch for three years. The initial experiment was started in July 1977 following a summer crop of okra. The field was divided into four sections and soil samples were taken from each section. Results of the soil analyses showed a uniformly infested field. A randomized complete block design was used.

Each section consisted of 15 main rows, 15 m long and 1.2 m between rows. Each row was divided into three sub rows 4.5 m in length. Twelve sweet potato cultivars and advanced breeding lines, along with okra and susceptible and resistant tomato cultivars, were randomly planted such that each main row consisted of three different cultivars of 16 plants. Each cultivar thus occurred in each block three times. Sweet potato slips and/or cuttings and tomato seedlings were hand planted 30 mm apart. The okra was direct seeded and later thinned to one plant per hill 30 mm apart. 'Centennial' was used as the susceptible check and 'Jewel' as the resistant check. 'Rojo Blanco' sweet potato cuttings were planted as guard rows.

The field was cultivated and fertilized four weeks after planting. A total of three harvests were made. The first harvest was made eight weeks, the second 14 weeks and the third 18 weeks after planting.

A row of 16 plants of each sweet potato cultivar was harvested from each block at each harvest. The vines were removed and roots were taken to the laboratory, where they were washed, and evaluated for root-knot nematode resistance. The same evaluation procedures were followed as in the greenhouse method. Soil samples were taken from each block for nematode counts at the end of each harvesting period.

At the third harvest, storage root cracks and deformities were evaluated in addition to the root gall and egg mass

indices.

Statistical analyses of the data were followed as outlined by Steel and Torrie (83).

RESULTS

Greenhouse Bed Method.

Sweet potato cuttings were planted in greenhouse beds after infestation levels had reached 600-800 larvae per pint of soil. Plants were harvested 12 weeks after planting.

When these plants were screened for resistance to M. incognita (Table 1), results indicated that FH-7-72, TI-1892, L3-186, TI-158-76, TI-152-76, and TI-184-76 were all resistant according to both gall and egg mass indices. However, only FH-7-72, TI-1892 and L3-186 were comparable in their resistance to 'Jewel'. 'Carver', TI-1895, TI-1894, TI-186-76 and TI-174-76 showed intermediate resistance. All other lines were as susceptible as 'Centennial'.

Results of screening for resistance to M. javanica (Table 2) showed that TI-1892, 'Carver', FH-7-72, TI-1894, TI-1895, TI-164-76, TI-152-76, TI-186-76, TI-62-76, TI-174-76, and TI-184-76 were resistant. However, TI-1892, TI-152-76, and TI-174-76 were significantly higher in their resistance level than 'Jewel'. The other resistant lines were comparable to Jewel according to both gall and egg mass indices. L3-186 was intermediate in resistance while 'Rojo Blanco', TI-180-76, TI-263-76 and TI-220-76 were equal to 'Centennial' in susceptibility ratings.

Table 1. Reaction of sweet potato cultivars and breeding lines to *M. incognita* using the Greenhouse Bed Method.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	1.0 a**	1.3 a
Centennial	5.0 d	5.0 d
Rojo Blanco	5.0 d	4.6 cd
Carver	3.3 bc	3.3 b
FH-7-72	1.0 a	1.3 a
TI-1894	3.6 bd	3.6 bc
TI-1892	1.3 a	1.6 a
TI-1895	3.3 bc	2.3 a
TI-164-76	4.6 cd	4.6 cd
TI-180-76	5.6 cd	4.6 cd
TI-263-76	4.6 cd	4.6 cd
TI-220-76	4.6 cd	4.6 cd
TI-152-76	2.6 b	2.6 ab
TI-186-76	3.0 bc	3.0 b
TI-191-76	4.6 cd	4.6 cd
L3-186	1.3 a	1.6 a
TI-158-76	2.6 b	3.6 bc
TI-62-76	4.0 c	4.6 cd
TI-174-76	3.3 bc	3.3 b
TI-184-76	2.30 b	2.0 a

* Gall and egg mass indices are rated on a scale of 1-5; 1 being most resistant and fewest egg masses and 5 being susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

Table 2. Reaction of sweet potato cultivars and breeding lines to *M. javanica* using the Greenhouse Bed Method.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	2.3 b**	2.6 b
Centennial	4.6 d	4.8 d
Rojo Blanco	4.6 d	4.4 cd
Carver	2.4 b	2.2 ab
FH-7-72	2.3 b	2.5 b
TI-1894	2.3 b	2.0 ab
TI-1892	1.3 a	1.2 a
TI-1895	2.0 ab	2.7 b
TI-164-76	2.3 b	2.1 a
TI-180-76	4.0 cd	4.8 d
TI-263-76	4.3 cd	4.8 d
TI-220-76	2.6 d	5.0 d
TI-152-76	1.6 a	1.4 a
TI-186-76	2.3 b	2.8 b
TI-191-76	2.6 b	2.6 b
L3-186	3.6 c	3.8 c
TI-158-76	-	-
TI-62-76	2.6 b	2.4 b
TI-174-76	1.6 a	1.4 a
TI-184-76	2.3 b	2.4 b

