HOST RANGE STUDIES WITH FOUR POPULATIONS OF THE ROOT-KNOT NEMATODE (MELOIDOGYNE INCOGNITA ACRITA CHITWOOD)

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INTRODUCTION

The root-knot nematode (*Meloidogyne incognita acrita* Chitwood) is responsible for a considerable amount of crop damage each year in Oklahoma and throughout the southern United States. While this nematode can be controlled with chemicals, this is for economic, or other reasons, not always a satisfactory control method. Crop varieties which are resistant to this nematode would provide a more satisfactory method of control.

The use of crop varieties resistant to *M. incognita acrita* is complicated by several factors among which are, our rather incomplete knowledge of the host range of this nematode, and the possible existence of races within this nematode subspecies. With the reclassification of what had previously been considered a single species of root-knot nematode into 5 species and 1 subspecies by Chitwood (6) in 1949, previous host lists became of relatively little value. This has necessitated a restudy of the host range of each of the presently recognized species or subspecies of root-knot nematodes. Evidence for the existence of races within *M. incognita acrita* has been presented from Louisiana (27), North Carolina (38) and California (25). In light of this latter situation it becomes important that whatever host range studies are made take into consideration the potential race situation.

The objectives of the present study were to determine the relative resistance or susceptibility of some of the commonly grown crop varieties to several populations of *M. incognita acrita* as it occurs in Oklahoma, and, at the same time, to determine the potential pathogenic variability between these populations.

REVIEW OF LITERATURE

The causal organism of root knot was first reported to be a nematode by Berkeley in 1855. From that time until 1949 the root-knot nematode was considered to be a single species. Goodey (17) investigated the nomenclature of the root-knot nematode prior to 1932 and changed the recognized name of the species from H. radicicola (Greeff) Müller to H. marioni (Cornu) Goodey, the oldest, valid name.

On the basis of critical morphological studies Chitwood (6) in 1949 named and described 5 species and 1 subspecies of root-knot nematodes which he removed from the genus Heterodera and placed in a separate, revived, genus, Meloidogyne. Since 1949 several other species and subspecies have been described.

The principal morphological character used by Chitwood (6) to differentiate and describe the species and subspecies of Meloidogyne was the cuticular markings found at the posterior end of mature females. These cuticular markings are referred to as the perineal pattern. Chitwood (6) pointed out that while the perineal pattern is a variable feature, and that no two patterns in the same species will be exactly alike; nevertheless, a basic pattern is characteristic of each species and subspecies described. The variation in perineal patterns emphasized the necessity of observing several specimens before making an identification. Studies by Allen (2) on the variation of the perineal pattern in Meloidogyne populations derived from single egg masses indicate that the variation within a single species may be greater than originally thought. Dropkin (14) reported the variation of the perineal pattern in 6 populations of M. incognita acrita and suggested that this pattern is sufficently consistent to be a reliable character in classifying species of Meloidogyne. These studies supported the findings of Chitwood, but failed to explain those of Allen.

The variations in the perineal pattern and the host-parasite relationships of certain populations of M. incognita incognita (Kofoid and White) Chitwood and M. incognita acrita make it difficult, at least in some cases, to distinguish the species from the subspecies. A suggestion by J. N. Sasser was reported by Hollis (21), relating that, on the basis of the morphology and host relationships of M. incognita incognita and M. incognita acrita, these organisms should possibly be considered a single, highly variable species or species complex, at least for the present.

Sasser (37) developed a procedure for identifying an unknown population of a root-knot nematode by testing the host reaction of at least 4 differential plant species to the population. This testing procedure is partially dependent upon negative results; therefore, it is best used in conjunction with morphological studies.

Different populations of M. incognita acrita have been shown to differ markedly in their ability to produce symptoms on plants. Available evidence suggests the existence of races which differ in their host-parasite relationships (15, 26). With this evidence it becomes necessary to consider possible races in any host range studies.

As has already been pointed out it is very difficult to determine what root-knot species were represented in the extensive host range studies carried out prior to 1949 (4, 5). In most cases these studies are of questionable value at present. Host records of Meloidogyne species after 1949 show that M. incognita acrita attacks a wide range of plants, including field crops, vegetable crops, fruit crops, ornamentals and weeds. In compiling these host lists several different criteria have been used in evaluating for resistance or susceptibility. Most of the authors have taken into consideration reproduction of the nematode as well as the host response as measured by relative amounts of galling in determining plant reaction. No attempt has been made here to list all of the plant species and varieties that have been reported resistant or susceptible to M. incognita acrita; however, an attempt has been made to summarize the approximate number of plant species and varieties that have been reported, with an evaluation of the reactions.

Holston and Crittenden (22), Sasser (37), and Dropkin (15) reported egg mass production of M. incognita acrita to be high in 19 varieties of soybean, intermediate in 5 varieties and low or absent in 8 varieties. Crittenden (10) tested a considerable number of soybean varieties for their resistance to M. incognita acrita and reported 10 varieties to be highly resistant. Holston and Crittenden, and Dropkin noted that the relative amount of galling on the soybean varieties tested could not be correlated with egg mass production. There were no conflicts in the ratings of 6 soybean varieties, each of which was reported by 2 or more of the above authors.

