1974

Inheritance of Resistance to the Wartelle Race of Root-Knot Nematode in Soybeans.

Donald James Boquet
Louisiana State University and Agricultural & Mechanical College

Follow this and additional works at: https://digitalcommons.lsu.edu/gradschool_disstheses

Recommended Citation

Boquet, Donald James, "Inheritance of Resistance to the Wartelle Race of Root-Knot Nematode in Soybeans." (1974). *LSU Historical Dissertations and Theses*. 2591.
https://digitalcommons.lsu.edu/gradschool_disstheses/2591

This Dissertation is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Historical Dissertations and Theses by an authorized administrator of LSU Digital Commons. For more information, please contact gradetd@lsu.edu.

INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.
2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.
3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.
4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.
5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

Xerox University Microfilms

300 North Zeeb Road
Ann Arbor, Michigan 48106

74-24,759

BOQUET, Donald James, 1945-
INHERITANCE OF RESISTANCE TO THE WARTELLE RACE
OF ROOT-KNOT NEMATODE IN SOYBEANS.

The Louisiana State University and Agricultural
and Mechanical College, Ph.D., 1974
Agronomy

University Microfilms, A XEROX Company, Ann Arbor, Michigan

INHERITANCE OF RESISTANCE TO THE WARTELLE RACE OF
ROOT-KNOT NEMATODE IN SOYBEANS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Agronomy

by

Donald James Boquet
B.S., Nicholls State University, 1968
M.S., Louisiana State University, 1971
May, 1974

EXAMINATION AND THESIS REPORT

Candidate: Donald James Boquet

Major Field: Agronomy

Title of Thesis: INHERITANCE OF RESISTANCE TO THE WARTELLE RACE OF ROOT-KNOT
NEMATODE IN SOYBEANS

Approved:

Curtis Williams

Major Professor and Chairman

James K. Traynham

Dean of the Graduate School

EXAMINING COMMITTEE:

May Birchfield

W. Blackmon

N. Henry

M. T. Henderson

Date of Examination:

April 19, 1974

ACKNOWLEDGMENTS

The author is deeply indebted to Dr. Curtis Williams for his guidance and assistance given during the course of the study and in preparing the manuscript.

He expresses appreciation to Dr. Wray Birchfield for his assistance and advice in identifying and handling the nematode populations.

To Dr. E. E. Hartwig the author expresses his appreciation for providing the F_2 seed used in this study.

The author extends his appreciation to the members of the examining committee for their constructive criticism and aid in correcting the manuscript.

Special thanks are extended to Dr. W. H. Willis for making possible the monetary assistance for this research.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS.	ii
LIST OF TABLES	iv
ABSTRACT	v
INTRODUCTION	1
REVIEW OF LITERATURE	4
MATERIALS AND METHODS.	23
RESULTS AND DISCUSSION	27
SUMMARY	32
RESISTANCE IN SOYBEANS TO FIVE LOUISIANA ISOLATES OF ROOT-KNOT NEMATODE	34
REFERENCES	52
VITA	59

LIST OF TABLES

1.	Classification of parents and their F ₁ and F ₂ progeny according to their reaction to the Wartelle race of root-knot nematode.. . . .	28
2.	Response of D69-6344 (res), D69-8178 (sus), and F ₁ to varying population densities of the Wartelle race of root-knot nematode	29
3.	Response of 18 soybean strains to 4 Louisiana isolates of root-knot nematode in greenhouse tests indicating differences between soybean strains, January-February, 1973.. . . .	40
4.	Response of 18 soybean strains to 4 Louisiana isolates of root-knot nematodes in greenhouse tests indicating differences between nematode isolates, January-February, 1973.	41
5.	Response of 18 soybean strains to 5 Louisiana isolates of root-knot nematodes in greenhouse tests indicating differences between soybean strains, October-November, 1973	43
6.	Response of 18 soybean strains to 5 Louisiana isolates of root-knot nematodes in greenhouse tests indicating differences between nematode isolates, October-November, 1973.	44
7.	Combined analysis of variance for winter and fall test data.	46
8.	Response of 18 soybean strains to 4 Louisiana isolates of root-knot nematode, combined data indicating differences between strains	48
9.	Response of 18 soybean strains to 4 Louisiana isolates of root-knot nematode, combined data indicating differences between isolates. . . .	49

ABSTRACT

A study was conducted to determine the nature of inheritance of resistance in soybeans (Glycine max [L.] Merrill) to the Wartelle race of root-knot nematode (Meloidogyne incognita [Kofoid and White] Chitwood). Reciprocal crosses were made between resistant D69-6344 and susceptible D69-8178 soybeans. Reaction of the parents and the F₁ and F₂ generations was studied in the greenhouse using a root-knot larvae density of 300 per 500 ml of soil. A second greenhouse experiment was conducted to determine the response of the parents and F₁ to nematode densities ranging from 100 to 1000, in multiples of 100, per 500 ml of soil. Parents and F₁ and F₃ generations were evaluated in the field under conditions of natural root-knot nematode infestation. Infestation of plants was determined by using an egg mass index based on percent of roots with root-knot nematode egg masses where 0 = no roots with egg masses, 1 = 1 - 9%, 2 = 10 - 19%, 3 = 20 - 29%, 4 = 30 - 39%, 5 = 40 - 49%, and 6 = 50 - 100% of the roots with egg masses.