*Gall and egg mass indices are rated on a scale of 1-5; 1 being most resistant and fewest egg masses and 5 being most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Table 3 indicates results obtained when plants were inoculated with a population of mixed Meloidogyne species. Results showed that TI-1892, and TI-152-76 were higher in resistance levels than other lines. 'Carver', FH-7-72, TI-1894, TI-1895, L3-186, TI-174-76, TI-184-76 and Jewel were intermediate in resistance. However, there were no significant differences in the level of resistance between 'Jewel', FH-7-72, TI-174-76, TI-1892 and TI-152-76 according to gall indices. There were no significant differences observed among TI-1892, TI-152-76, FH-7-72, 'Jewel', TI-1894, TI-174-76 and TI-184-76, according to egg mass indices. 'Rojo Blanco', TI-164-76, TI-180-76, TI-263-76, TI-220-76, TI-186-76, TI-191-76 and TI-62-76 showed no significant differences when compared to 'Centennial' which is susceptible. These results indicate that some of the cultivars and breeding lines that are resistant to a single species may become susceptible in a mixed population probably due to the interaction of different species on the plant.

Soil from the field plots contained other nematode genera such as Pratylenchus Xephinema and Rotylenchus (appendix 2) but mostly M. incognita. Evaluation of plants in this bed (Table 4) showed that FH-7-72, TI-1892, L3-186, TI-174-76 and TI-184-76 were comparable in their resistance to 'Jewel'. 'Carver', TI-1894, TI-1895, TI-152-76, TI-186-76 and TI-191-76 were intermediate in resistance. The other breeding lines were

equal to 'Centennial' in susceptibility.

Table 3. Reaction of sweet potato cultivars and breeding lines to a mixed population of Meloidogyne species (M. incognita and M. javanica) using the Greenhouse Bed Method.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	3.0 ab**	2.9 ab
Centennial	4.6 cd	5.0 e
Rojo Blanco	4.6 cd	5.0 e
Carver	3.6 c	3.3 bc
FH-7-72	3.0 ab	2.7 ab
TI-1894	3.6 c	3.0 ab
TI-1892	2.3 a	1.8 a
TI-1895	3.6 c	3.4 bc
TI-164-76	4.6 cd	5.0 d
TI-180-76	5.0 d	4.8 de
TI-263-76	4.0 cd	4.3 c
TI-220-76	4.6 d	4.6 de
TI-152-76	2.4 a	2.1 a
TI-186-76	4.7 cd	4.8 de
TI-191-76	4.6 cd	4.6 cd
L3-186	3.3 b	3.6 bc
TI-158-76	-	-
TI-62-76	4.6 d	4.5 d
TI-174-76	3.0 ab	3.2 bc
TI-184-76	3.6 c	2.4 c

* Gall and egg mass indices are rated on a scale of 1-5, 1 being most resistant and fewest egg masses and 5 being most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Table 4. Reaction of sweet potato cultivars and breeding lines to a heavily nematode infested field soil using the Greenhouse Bed Method.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	1.3 a**	1.0 a
Centennial	5.0 e	4.8 e
Rojo Blanco	4.3 de	5.0 e
Carver	3.6 cd	3.2 cd
FH-7-72	1.6 a	1.3 a
TI-1894	3.7 c	3.7 d
TI-1892	2.0 a	2.4 b
TI-1895	3.0 bc	3.2 cd
TI-164-76	4.3 de	4.8 e
TI-180-76	5.0 e	5.0 e
TI-263-76	4.6 de	5.0 e
TI-220-76	4.6 de	4.8 e
TI-152-76	3.0 bc	2.8 bc
TI-186-76	3.3 bc	3.4 cd
TI-191-76	3.3 bc	3.3 cd
L3-186	1.6 a	1.5 ab
TI-158-76	-	-
TI-62-76	4.6 de	4.8 e
TI-174-76	2.6 ab	2.3 b
TI-184-76	1.3 a	1.4 a

* Gall and egg masses indices are rated on a scale of 1-5; 1 being the most resistant and fewest egg masses and 5 being most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Greenhouse Improved Method.

In these experiments, optimum environmental conditions were maintained for egg hatching, and growth and development of the larvae. Medium sized vines (3-4 mm in diameter) were used and fertilizer applications and watering of plants were controlled to avoid vigorous plant growth. Twenty cultivars and breeding lines were used for each experiment.