Hare (20) reported 9 varieties of cowpea to be susceptible to M.

incognita acrita; 1 variety and 4 breeding lines were reported resistant. The method of evaluation was not given.

Dropkin (15) reported the amount of galling and nematode reproduction in 9 lines of inbred corn; 8 varieties were susceptible and 1 resistant. Sasser (37) reported the amount of infection and reproduction to be low in 1 variety of corn and high in another variety.

Crittenden (11) reported several varieties of oats to be susceptible to *M. incognita acrita* and several others, including the variety Arlington, to be resistant, but he did not state how resistance or susceptibility to the nematode was determined. Sasser (37) reported the oat variety Arlington to be resistant on the basis that no infection had occurred. Sasser also reported a moderate amount of infection and nematode reproduction in 1 variety of barley, and a low amount of infection and reproduction in 1 variety each of wheat and rye.

The amount of injury produced by *M. incognita acrita* on 6 cotton varieties was determined in greenhouse studies by Wiles (47). The amount of injury was moderate on 1 variety and severe on 5 varieties. Sasser (37) reported the amount of infection and nematode reproduction to be moderate in 1 variety each of cotton and kenaf. Pate, Summers, and Memyel (32) also reported kenaf to be susceptible.

McGlohon and Baxter (29) tested 25 *Trifolium* species which could be used in a white clover breeding program for resistance to *M. incognita acrita* and found that all species were severely galled. Reynolds (35) reported 3 varieties of alfalfa to be susceptible, 2 varieties to be lightly infected, including the variety Atlantic, and 5 varieties to be resistant. Sasser (37) reported a moderate amount of infection and nematode reproduction in the alfalfa variety Atlantic.

The amount of infection and reproduction of _M. incognita acrita_ was found to be low in 2 tobacco varieties (37). Drolsom and Moore (13) reported several breeding lines of tobacco to be resistant on the basis of nematode reproduction. Different species of _Nicotiana_ were tested for resistance by Graham (18) and 5 species were reported susceptible and 3 resistant depending upon the egg mass production.

The reaction of several different vegetable crops to _M. incognita acrita_ has been reported. Of 10 commonly grown tomato varieties tested in the field by Houssny and Oteifa (23), 6 varieties were severely galled and 4 varieties, including the variety Rutgers, were moderately galled. Sasser (37) reported the amount of infection and nematode reproduction to be high in the variety Rutgers, and also reported that the amount of infection and reproduction was low in _Lycopersicon peruvianum_ (L.) Mill.

Hare (19) reported the relative amount of galling on several pepper varieties and listed 135 varieties as susceptible, 14 varieties moderately susceptible and 4 varieties highly resistant. Sasser (37) reported the infection and reproduction rate to be low in 1 variety of pepper.

Sasser (37), Thomason and McKinney (43) and Winstead and Sasser (48) have reported the amount of galling, infection, and nematode reproduction on a large number of cucurbit varieties. All varieties of cantaloupe, cucumber, pumpkin, squash, watermelon, and wintermelon tested were susceptible to _M. incognita acrita_.

Sasser (37) reported infection and nematode reproduction to be high in 1 variety of each of the following: beet, cabbage, carrot, radish, okra, pea, egg plant, and potato. Sasser (37) and Lewis, Mai, and Newhall (24) each reported 1 variety of onion to contain a large number of nematodes and egg masses. *M. incognita acrita* larvae did not invade the variety of asparagus tested by Crittenden (9).

McGuire and Allard (30) and Allard (1) reported from field studies that 14 different varieties of bean including snap beans and lima beans were susceptible on the basis of galling produced by the nematode.

A few ornamentals have been tested for their resistance or susceptibility to *M. incognita acrita*. Sasser (37) reported that only a few nematodes and no egg masses were found in the roots of oleander, 2 varieties of geranium, and 1 variety each of carnation and azalea. Wells and Winstead (46), using galling of the host and reproduction of the nematode as the criteria for determining susceptibility or resistance, reported 12 varieties of gladiolus to be susceptible and 8 varieties resistant.

Only a few fruit crops have been reported for their susceptibility or resistance to *M. incognita acrita*. Sasser (37) reported that 4 varieties of strawberry were not infected by the nematode. Lider (25) reported the amount of infection to vary from none to severe in 5 species of *Vitis* depending on the population of *M. incognita acrita* against which they were tested. Two species of *Vitis* were severely infected with all populations of the nematode used.

Gaskin (16) reported a large number of common weed hosts of *M. incognita incognita* and *M. incognita acrita* in Indiana based on greenhouse studies. Sasser (37) reported that the amount of infection and nematode reproduction was high in 2 common weeds and no nematodes were found in common rag weed (Ambrosia artemisiifolia L.).

The nature of resistance exhibited by plants in the host studies reported has not been determined in most cases. Only a few plants are thought to have the kind of resistance described by Tyler (45), where the plant is relatively resistant to invasion by the nematodes.

Barrons (3) pointed out that there is no general relationship between the number of nematodes penetrating and the resistance of a given plant. He suggested that resistance was dependent upon the presence of certain unidentified substances in resistant plants which neutralize the effect of the nematode saliva. The neutralization of the nematode saliva would inhibit the formation of giant cells, thus cutting off the food supply from the developing nematode. Christie (8) was in agreement with Barrons on the nature of root-knot resistance, but did not exclude other possible factors that might make resistant plants what he designated as an "unsuitable host." The ways in which an unknown chemical may be responsible for resistance of a plant to root-knot nematodes have been summarized by Peacock (33).