At a population density of 300 larvae per 500 ml of soil, the mean index of the resistant and susceptible parents was 1.4 and 5.8, respectively. There was a wide range in reaction in

the F_1 , ranging from an egg mass index of 1.0 up to an index of 6.0. In the population density study, the egg mass indices of D69-6344 and D69-8178 were not significantly affected by changes in population densities of the nematodes. D69-6344 had an egg mass index of 0.5 at 100 nemas per 500 ml of soil and 1.2 at 1000 nemas per 500 ml of soil. The reaction of D69-8178 was a consistent egg mass index of 6.0 regardless of nematode density. The F_1 , however, ranged from an egg mass index of 1.8 at 100 larvae per 500 ml of soil to 6.0 at 1000 larvae per 500 ml of soil.

Egg mass indices of the F_2 plants ranged from 1 to 6 with no plants receiving a 0 rating. Thirty-six plants received a rating of 1, 34 a 2, 25 a 3, 25 a 4, 50 a 5 and 116 plants received a rating of 6. The variability of reaction in the F_1 indicated that exact determination of segregation ratios in the F_2 was not possible.

Forty-eight lines, evaluated in the field, produced 18 lines with all plants susceptible, 23 segregating lines and 7 lines with all plants resistant. Intermediate types with indices of 3 or 4 were of low frequency in most of the F_3 lines which segregated.

The F_1 data indicated that susceptibility was partially dominant to resistance, particularly at high nematode population densities. Segregation ratios in the F_2 and F_3 generations

indicated that resistance to the Wartelle race of root-knot nematode was controlled by a relatively small number of genes, probably two.

Parallel studies were conducted in the greenhouse with five Louisiana isolates of M. incognita to determine the reaction of soybean cultivars and strains which had been reported to be resistant to M. incognita. Differences in levels of resistance occurred among cultivars and strains within each of the root-knot nematode isolates. D69-6344 had the highest level of resistance to the isolates tested. Cultivars with high levels of resistance were 'Laredo', 'Delmar' and 'Bethel'. There were differences among isolates in their ability to reproduce on many of the cultivars and strains, which indicated that there were physiological differences among these five isolates of root-knot nematode.

INTRODUCTION

The root-knot nematode (Meloidogyne incognita [Kofoid and White] Chitwood) is a destructive pest of soybeans (Glycine max [L.] Merrill) which occurs primarily in lighter soils of the Southern one-half of the United States. Control measures have been suggested since 1889 when this nematode was first recognized as a problem in the South. These include crop rotation, resistant varieties and, beginning in 1944, chemical control. Chemical control through soil fumigation with nematocides is expensive for soybeans, leaving cultural practices and resistance as the most practical control measures once root-knot nematodes are present in a field.

Varietal resistance in soybeans to various species of root-knot nematode including M. incognita has been recognized since 1900. Early sources of resistance from plant introductions were incorporated into many cultivars. Today, the number of soybean cultivars resistant to M. incognita is approximately twenty. Resistance in these cultivars is relative, ranging from a moderately high level to a low level. Further, the response of a particular cultivar or strain to root-knot nematode may differ depending upon the area in which it was tested and reported resistant. Cultivars reported resistant in one area

have, therefore, not always proven to be resistant when grown elsewhere. Evidence indicates this may be due to the existence of races of root-knot nematode.

A root-knot nematode found in soil on the Jack Wartelle Farm in St. Landry Parish, Louisiana, was determined by Martin and Birchfield (45) to be M. incognita, but it failed to attack 'Centennial' sweet potato Ipomoea batatis L., a cultivar commonly susceptible to M. incognita. However, this nematode termed the 'Wartelle' race caused severe yield reductions in 'Bragg', a soybean cultivar previously considered to have a moderately high level of resistance to M. incognita.

Soybean cultivars and strains were subsequently tested for resistance to this Wartelle race of root-knot nematode by Williams, Birchfield and Hartwig (74). They found high levels of resistance in several strains including D69-6344, D69-6341 and D69-6223. These three strains were selections from D63-6094 x D62-7562.

The objective of this study was to determine the nature of inheritance of resistance to the Wartelle race of root-knot nematode using a source of resistance identified by Williams et al.

Parallel studies were also undertaken to gain further information on the reaction of reportedly resistant soybean strains to isolates of Louisiana root-knot nematodes. This

series of experiments entitled 'Resistance in soybeans to five Louisiana isolates of root-knot nematode' is reported beginning on page 34.

REVIEW OF LITERATURE

The history of root-knot disease began in 1855 with the discovery by Berkely (9) of root-galls on cucumber roots in an English greenhouse. It is probably best to consider the subsequent studies of root-knot as having occurred in two eras. The first was pre-1949, and consisted of considerable work on the nature and development of the inciting organism and the various factors affecting its development. However, some of the early workers were interested in control of root-knot nematode and the potential of resistant varieties was frequently referred to in the literature. There was during this time a great deal of confusion concerning the taxonomy of root-knot nematodes which made it difficult to ascertain what species were involved in a given study. This led to conflicting reports when researchers unknowingly conducted experiments in which the organisms involved were what are considered today to be different species.