Evaluation of plants against M. incognita infestation (Table 5) showed that FH-7-72, TI-1892, TI-152-76, TI-186-76, L3-186, and TI-184-76 were comparable in their resistance to 'Jewel'. TI-174-76 and TI-1895 although resistant, were significantly lower in resistance than 'Jewel'. 'Carver', TI-1894, TI-164-76, TI-263-76, TI-158-76 were intermediate in resistance while 'Rojo Blanco', TI-180-76, TI-220-76, TI-191-76, TI-62-76 did not differ significantly from 'Centennial' in susceptibility according to the gall index ratings. Similar results were obtained when egg mass indices were used; however, the ratings were generally lower than the gall indices. This may be due to the fact that not enough egg masses had developed at the time of evaluation, even though heavy galling was evident on some cultivars resulting in severely damaged plants which produced poor top growth.

Results obtained when the same cultivars, under similar conditions were inoculated with M. javanica (Table 6) showed that TI-152-76, TI-1895, TI-186-76, TI-62-76, TI-174 and

Table 5. Reaction of sweet potato cultivars and breeding lines to *M. incognita* when inoculated by an Improved Method

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	1.0 a**	1.0 a
Centennial	4.20 def	2.8 efg
Rojo Blanco	5.0 f	4.2 fg
Carver	3.0 cd	3.2 def
FH-7-72	1.2 a	1.2 ab
TI-1894	3.0 cd	2.8 cde
TI-1892	2.2 abc	2.0 abc
TI-1895	2.40 bc	2.6 cde
TI-164-76	3.8 def	3.6 cde
TI 180-76	4.4 ef	4.4 g
TI-263-76	3.6 de	4.4 g
TI-220-76	4.2 def	4.0 fg
TI-152-76	2.0 abc	2.2 bcd
TI-186-76	2.0 abc	2.2 bcd
TI-191-76	4.2 def	4.2 fg
L3-186	1.0 a	1.2 ab
TI-158-76	3.0 cd	2.8 cde
TI-62-76	4.0 def	3.2 def
TI-174-76	2.4 bc	3.4 efg
TI-184-76	1.6 ab	1.2 ab

* Gall and egg mass indices are rated on a scale of 1-5; 1 being the most resistant and fewest egg masses and 5 being the most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Table 6. Reaction of sweet potato cultivars and breeding lines to M. javanica when inoculated by an Improved Method.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	4.8 hi**	4.8 de
Centennial	4.6 ghi	4.6 de
Rojo Blanco	4.6 ghi	5.0 e
Carver	3.2 def	3.4 bc
FH-7-72	4.0 fgh	4.0 cd
TI-1894	3.6 efg	2.8 b
TI-1892	2.0 abc	3.4 bc
TI-1895	2.0 abc	2.8 b
TI-164-76	5.0 i	5.0 e
TI-180-76	5.0 i	5.0 e
TI-263-76	3.4 def	3.2 bc
TI-220-76	3.4 def	3.4 bc
TI-152-76	1.6 ab	1.8 a
TI-186-76	2.8 bcd	3.2 bc
TI-191-76	5.0 i	5.0 e
L3-186	5.0 i	5.0 e
TI-158-76	5.0 i	5.0 e
TI-62-76	2.4 bcd	2.8 b
TI-174-76	1.0 a	1.0 a
TI-184-76	4.6 ghi	4.6 de

* Gall and egg mass indices are rated on a 1-5 scale; 1 being the most resistant and fewest egg masses and 5 being the most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

TI-1892 were the most resistant cultivars. However, TI-174-76 was significantly higher in resistance than the other resistant lines, according to both gall and egg mass indices. TI-263-76, TI-220-76, TI-180-76, TI-1894, and Carver were intermediate in resistance. All other lines and cultivars including 'Jewel' were susceptible.

In a similar experiment, under the same greenhouse conditions, the plants were inoculated with larvae and egg masses collected from the heavily nematode infested field soil bed. Results of this experiment (Table 7), showed that FH-7-72, TI-1892, TI-184-76, and TI-152-76 were comparable in resistance. 'Carver', TI-1895, TI-186-76 and TI-1894 were intermediate in resistance. Although Carver and TI-1895 were intermediate in resistance they were not significantly different from 'Jewel'. They were significantly different from FH-7-72, TI-1892 and TI-184-76. The other lines were as susceptible as 'Centennial'. Similar results were obtained for both gall and egg mass indices, except that the egg mass indices of Carver and TI-1895 were significantly higher than that of 'Jewel'.