Shibuya (40), Dean and Struble (12), and Radewald (34) demonstrated that root-knot nematodes entered roots of resistant sweet potato plants as readily as they did those of susceptible plants, but in resistant roots development of the larvae was significantly retarded. Radewald also noted that in resistant roots there was considerable necrosis associated with root-knot larvae.

It has been demonstrated that certain environmental and nutritional conditions to which the host plant has been subjected will produce an indirect effect on the nematode. Oteifa (31) reported that with lima beans the time required for egg mass production by mature females of M. incognita incognita could be altered from 16 to 40 days by decreasing or increasing the amount of potassium available to the plant. High levels of potassium and nitrogen have been reported to increase the number of larvae penetrating a resistant variety of soybean and the amount of galling on a more susceptible variety (39).

Tyler (44) has pointed out the critical influence of temperature on the root-knot nematode Heterodera marioni. More recently Thomason (42) has reported that reproduction of M. incognita acrita will occur between 20°C and 30°C, with only slight reproduction at 35°C.

Tarjan (41) has demonstrated that an increased photoperiod at higher temperatures increased the rate of development of M. incognita acrita. It has been reported by Ritter and Ritter (36) that the rate of reproduction for M. incognita acrita in tomato can be significantly increased by using older plants as compared with younger plants.

MATERIALS AND METHODS

The populations of M. incognita acrita used in the present studies were obtained from field soils infested with this nematode at different locations in Oklahoma. Population I was taken from a mung bean field on the farm of C. Moery near Hennessey. Population IV was taken from what had been a wooded area which had been cleared and planted with sweet potatoes for 1 season on the farm of K. Drake near McLoud. In addition 2 populations of M. incognita acrita which had been established in the greenhouse at Stillwater by former students were used. One of these populations was from a soil sample taken from the cotton nematode-wilt nursery near Hollis and was designated as population III; the other established population was from a soil sample taken from the University Horticulture farm near Perkins and was designated population II.

Several single egg mass isolates from each of the above populations were propagated on tomato roots.[1] After progeny from each of these cultures had been examined for trueness to type for M. incognita acrita, each population was then established by pooling progeny from each of 4 single egg mass cultures. The purpose in this was to establish pure cultures which were reasonably representative of the population as it might have occurred in the field. Each population was

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[1]Tomato plants, var. Rutgers, used throughout the present studies were started in steam sterilized soil.

increased and maintained on tomato plants in a 6" x 18" x 36" wood-lined metal tray filled with steam sterilized soil.[2] Chopped, galled roots from repeated plantings in this soil were used as a source of inoculum.

The crops and varieties tested are listed in Table I in the section on results. Variety tests were carried out in the greenhouse with the soil temperature ranging from 22°C to 27°C. For each crop variety tested twenty 4-inch pots were filled with a steam sterilized potting mixture of 1 part sand to 2 parts loam. The soil in 4 pots was infested with a given population by mixing 1 g of chopped root inoculum[3] into the soil of each pot. This procedure was used for each of the 4 populations. The 4 pots which did not receive inoculum served as controls. Four to 5 seeds of a given variety were planted in each of the 20 pots and covered with steam sterilized soil. All pots which contained the soil infested with the same population were placed together in metal trays. When the plants emerged, they were thinned to 3 plants per pot.

Approximately 35 days after planting, the plants were removed from the pots and the roots were washed thoroughly. The relative severity of galling produced on the plants by a given population was rated on a 1-5 scale: 1 indicated no galls, 2 indicated a trace of galls, 3 indicated a moderate amount of galling, 4 indicated severe

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[2]Sterilization of soil in flats at 15 lbs. pressure for 1 hour was found to be adequate to prevent contamination by naturally occurring nematodes. This procedure was used throughout the present studies.

[3]Preliminary tests using several levels of inoculum indicated 1 g per 4-inch pot to be adequate. This amount was used throughout the present studies.

galling, and 5 indicated very severe galling. The mean root-knot index was determined for each variety that had been inoculated with a given population. The root system of 1 plant from each replication of a given variety infested with a given population was chopped into pieces approximately 5 mm in length and mixed thoroughly. A 200 mg sample was taken from this mixture to be stained.

In studying the nematode in whole roots the staining technique of McBeth, Taylor, and Smith (28) was used. This consisted essentially of boiling the washed root samples in a mixture of lactophenol and acid fuchsin for 1 minute or more depending upon the intensity of staining desired. The roots were then washed in tap water to remove excess stain and placed in lactophenol to clear for a period of 4-24 hours.

Examination of the nematodes in the roots was accomplished by placing the stained root sample between 2 slides, gently crushing the roots, and then examining them with the aid of a dissecting microscope. The number of nematodes present in each sample was counted and classified into their respective developmental groups, as described by Christie (7). Group A included second stage larvae to the stage where they still possessed a more-or-less conical tail. Group B included the stage from which larvae had acquired a more-or-less hemisperical posterior end terminated by a spike to the stage where larvae were about to complete the final molt. Group C included the stage where the females had completed their molts to the stage where they were almost fully grown, but had not yet laid eggs. Group D included fully grown females which had not yet laid eggs. Group E included egg-laying females (Fig. 1).