During the preliminary experiment of the Greenhouse Bed Method, it was observed that tomato plants appeared to be more readily susceptible to root-knot nematodes than sweet potato plants. In a later experiment conducted using the cylinder method, 'Rojo Blanco' cuttings and 'Homestead' tomato seeds were planted in each cylinder. Twelve days after planting when

Table 7. Reaction of sweet potato cultivars and breeding lines to a heavily nematode infested field soil when inoculated by an Improved Method.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	2.0 ab**	1.8 a
Centennial	5.0 f	5.0 e
Rojo Blanco	5.0 f	5.0 e
Carver	3.0 bc	3.6 bc
FH-7-72	1.8 a	2.2 a
TI-1894	3.6 cde	3.6 bc
TI-1892	1.8 a	2 a
TI-1895	3.0 bc	3.2 b
TI-164-76	4.8 f	4.8 de
TI-180-76	5.0 f	5.0 e
TI-263-76	4.4 ef	4.0 bcd
TI-220-76	5.0 f	5.0 e
TI-152-76	2.6 abc	4.4 cde
TI-186-76	3.2 cd	3.6 bc
TC-191-76	4.6 ef	4.6 de
L3-186	4.2 def	4.6 de
TI-158-76	4.4 ef	4.6 de
TI-62-76	5.0 f	5.0 e
TI-174-76	4.2 def	4.2 ede
TI-184-76	1.4 a	1.8 a

* Gall and egg mass indices are rated on a scale of 1-5; 1 being the most resistant and fewest egg masses and 5 being the most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

the tomatoes had reached the first true leaf stage, cylinders were opened and roots inoculated with M. incognita larvae. Two weeks after inoculation some of the pots were opened, roots washed and examined under a dissecting microscope. Galls were clearly visible on tomato roots at this time, while galling was not detectable before the fourth or fifth week with respect to sweet potatoes. This concurs with results observed in the preliminary greenhouse experiment which indicated that some tomato cultivars are more readily attacked by M. incognita than sweet potatoes.

Field Experiment.

Roots of sweet potato plants were dug, taken to the lab, washed, and observed under a dissecting microscope. Sixteen plants of each cultivar per block were evaluated at each of the three harvests. The plants were rated on a scale of 1-5 according to the percentage of roots infested with one being less than 10% of the roots infested and five being more than 76% of the roots infested. 'Jewel' was used as the resistant check and 'Centennial' as the susceptible check. In addition to the sweet potatoes, roots of resistant and susceptible tomato cultivars and okra were also dug to check the degree of infestation in each block during each harvest. Nematode counts were made for each block. The initial population counts are shown in appendix 2. It was observed that, in blocks where nematode populations were extremely high, some of the sweet

potato cultivars exhibited poor growth and eventual death of some plants.

Table 8 shows the gall and egg mass indices of the field experiment at first harvest, eight weeks after planting. Results indicated that FH-7-72, TI-1892, TI-1895, and TI-263-76 were resistant. However, only FH-7-72, TI-1892, and TI-1895 were comparable in their resistance to 'Jewel'. 'Carver', 'Rojo Blanco', TI-1894, TI-220-76, and TI-164-76 showed intermediate resistance while TI-180-76 was as susceptible as 'Centennial'. The nematode population count at this harvest is shown in appendix 2.

The second harvest was made 14 weeks after planting. Results as presented in Table 9 show that FH-7-72 and TI-1892 were as resistant as 'Jewel'; while 'Carver', TI-1895 and TI-263-76, showed intermediate resistance. 'Rojo Blanco', TI-1894, TI-164-76, TI-180-76 and TI-220-76 were as susceptible as 'Centennial' when they were evaluated according to gall and egg mass indices.

Both feeder and storage roots were examined 18 weeks after planting (Tables 10 & 11). Evaluation of feeder roots as shown in Table 10 indicated that FH-7-72, and TI-1892 were comparable in their resistance to Jewel. Although TI-1892 was resistant it was significantly lower than 'Jewel'. The degree of resistance in the other lines was similar to that observed at the second harvest except for TI-263-76 which had ratings of 5.0

Table 8. Reaction of sweet potato cultivars and breeding lines in a heavily nematode infested field - Harvest 1.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	1.0 a**	1.0 a
Centennial	4.25 f	4.0 d
Rojo Blanco	3.5 ef	2.75 bcd
Carver	3.25 def	3.25 cd
FH-7-72	1.25 ab	1.0 a
TI-1894	3.75 ef	4.0 d
TI-1892	2.0 abc	2.0 abc
TI-1895	1.50 abc	1.75 ab
TI-164-76	3.75 ef	3.5 d
TI-180-76	4.0 f	4.0 d
TI-263-76	2.50 bcd	2.0 abc
TI-220-76	3.0 cdef	3.25 cd

* Gall and egg mass indices are rated on a scale of 1-5; 1 being most resistant and fewest egg mass and 5 being most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Table 9. Reaction of sweet potato cultivars and breeding lines in a heavily nematode infested field - Harvest 2.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	2.0 ab**	2.0 a
Centennial	5.0 d	5.0 f
Rojo Blanco	4.5 cd	5.0 f
Carver	3.0 b	3.0 abc
FH-7-72	1.75 a	2.0 a
TI-1894	4.0 cd	4.0 cdef
TI-1892	2.0 ab	2.5 a
TI-1895	3.5 c	4.25 def
TI-164-76	5.0 d	4.5 ef
TI-180-76	5.0 d	5.0 f
TI-263-76	3.5 bc	3.75 bcde
TI-220-76	4.5 cd	5.0 f

* Gall and egg mass indices are rated on a scale of 1-5; 1 being most resistant and fewest egg mass and 5 being most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Table 10. Reaction of sweet potato cultivars and breeding lines in a heavily nematode infested field - Harvest 3.