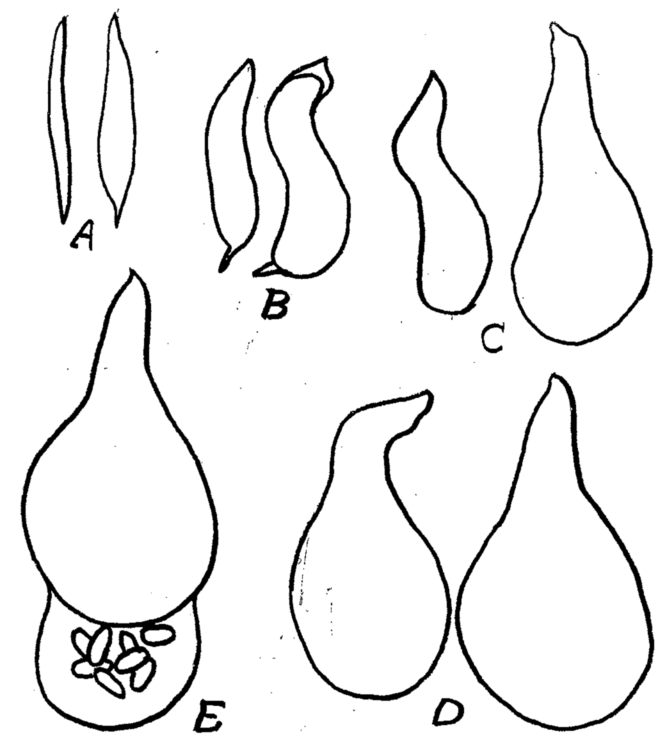

Fig. 1. Classes into which nematodes were grouped according to the amount of development they had undergone. (After Christie)

A nematode reproduction index for each population in each crop variety was calculated from the number and size of egg masses found in the 200 mg root sample taken from a given crop variety. One indicates no reproduction; however 10-20 nematodes would be present, except in the spinach varieties tested a much larger number of nematodes were found. Two indicates slight to moderate reproduction represented by 1 female producing a normal size egg mass (400 eggs or more) or not more than 20 females producing egg masses of an abnormally small size egg mass (20-40 eggs). The number of nematodes ranged from 20 to 50 with the majority of them being immature. Three indicates abundant reproduction represented by at least 7 mature females producing normal size egg masses. The number of nematodes ranged from 20 to 90 with the majority being mature or approaching maturity.

RESULTS

Reaction of Crop Varieties to Different Populations of the Nematode

The reproduction index of each nematode population in each crop variety and the mean root-knot index of each crop variety inoculated with a given population is recorded in Table I. No differences were observed in the reproduction indexes of any of the four populations in any given crop variety or in the root-knot index of any given variety tested against the different populations. This suggests that the populations of *M. incognita acrita* used in the present studies did not represent races of this nematode which differ in their host-parasite relationships. The relative susceptibility of each crop variety can be determined from the data in Table I. A low root-knot index along with a low reproduction index indicates at least some degree of resistance while high values for these indexes indicate susceptibility.

TABLE I

REACTION OF CROP VARIETIES TO EACH OF FOUR POPULATIONS OF MELOIDOGYNE INCOGNITA ACRITA

	Mean root-knot index[a] for each population				Reproduction index[b] for each population			
Barley *Hordeum vulgare* L.	I	II	III	IV	I	II	III	IV
Harbine	2.7	2.7	2.8	2.8	2	2	2	2
Rogers	2.7	2.8	2.8	2.7	2	2	2	2
Tenkow	3.1	3.1	3.2	3.2	2	2	2	2
Ward	3.1	3.2	3.2	3.2	2	2	2	2
Bush bean *Phaseolus vulgaris* L.								
Contender	4.9	4.9	5.0	5.0	3	3	3	3
Tendergreen Stringless	4.8	4.9	4.8	4.8	3	3	3	3
Top Crop	5.0	4.8	4.8	5.0	3	3	3	3
Wade	5.0	5.0	4.9	5.0	3	3	3	3
Cantaloupe *Cucumis melo* var. *reticulatus* Naud.								
Hale's Best	5.0	5.0	5.0	5.0	3	3	3	3
PMR 45	5.0	5.0	5.0	5.0	3	3	3	3
Rio Sweet	5.0	5.0	5.0	5.0	3	3	3	3
Texas No. 1	5.0	5.0	5.0	5.0	3	3	3	3

[a]1 = no galling; 2 = trace of galling; 3 = moderate galling; 4 = severe galling; 5 = very severe galling.

[b]1 = no reproduction; 2 = slight to moderate reproduction; 3 = abundant reproduction.

TABLE I (Continued)

	Mean root-knot index for each population				Reproduction index for each population			
	I	II	III	IV	I	II	III	IV
Corn (field) *Zea mays* L.								
Funks G-711B	3.0	3.0	3.4	3.0	2	2	2	2
Kansas 1859	3.0	3.0	3.0	3.0	2	2	2	2
Texas 28	3.2	3.3	3.2	3.4	2	2	2	2
Texas 30	3.0	3.0	3.0	3.0	2	2	2	2
Watson III	3.0	3.1	3.1	3.1	2	2	2	2
Corn (sweet) *Zea mays* L.								
Aristogold Bantam Evergreen	2.4	3.0	2.7	2.6	2	2	2	2
Golden Bantam Cross	3.0	3.0	3.0	3.0	2	2	2	2
Gold Rush	3.0	3.2	3.0	3.3	2	2	2	2
Golden Security	3.0	3.0	3.0	3.0	2	2	2	2
Ioana	3.0	2.8	3.0	3.0	2	2	2	2
Cowpea *Vigna sinensis* (L.) Endl.								
Blackeye	3.7	4.0	4.0	4.0	3	3	3	3
Brabham	3.4	3.0	3.5	3.4	1	1	1	1
Brown Sugar Crowder	4.8	4.9	4.9	4.9	3	3	3	3
Calva #3	4.6	4.8	4.8	4.7	3	3	3	3
Iron K-329	2.8	-	3.0	-	2	-	2	-
Purple Hull	5.0	4.8	4.6	4.9	3	3	3	3
Purple Hull Dixie Queen	5.0	4.9	4.8	4.8	3	3	3	3
Texas #12	3.2	3.0	3.3	3.2	2	2	2	2

TABLE I (Continued)

	Mean root-knot index for each population				Reproduction index for each population			
Cowpea (Continued)	I	II	III	IV	I	II	III	IV
Victor K-798	3.0	3.0	3.0	3.0	2	2	2	2
White Acre	5.0	4.9	4.7	4.8	3	3	3	3
Cucumber *Cucumis sativus* L.								
Black Diamond	5.0	5.0	5.0	5.0	3	3	3	3
Chicago Pickling	5.0	5.0	5.0	5.0	3	3	3	3
Marketer	5.0	5.0	5.0	5.0	3	3	3	3
National Pickling	4.9	5.0	5.0	5.0	3	3	3	3
Ohio MR 17	5.0	5.0	5.0	5.0	3	3	3	3
Straight Eight	4.7	4.9	5.0	5.0	3	3	3	3
Mung bean *Phaseolus aureus* Roxb.								
Golden mung bean	3.5	-	3.5	-	3	-	3	-
Kiloga	4.0	-	4.0	4.0	3	-	3	3
Okla. 12	3.8	-	3.7	3.8	3	-	3	3
Oat *Avena sativa* L.								
Arkwin	3.2	3.0	3.5	3.2	2	2	2	2
Cimarron	2.0	2.3	2.5	2.1	2	2	2	2
Forkedeer	3.2	3.4	3.0	3.2	2	2	2	2
Kanota	3.0	2.8	2.9	3.0	2	2	2	2
Traveler	3.0	3.0	3.2	3.0	2	2	2	2

TABLE I (Continued)

Oat (Continued)	Mean root-knot index for each population				Reproduction index for each population			
	I	II	III	IV	I	II	III	IV
Wintok	3.0	3.0	3.0	3.0	2	2	2	2
Pepper *Capsicum frutescens* L.								
Burpees Fordhook	4.0	4.0	-	4.0	3	3	-	3
Burpees Ruby King	3.8	3.7	-	3.7	3	3	-	3
California Wonder	4.0	4.0	-	4.0	3	3	-	3
King of the North	4.0	-	-	4.0	3	-	-	3
Worldbeater	3.8	-	-	4.0	3	-	-	3
Yolo Wonder	3.8	4.0	-	-	3	3	-	-
Rye *Secale cereale* L.								
Balbo	2.8	3.0	3.0	2.9	2	2	2	2
Elbon	2.6	2.8	2.8	2.8	2	2	2	2
Tetraploid	3.0	3.0	2.8	3.0	2	2	2	2
Sorghum *Sorgum vulgare* Pers.								
D-Milo 332-R	2.6	2.5	2.7	2.7	1	1	1	1
Kafir 44-14	2.0	2.0	2.0	2.0	1	1	1	1
Martain	3.0	-	-	3.0	1	-	-	1
Redlan	3.0	3.0	3.0	3.0	2	2	2	2
Sugar Drip	3.0	3.0	2.8	2.8	2	2	2	2

TABLE I (Continued)

	Mean root-knot index for each population				Reproduction index for each population			
	I	II	III	IV	I	II	III	IV
Soybean *Glycine max* (L.) Merr.								
Clark	4.2	4.0	4.0	4.3	2	2	2	2
D53-354	4.0	4.0	4.0	4.0	3	3	3	3
D53-526	3.2	3.3	3.0	3.0	3	3	3	3
Dorman	3.8	4.0	3.9	4.0	3	3	3	3
Hood	3.0	3.2	3.2	3.0	1	1	1	1
Jackson	2.1	2.2	2.0	2.0	2	2	2	2
Lee	4.0	4.0	4.0	4.0	3	3	3	3
Spinach *Spinacia oleracea* L.								
Early Hybrid #7	4.7	4.8	4.8	4.8	1	1	1	1
Long-Standing Bloomsdale	4.3	4.8	4.7	4.8	1	1	1	1
Nobel-Giant Leaved	4.8	4.7	4.7	4.7	1	1	2	2
Reuter's Monstrous Viroflay	4.7	4.8	4.7	4.7	1	1	1	1
Virginia Blight Resistant	4.7	4.7	4.7	4.7	1	1	1	1
Watermelon *Citrullus vulgaris* Schard.								
Black Diamond	4.9	4.9	4.9	4.9	3	3	3	3
Blacklee	4.8	4.9	4.9	4.9	3	3	3	3
Blackstone	4.9	4.9	5.0	5.0	3	3	3	3
Charleston Gray	4.9	5.0	4.9	5.0	3	3	3	3
Congo	5.0	4.9	4.9	4.9	3	3	3	3
Dixie Queen	5.0	4.9	4.9	5.0	3	3	3	3