CULTIVAR	GALL INDEX*	EGG MASS INDEX*
Jewel	1.0 a**	1.0 a
Centennial	5.0 f	5.0 d
Rojo Blanco	5.0 f	5.0 d
Carver	3.0 b	3.25 b
FH-7-72	1.0 a	1.25 a
TI-1894	4.25 de	4.75 d
TI-1892	2.5 b	2.75 b
TI-1895	3.5 c	4.0 c
TI-164-76	4.75 ef	5.0 d
TI-180-76	4.5 def	5.0 d
TI-263-76	5.0 f	4.75 d
TI-220-76	5.0 f	4.75 d

* Gall and egg mass indices are rated on a scale of 1-5; 1 being most resistant and fewest egg mass and 5 being most susceptible and greatest egg masses.

** Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

Table 11. Effect of Nematodes on % Root Cracking and Deformities on several sweet potato cultivars and breeding lines.

CULTIVAR	% ROOT CRACKS AND DEFORMITIES	
Jewel	2.5	a*
Centennial	57.5	c
Rojo Blanco	15.0	ab
Carver	7.5	a
FH-7-72	10	a
TI-1894	4.25	a
TI-1892	3.75	a
TI-1895	4.25	a
TI-164-76	7.5	a
TI-180-76	28.75	b
TI-263-76	12.5	a
TI-220-76	47.5	c

* Means followed by the same letter in each column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

and 4.75 for the gall index and egg mass index respectively. This was comparable in susceptibility to that of 'Centennial'.

The percentage of root cracks and deformities is shown in Table 11. These results indicated that more than 45% and 50% of TI-220-76, and 'Centennial' storage roots respectively were badly damaged by nematodes. However, some of the susceptible cultivars showed only slight damage to the roots. Root cracking was also observed in the resistant cultivars with Jewel and FH-7-72 showing 2.5% and 10% respectively. Some of the roots which were severely damaged by nematodes had begun to rot.

Tables 12, 13, and 14 show the comparison of reactions of different sweet potato cultivars when inoculated with M. incognita and M. javanica using different experimental methods. The data (Table 12) indicate no significant difference in reaction of plants when inoculated with M. incognita using either of the two greenhouse methods at 5% level of probability. With M. javanica (Table 13) there were differences in the reaction of some cultivars to this species using the different greenhouse methods. Using the bed method, some cultivars showed resistance to the nematodes while they appeared to be highly susceptible when the improved method was used. The difference in reaction probably arose from high populations established in the cylinders. Results of the reaction of plants to nematode populations of the heavily infested field soil using the two

Table 12. Comparison of reactions of sweet potatoes to *M. incognita* gall infestation using two greenhouse methods.

CULTIVAR	GREENHOUSE IMPROVED METHOD	GREENHOUSE BED METHOD
Jewel	1.0*	1.0
Centennial	4.20	5.0
Rojo Blanco	5.0	5.0
Carver	3.0	3.3
FH-7-72	1.2	1.0
TI-1894	3.0	3.6
TI-1892	2.2	1.3
TI-1895	2.40	2.3
TI-164-76	3.8	4.6
TI-180-76	4.4	4.6
TI-263-76	3.6	4.6
TI-220-76	4.2	4.6
TI-152-76	2.0	2.0
TI-186-76	2.0	3.0
TI-191-76	4.2	4.6
L3-186	1.0	1.3
TI-158-76	3.0	2.6
TI-62-76	4.0	4.0
TI-174-76	2.4	3.3
TI-184-76	1.6	2.0

* Gall index ratings of 1-5 were used, with 1 being the most resistant and 5 being the most susceptible.

Table 13. Comparison of reactions of sweet potato to *M. javanica* gall infestation using two greenhouse methods.

CULTIVAR	GREENHOUSE IMPROVED METHOD	GREENHOUSE BED METHOD
Jewel	4.8*	2.3
Centennial	4.6	4.6
Rojo Blanco	4.6	4.6
Carver	3.2	2.4
FH-7-72	4.0	2.3
TI-1894	3.6	2.3
TI-1892	2.0	1.3
TI-1895	2.0	2.0
TI-164-76	5.0	2.3
TI-180-76	5.0	4.0
TI-263-76	3.4	4.3
TI-220-76	3.4	4.6
TI-152-76	1.6	1.6
TI-186-76	2.8	2.3
TI-191-76	5.0	2.6
L3-186	5.0	3.6
TI-158-76	5.0	-
TI-62-76	2.4	2.6
TI-174-76	1.0	1.6
TI-184-76	4.6	2.3

* Gall index ratings of 1-5 were used with 1 being the most resistant and 5 being the most susceptible.

Table 14. Comparison of sweet potato reactions to a heavily nematode infested soil using three experimental methods.

CULTIVAR	GREENHOUSE IMPROVED METHOD	GREENHOUSE BED METHOD	FIELD EXPT*
Jewel	2.0**	1.3	1.0
Centennial	5.0	5.0	5.0
Rojo Blanco	5.0	4.3	5.0
Carver	3.0	3.6	3.0
FH-7-72	1.8	1.6	1.0
TI-1894	3.6	3.7	4.25
TI-1892	1.8	2.0	2.5
TI-1895	3.0	3.0	3.5
TI-164-76	4.8	4.3	4.75
TI-180-76	5.0	5.0	4.5
TI-263-76	4.4	4.6	5.0
TI-220-76	5.0	4.6	5.0
TI-152-76	4.0	3.0	-
TI-186-76	3.2	3.3	-
TI-191-76	4.6	3.3	-
L3-186	4.2	1.6	-
TI-158-76	4.4	-	-
TI-62-76	5.0	4.6	-
TI-174-76	4.2	2.6	-
TI-184-76	1.4	1.3	-

* Gall indices based on 3rd harvest.

** Gall index ratings of 1-5 were used with 1 being the most resistant and 5 being the most susceptible.

greenhouse tests and the field test indicated no significant differences among methods (Table 14) at 5% level of probability.

Table 15 shows the mean disease ratings of gall indices from each block at each harvest and the corresponding nematode count. The data show that at low nematode populations, disease ratings were low. There were significant differences in gall indices between blocks 1, 2, and 3, and also between blocks 1 and 4 at first harvest. At 2nd and 3rd harvests, there were no significant differences in the disease ratings in any of the blocks. This shows that at root-knot nematode populations below 1,000 larvae per pint of soil in the field, eight weeks after planting, some sweet potato cultivars are quite tolerant, but may become susceptible as population increases above 1,000 larvae per pint of soil. The low disease ratings at low population densities may also be attributed to some weeds which might have served as more preferred hosts, and also to some biotic factors such as other soil microorganisms.

Table 15. Reaction of sweet potatoes to different root-knot nematode population densities in the field.

	FIRST HARVEST		SECOND HARVEST		THIRD HARVEST	
BLOCKS	COUNT/PINT OF SOIL (ROOT-KNOT)	MEAN GALL INDEX	COUNT/PINT OF SOIL (ROOT-KNOT)	MEAN GALL INDEX	COUNT/PINT OF SOIL (ROOT-KNOT)	MEAN GALL INDEX
1	1,017	3.5c*	4,680	3.5a	17,650	3.6a
2	558	2.1a	3,150	3.5a	16,560	3.5a
3	1,152	3.0bc	4,995	4.1a	15,760	3.6a
4	1,008	2.5ab	6,165	3.4a	14,500	3.7a

* Gall index rating on a 1-5 scale with 1 being the most resistant and 5 being the most susceptible.

Table 16. A summary of reactions* of four commercial sweet potato cultivars and TI-breeding Lines to four different types of root-knot nematode infestations.

CULTIVAR	M. INCOGNITA	M. JAVANICA	M. JAVANICA AND M. INCOGNITA	HEAVILY NEMATODE INFESTED FIELD
Jewel	R**	S	I	R
Centennial	S	S	S	S
Rojo Blanco	S	S	S	S
Carver	I	I-R	I	I
FH-7-72	R	I-R	I-R	R
TI-1894	I	I	I	I
TI-1892	R	R	R	R
TI-1895	R	I-R	I	R
TI-164-76	S	I-R	S	S
TI-180-76	S	I-R	S	S
TI-263-76	S	I	S	S
TI-220-76	S	I-S	S	S
TI-152-76	R	R	I-R	R
TI-186-76	I	R	S	S
TI-191-76	S	I	S	S
L3-186	R	S	I	R
TI-158-76	I	S	-	-
TI-62-76	S	R	S	S
TI-174-76	R	R	I	R
TI-184-76	R	I-R	I-R	R

* The disease reactions for each species were based on the overall means of the reactions of all the methods used.

** R=Resistant, I=Intermediate Resistance, S=Susceptible, I-R=Shows R Sometimes and I other times.

DISCUSSION OF RESULTS

Several workers have reported varietal differences in susceptibility of sweet potato to root-knot nematodes (19, 20, 21, 31, 32, 55). All the experimental methods used in this study indicated differences in the reaction of sweet potato cultivars and breeding lines to different Meloidogyne spp.

It was observed that some of the resistant cultivars and breeding lines used in this study tended to show extreme root necrosis while others showed none. This supports the two types of resistance in sweet potatoes suggested by Dean and Struble (21), and Giamalva et al (32).