TABLE I (Continued)

	Mean root-knot index for each population				Reproduction index for each population			
Watermelon (Continued)	I	II	III	IV	I	II	III	IV
ES 18-2	5.0	5.0	5.0	5.0	3	3	3	3
ES 20-1	4.9	5.0	5.0	5.0	3	3	3	3
Fairfax	4.8	4.9	5.0	5.0	3	3	3	3
Ga-4	5.0	5.0	5.0	5.0	3	3	3	3
Hope Diamond	5.0	4.9	4.9	5.0	3	3	3	3
Summit L-1	5.0	5.0	5.0	5.0	3	3	3	3
Wheat *Triticum aestivum* L.								
Comanche	3.0	3.0	3.0	3.0	2	2	2	2
Concho	3.0	2.9	3.0	3.0	2	2	2	2
Pawnee	2.9	3.0	3.0	3.0	2	2	2	2
Triumph	3.0	3.3	3.0	3.2	2	2	2	2
Wichita	3.0	3.0	3.0	3.0	2	2	2	2

Crop Variety Response and Suitability for Nematode Development and Reproduction

A considerable amount of variation in host-parasite relationships existed between crops and the varieties of some crops used in the present studies regardless of the population of *M. incognita acrita* against which they were tested. Representative varietal reactions of the varieties of each crop tested in the present studies have been listed in Table II. Data from the root samples of the selected varieties were taken from trials with Population I and IV. These data include the number of nematodes in each developmental stage and the relative size of egg masses produced in the host. The nematode reproduction index and root-knot index of all crop varieties tested is listed in Table I.

All of the bush bean, cantaloupe, cucumber, and watermelon varieties tested were severely galled, contained a large number of nematodes, and supported a high level of nematode reproduction. Of all the crop varieties tested in the present studies only the cucurbit varieties exhibited a noticeable degree of stunting in the 35-day test period.

All of the pepper varieties tested were severely galled and the level of nematode reproduction was high; however, the nematodes were not as numerous as in other susceptible crop varieties.

Galling on mung beans was moderate on 2 varieties and severe on 2 other varieties. The number of nematodes and nematode reproduction was high in all four of the varieties.

All varieties of barley, oats, rye, and wheat tested exhibited a moderate number of small galls which usually contained a relatively

TABLE II

NEMATODE DEVELOPMENT AND REPRODUCTION IN REPRESENTATIVE VARIETIES OF EACH CROP

	Nematodes in each developmental stage					Size of egg masses[a]	
	A	B	C	D	E	L	S
	No.	No.	No.	No.	No.		
Barley							
Ward	0	2	3	12	19		*
Bush bean							
Top Crop	0	0	5	41	9	*	
Cantaloupe							
Texas No. 1	0	5	17	24	21	*	
Corn							
Ioana	2	0	16	15	5		*
Cowpea							
Brown Sugar Crowder	0	4	9	30	16	*	
Texas #12	0	0	5	8	1	*	
Brabham	7	3	5	0	0		
Cucumber							
Marketer	0	2	12	30	13	*	
Mung bean							
Golden mung bean	0	5	10	41	9	*	

TABLE II (Continued)

	Nematodes in each developmental stage					Size of egg masses	
	A	B	C	D	E	L	S
	No.	No.	No.	No.	No.		
Oat							
Wintok	0	6	2	7	12		*
Pepper							
California Wonder	0	4	2	10	9	*	
Rye							
Tetraploid	0	2	8	4	9		*
Sorghum							
Redlan	0	7	4	10	2		*
Kafir 44-14	0	6	3	1	0		
Soybean							
Clark	0	1	11	9	2	*	
Hood	0	12	7	1	0		
Lee	0	2	4	9	11	*	
Spinach							
Nobel	41	30	3	5	4		*
Long-Standing Bloomsdale	65	26	2	1	0		
Watermelon							
Black Diamond	0	7	23	44	11	*	

TABLE II (Continued)

	Nematodes in each developmental stage					Size of egg masses	
	A	B	C	D	E	L	S
	No.	No.	No.	No.	No.		
Wheat							
Triumph	0	3	2	7	11		*

[a] L = large egg masses, 400 eggs and above; S = small egg masses, 50 eggs or less.

high number of nematodes in all developmental stages. The females which had reached maturity were smaller than normal and the egg masses contained only 30-50 eggs.

The amount of galling on 5 sorghum varieites tested was low and the number of nematodes present was also low. Three varieties of sorghum supported a low level of nematode reproduction and the size of the egg masses produced was comparable to those produced in the other small grain varieties. Two of the sorghum varieties did not support reproduction of the nematodes in 35 days. Frequently galls on the sorghum varieties tested would contain only debris of nematodes.