The initial population and the rate of growth and development of nematodes seem to have tremendous effect on resistance (4, 78, 94, 101) which in general affects total yield of plants (3, 7, 39, 66, 75, 81). Results of the field experiment as well as some of the greenhouse experiments revealed that some cultivars and breeding lines showed some degree of tolerance at low nematode population levels but may become susceptible as the population density increases beyond a certain tolerance limit. Such tolerance limits as suggested by Seinhorst (78) could be determined. This would be of great importance in breeding cultivars that have high tolerance limits which could be used at low population levels without any crop damage

especially where fumigation is quite expensive and resistant cultivars do not perform well in that locality.

Severe root damage was observed especially in 'Centennial' and TI-220-76 in the field at high population densities and root rot was very severe. Perhaps the interaction effect of root-knot and other plant parasitic nematodes, which were present in appreciable amounts (appendix 2), coupled with the interaction of other soil rot plant pathogens such as bacteria and fungi might have contributed to root rots observed, even in the most resistant cultivars.

Krusberg and Nielson (57) found many nematodes in non-cracked roots and also cases of no infections were found in some cracked roots. They suggested factors other than nematodes such as soil moisture and high nitrogen which play a role in root cracking. One can possibly attribute the cause of the indifferent cracking observed in this study, even in resistant cultivars, to the uneven distribution of rainfall during the 1977 growing season and to the high organic matter plowed under prior to planting the sweet potatoes.

Temperature and moisture as well as other environmental factors as observed by some workers tend to affect the activity of nematodes and their relative effects on yield (46, 48, 50, 99, 100). In the greenhouse "Bed Method", no heating cables were used and there were great fluctuations in temperature. This resulted in low infestation rates as compared to the

"Improved Method" where optimum temperatures were maintained, allowing the plants to be evaluated within a short period of time after inoculation.

Resistance of some sweet potato cultivars and breeding lines to M. incognita in these studies both in the Bed and Improved Methods is similar to that observed by Dukes et al (27). In another experiment, Dukes et al (27) showed that the frequency of resistance to M. javanica is quite high in sweet potatoes. However, results of the Improved Method in this study indicated that sweet potatoes are not as high in resistance to this root-knot nematode species as had been previously observed. These differences might have resulted from the high initial population densities that were used in the Improved Method. Also the vine cuttings used were obtained from plants that were previously subjected to M. incognita infestation and this might have resulted in hormonal imbalance in the plants due to the M. incognita attack, thus predisposing the plants to be more susceptible to M. javanica. Thus the optimum environmental conditions (24, 48) coupled with hormonal imbalance (2, 5, 26, 77) as shown by some workers may result in breaking of resistance.

It may also be possible that the differences observed were due to a resistant breaking race present in either of the cultures used since the cultures were obtained from two different sources--Beltsville, MD. and Geneva, NY.

Results of the mixed species experiment (Table 3,) appear to support the above observations. Data indicate that some cultivars resistant to either of the Meloidogyne spp. may be susceptible in a mixed population situation. Such situations can be quite serious in sweet potato production; however, Kinloch and Allen (53) showed that in a mixed species infection, only one of the species will predominate within a certain temperature range, and the predominance depends on the initial inoculum levels. The Bed Method showed similar results as observed by Dukes (27) even though resistance was not as high. The level of growth hormones in plants (12, 24, 33, 56), or the masking of the attractant substance in the roots, or actively repelling the nematode (70) may be the result of the preference shown when the tomato and sweet potatoes were grown together with tomato being more susceptible than sweet potato. This might be of interest in a control program where trap cropping is to be considered. However there are disadvantages in the use of this control system.

Resistance in sweet potatoes as observed by some workers is inherited in multiple gene factors with resistance being dominant (87). Cordner et al (19) showed that when a resistant parent was crossed with a resistant parent, approximately 50% of the offsprings were resistant to root-knot, 30% were intermediately resistant and 20% were susceptible. The individuals from the Resistance x Susceptible parantage were about equally

distributed in the resistant, intermediate and susceptible classes. When two susceptible parents were crossed, the offspring showed a 10%, 25% and 65% distribution in the resistant, intermediate and susceptible classes respectively. It is therefore possible that some of the resistant TI breeding lines might have resulted from crosses between susceptible parents or intermediate parents and not only when a resistant parent was used.

When all experimental methods are considered (Table 16) several TI breeding lines show good resistance to M. incognita while a few of them show resistance to M. javanica with TI-1892, TI-152-76 and TI-174-76 showing resistance to both the Meloidogyne species in single species population situation. Most of the breeding lines are susceptible in a mixed population situation.

Based on field observation, it is felt that some of the resistant breeding lines with good horticultural characters should be continued in the breeding program and eventually released as new cultivars whereas breeding lines like FH-7-72 and TI-1892 with very high resistance but some undesirable horticultural characteristics could be used as breeding parents.