In all varieties of corn tested most of the galling occurred on the branches of the adventitious root system as can be seen in Fig. 2. A large number of nematodes, many of which were not nearing maturity, were associated with a single gall. The egg masses were small but slightly larger than those produced by females in the small grain varieties. Occasionally a few nematodes, not associated with branches, were found in adventitious roots of the corn varieties. Usually very slight or no galling was associated with these individuals.

Three of the soybean varieties tested were severely galled and supported a high level of nematode reproduction. The variety Clark was severely galled, but did not support a high level of nematode reproduction. Two soybean varieties were moderately galled; 1 variety supported a high level of nematode reproduction while the other contained very few nematodes and no egg masses. Only a trace of galling occurred on the soybean variety Jackson and nematode reproduction was low.

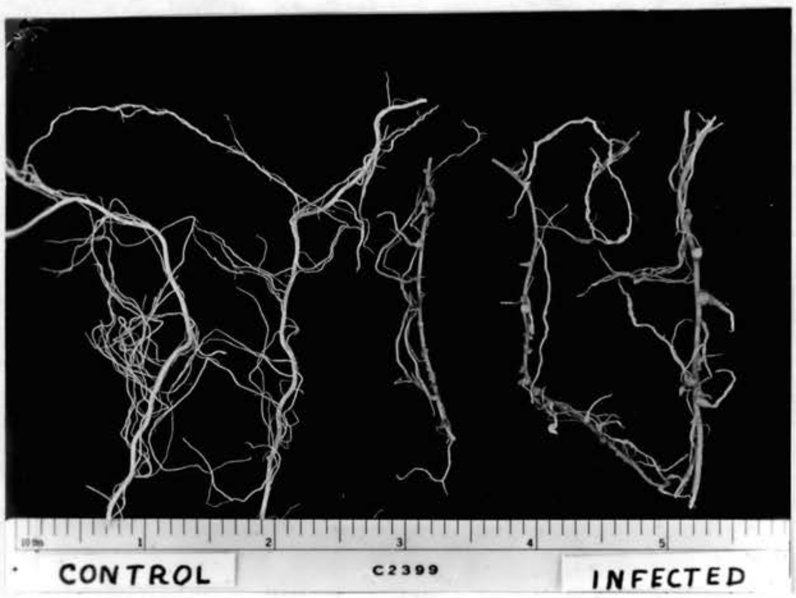

Fig. 2. Reduction and galling of the branches on the adventitious root system of corn, var. Funks G-711B.

Six of the cowpea varieties tested were severely galled and supported a high level of nematode reproduction. The amount of galling was moderate and the rate of nematode reproduction was low in 3 varieties of cowpea. The cowpea variety Brabham was moderately galled, but did not support reproduction of the nematodes.

All of the spinach varieties were severely galled and contained a large number of nematodes; the majority of the nematodes were still immature at the end of the 35-day test period. A trace of nematode reproduction occurred in one variety in 2 of the population trials.

The Effect of Photoperiod on the Rate of Nematode Maturity and Egg Mass Production

During the present studies a fluctuation in the required time to obtain maximum egg mass production was noticed. The difference occurred in the population increase plants which were to be used for inoculum. It appeared that the relative number of egg masses produced during the period, February 1 to March 1, was greater than during the previous 30-day period. All conditions had remained very much the same in the greenhouse for both 30-day periods except the increasing length of day and the quality of light. A preliminary investigation was carried out in the following way in an attempt to determine whether the increased length of day was responsible for the increase in egg mass production.

A light-tight hood was constructed by covering a 18" x 36" x 24" wood frame with cardboard which was painted with flat-black paint on the inner surface and covered with aluminum foil on the outer surface. Light-tight vents were placed in the sides and top of the hood to allow air passage. The sides of 1 of the 2 metal trays to be used was painted with the flat-black paint so that when the hood was placed over the tray the unit would be light tight.

Forty-two 5-week old tomato plants, var. Rutgers, were transplanted, 1 plant per 4-inch pot. The pots had previously been filled with a steam sterilized potting mixture. Thirty-two of the plants were inoculated with *M. incognita acrita* in the same manner as previously described in Materials and Methods. Sixteen of the inoculated plants and 5 of the control plants were placed in each of the 2 metal trays. The space between the pots was filled with steam sterilized sand.

The plants in the decreased photoperiod treatment received a 9-hour day by covering them with the hood at 6:00 p.m. and removing it at 9:00 a.m. the following day. The plants in the control were subjected to a 11-hour day length at the start of the experiment in March; the length of day increased slightly throughout the experiment.

The variation in soil temperature between the shaded and unshaded treatment did not exceed 2°C during the experiment. The soil temperature in the control container decreased slightly faster at night and increased slightly faster in the morning than did that in the shaded treatment.

Eighteen days after inoculation 4 of the infected plants were taken at random from each treatment. The roots were washed and stained for observation. One hundred nematodes were counted per plant and recorded according to their stage of development as described by Christie (7). This procedure was again repeated at 22 and 27 days after inoculation.

Mature females with egg masses did not appear until 27 days after inoculation. There was no significant difference between the treatments with respect to number of mature females or mature females with egg masses.