Considering the different methods used, the Improved Method proved to be the fastest and just as accurate as other methods of evaluation of sweet potato reactions to root-knot nematode. Apart from the fact that plants could be evaluated

within a short period of time after inoculation (6 weeks), this method allows environmental conditions to be maintained. It also confines the roots to a readily accessible area to the nematodes and allows periodic observations without destroying the plants.

SUMMARY AND CONCLUSIONS

Several sweet potato cultivars and advanced breeding lines were evaluated in the greenhouse for resistance to two pure culture species of Meloidogyne. They were also evaluated in a heavily nematode infested field which contained primarily Meloidogyne incognita. Twenty cultivars and breeding lines were used in each of the greenhouse tests and 12 cultivars and breeding lines were used in the field test.

The plants were evaluated on a scale of 1-5 based on the percentage number of roots infested using both gall and egg mass indices.

From the results of this study, the following summary and conclusions can be drawn.

1. Some of the TI breeding lines, such as FH-7-72, TI-1892, TI-152-76 and TI-184-76 showed very good resistances to M. incognita with FH-7-72 and TI-1892 showing the highest resistance.

2. Even though sweet potatoes generally exhibit good resistance to M. javanica, this resistance may be broken when plants are predisposed to infestation of M. incognita or in a mixed specie population of M. incognita and M. javanica.

3. TI-1892 showed a high multi-specie resistance even in mixed species situations.

4. Similar resistance levels were observed in the green-house bed method, improved method, and in the field test with *M. incognita*.

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A P P E N D I X 1

GREENHOUSE BED METHOD NEMATODE COUNT

LARVAE/PINT OF SOIL

DATE	M. INCOGNITA	M. JAVANICA	M. INCOGNITA AND M. JAVANICA	HEAVILY NEMATODE INFESTED SOIL
Nov 1976	0	0	0	10
Dec 1976	28	10	8	56
Feb 1977	30	24	10	35
Jun 1977	972	576	243	585

APPENDIX 2

NEMATODE COUNTS (LARVAE/PINT OF SOIL)

DATE	MELOIDOGYNE SPP ROOT-KNOT				ROTYLENCHUS SPP SPIRAL				XIPHINEMA SPP DAGGER				PRATYLENCUS SPP LESION			
	BLOCKS				BLOCKS				BLOCKS				BLOCKS			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
07/08/77	200	120	500	300	200	-	40	9	6	-	-	2	-	9	-	-
09/20/77	1017	558	1152	1008	432		180	18	18	-	-	9		9	-	-
10/12/77	4680	3150	4995	6165	36	81	153	9	-	-	-	-	-	9	-	-
11/04/77	17650	16560	15760	14500	315	180	63	99	-	-	-	-	-	-	-	-

V I T A

Conrad Komla Bonsi was born on December 11, 1952 in Ghana, West Africa. He attended Evangelical Presbyterian Elementary School at Akpafu-Todzi. He received his G. C. E. Ordinary Level Certificate from Hohoe Evangelical Presbyterian Secondary School in 1968, and the G. C. E. Advanced Level Certificate from Kpandu Secondary School in 1971.

He entered the University of Ghana in October, 1971 where he received a Bachelor of Science Honors Degree in Agriculture in July, 1975.

He was employed as a teaching and research assistant in the Faculty of Agriculture, University of Ghana, under the National Service Scheme from August, 1975 to August, 1976.

On September 1, 1976, he entered Tuskegee Institute for advanced study in Plant and Soil Science where presently he is a candidate for the Master of Science Degree in Plant and Soil Science.

THE GRADUATE PROGRAM

TUSKEGEE INSTITUTE
Tuskegee Institute, Alabama

Date April 7, 1978

TO: Dean, Graduate Programs

We, the undersigned, report that as a committee we have examined

Conrad K. Bonsi (Name) upon the work done in the following fields:

Major Plant and Soil Science

Minor (if any) _____

and that he (he or she) has passed (passed or failed) his (his or her) examination. We find

that his (his or her) thesis, the title of which is Evaluation of Sweet Potato (Ipomoea batatas L.) Cultivars and Advanced Breeding Lines for Resistance to two Root-knot nematode species (M. incognita, M. javanica)

is acceptable (acceptable or not acceptable) to us and has met (met or not met) the editorial

approval of the Library Committee.

We find that his (his or her) attainments are such that he (he or she) may be

recommended (recommended or not recommended) for the degree of Master of Science in Plant and Soil Science.

Student's Examining Committee
(signatures)

Rajinder S. Saini
James R. Allen
Walter A. Hill
Bishnu C. Mallory
Bobby R. Phills

dissent from the foregoing report:

_____

_____

he Library Committee has (approved or not approved) the thesis editorially.

Signature _____
(Librarian)

Recommendations of the Committee
(Only for students who have failed some part of the requirements stated above.)

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