DISCUSSION

One of the objectives of the present studies was to determine the resistance or susceptibility of several crop varieties to M. incognita acrita. Inasmuch as the response of each crop variety was not determined for a period of time greater than 35 days, resistance or susceptibility of a crop variety was determined by the ability of the host plant to inhibit or permit survival and reproduction of the nematode. Thus, a resistant crop variety would not contain a large number of nematodes, and mature females and egg masses would be very few or absent. A large number of nematodes, including mature females and egg masses, would be found in the roots of a susceptible crop variety.

The number of larvae to which each plant was subjected throughout the present studies was undoubtedly higher than what would ordinarily be encountered under field conditions. This high level of inoculum may have decreased the resistance of some varieties to some degree.

All of the bush bean, cantaloupe, cucumber, watermelon, pepper, and mung bean varieties tested were found to be highly susceptible and would not be satisfactory in a crop rotation program to decrease a population of M. incognita acrita.

The barley, oats, rye, and wheat varieties tested supported a low level of nematode reproduction and therefore would be considered moderately susceptible. A population of M. incognita acrita on the small grain varieties tested could be maintained at a low level, and this would be adequate inoculum for a susceptible crop. Three of the sorghum varieties reacted very much the same as the small grain varieties; however, the 2 other sorghum varieties tested did not support nematode reproduction and would be considered resistant. The corn varieties supported a slightly higher level of nematode reproduction than did the small grain varieties; therefore, the corn varieties would be less suitable as a rotation crop.

There was no correlation between the amount of nematode reproduction and the galling produced on some of the soybean varieties tested. A moderately galled variety supported a high level of nematode reproduction and a severely galled variety supported a moderate amount of nematode reproduction. Hood was the only soybean variety tested that did not support nematode reproduction. This should be a desirable crop to decrease a M. incognita acrita population.

Six of the cowpea varieties tested were highly susceptible. The 3 varieties Iron, Texas #12 and Victor supported a low level of nematode reproduction and would not be as satisfactory for controlling M. incognita acrita as the variety Brabham which was resistant.

The roots of the spinach varieties tested contained a large number of nematodes, but only a trace of reproduction occurred in 1 variety. The reason why nematode reproduction did not occur in all spinach varieties tested was not determined.

None of the resistant or moderately susceptible crop varieties in the present studies were noticeably stunted in the 35-day test period. The root systems of highly susceptible crops were severely stunted by the large number of larvae. Usually when these severely infected plants received ample water, a severe stunting of top growth did not occur during the 35-day test period; however, if these plants should have been subjected to moisture stress for a short period of time, they would likely have died.

A few of the varieties of bush bean, cantaloupe, cucumber, corn, cowpea, pepper, soybean, and the small grains tested for their reaction to M. incognita acrita have also been tested for their reaction to this nematode by other workers. The results reported by other workers were similar to the findings in the present studies except for the pepper variety California Wonder. In the present studies California Wonder was severely galled and supported abundant nematode reproduction. Sasser (37) reported a low index of infection and reproduction of the nematode in the variety California Wonder; however, Hare (19) reported the root-knot index to be moderate to severe on this same pepper variety depending upon the seed source.

Reported evidence suggesting that races of the root-knot nematode M. incognita acrita exist has already been pointed out. One of the objectives of the present studies was to determine whether races of this nematode exist in Oklahoma. The 4 populations of this nematode used in the present studies reacted as a single population to the varieties tested which indicates that races were not represented. The varietal tests in the present studies do not demonstrate that races of M. incognita acrita do not exist in Oklahoma because a population representing a different race may not have been selected or a differential host plant may not have been included in the varieties tested.

The photoperiod which effects the host has also been shown to have an indirect effect on the reproduction of the nematode (41). A photoperiod experiment in the present studies failed to show any relationship between the length of photoperiod and the development and reproduction rate of the nematode. The quality rather than the quantity of light or the temperature variation may have been the factor or factors responsible for the delay in egg mass production during the winter months.

SUMMARY

Ninety varieties of agronomic and horticultural crops were tested for their resistance to 4 populations of the root-knot nematode M. incognita acrita. There was no evidence that any of the crop varieties reacted differently to any of the 4 nematode populations. It was concluded that the populations used did not represent races of M. incognita acrita.

None of the varieties tested was resistant to invasion by the nematode. One variety each of cowpea and soybean and 2 varieties of sorghum were slightly galled. Roots of these plants contained only a few mature females and did not support reproduction of the nematode. Two varieties of cowpea, 1 variety of soybean, and 3 varieties of sorghum were slightly galled and supported a slight amount of nematode reproduction. One variety of soybean was severely galled, and there was a low level of nematode reproduction. Roots of 28 grain varieties tested including corn, barley, oats, rye, and wheat contained a large number of nematodes, but the rate of reproduction was low in all varieties. The 22 varieties of cucurbits tested including cantaloupe, cucumber, and watermelon were severely galled, contained a large number of nematodes, and supported a high level of nematode reproduction. Four varieties each of bush bean, mung bean and soybean and 6 varieties each of cowpea and pepper were considered very susceptible on the basis of severe galling, large numbers of nematodes in the roots and a high

rate of nematode reproduction. The 5 spinach varieties tested were severely galled and the roots contained a large number of immature nematodes, but in only 1 of the varieties was there reproduction and this was at a low level.

In a preliminary investigation there was no evidence that an increased photoperiod with tomato had significantly affected either the number of mature female nematodes or the number of mature females with egg masses.

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VITA

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