The current era of root-knot study began in 1949 with the revision of the root-knot nematode genus by Chitwood (12). Beginning about this time, work on root-knot nematode was concentrated more toward chemical control and the nature and inheritance of resistance in plants.

Several authors (9, 12, 56) have furnished information on the early work on root-knot nematode classification. Greef (9) observed galls on grass roots in 1864 and named the parasite Anguillula radiculicola in 1872. Muller (9), studied the same organism in 1884 and placed it in the genus Heterodera radiculicola (Greef) Muller. Goodey (33) showed that this nematode was not closely related to Heterodera or Meloidogyne and placed it in the genus Anguillulina. This species was later placed in the genus Ditylenchus by Filipjev (56).

In 1879, Cornu (33) described a species of root-knot nematode on sainfoin Onobrychis viciaefolia Scop. in France, naming it Anguillula marioni. In 1932, Goodey renamed it Heterodera marioni (Cornu) Goodey.

Treub (9) in 1885 described what he thought to be a new root-knot nematode species on sugarcane in Java and called it Heterodera javanica. Some workers did not accept it as a new species, believing it belonged in H. radiculicola.

In 1887, Goeldi (56) described Meloidogyne exigua as a new species causing root galling of coffee trees in Brazil. Other authors, however, generally considered this species to be a synonym for H. radiculicola.

The first published reference to root-knot in the United States was a report by May (9) in 1876 of root galls on violets. Independent studies by Neal (50) in Florida and Atkinson (2)

in Alabama, carried out in 1889, were the first comprehensive monographs on root-knot nematodes published in the United States. Neal named the organism involved Anguillula arenaria. Atkinson identified the one in Alabama as H. radicicola. Stone and Smith (10) working in Massachusetts described a root-knot nematode as H. radicicola which they believed was the same as those in Florida and Alabama.

Lavergne (56) in 1901 described a root-knot nematode on grapevine roots in Chile as Heterodera vialae.

In 1919, Kofoed and White (41) described Oxyuris incognita from fecal samples of soldiers in Texas.

Cobb (56) in 1924 erected a new genus Caconema for the root-knot nematodes, separating them from the genus Heterodera.

Work by Christie and Albin (13) and Christie (14) established that there were several strains or races of root-knot nematodes. These investigations prompted Chitwood (12) to make a morphological study of the root-knot nematodes, after which he removed them from the genus Heterodera and reassigned them to the genus Meloidogyne. Five species and one variety were described by Chitwood in 1949. These were Meloidogyne exigua (Goeldi, 1887); M. javanica (Treub, 1885); M. hapla, new species; M. incognita (Kofoed and White, 1919); Meloidogyne incognita var acrita, new variety and M. arenaria (Neal, 1889). Since 1949, twenty-four other species have been described bringing the total to thirty (26).

According to Chitwood (12), M. arenaria and M. hapla were at one time the same organism, probably Anguillula marioni (Cornu, 1887), but represent separate introductions from Europe. M. incognita is proposed as native to the Southern United States and subtropical American islands.

Taylor (64) reported on the distribution of root-knot nematodes in the United States. South of the latitude of Washington D.C. the most common nematodes are M. incognita and M. incognita acrita. North of this latitude M. hapla is the most prevalent. M. arenaria and M. hapla are fairly common in fields where peanuts are grown in Alabama, Georgia and Virginia. M. javanica is scattered throughout the South and Southwest, and M. arenaria thamesi Chitwood is found only in Florida.

Studies to determine the nature of resistance and mode of inheritance to root-knot nematode have been carried out with many crops. Orton (52) in 1908, conducted the first genetic study with root-knot when he crossed the 'Iron' variety of cowpea Vigna sinensis L., resistant to root-knot, with a susceptible variety. He reported that the F_1 were uniformly resistant, and the F_2 showed the greatest possible variation with no discernible ratio.

Isbell (39) searched for resistance to root-knot in pole beans Phaseolus vulgaris L. and found several resistant selections, one of which was released as the variety 'Alabama No. 1' in 1932.

Barrons (8) used Alabama No. 1 as the source of resistance in a genetic study of resistance to root-knot nematode H. marioni in pole bean. All F_1 plants appeared almost as susceptible as the susceptible parent. The F_2 segregated into a ratio of 11 susceptible, 4 intermediate and 1 resistant. He concluded that resistance was inherited as a double recessive trait.

Allard (1) surveyed 380 varieties and strains of lima beans P. lunatus L. in an effort to find resistance to root-knot nematode M. incognita acrita. He found a wide range of reaction suggesting that a number of genes governed resistance to this species of root-knot. Twelve highly resistant strains were selected as a result of the tests.

McGuire and Allard (48) working with lima beans in Hawaii agreed with the results of Allard, but stated that most of the difference between resistant and susceptible parents was accounted for by only one or two major genes.

Inheritance of resistance to galling by root-knot nematodes in lima beans was studied a second time by McGuire et al. in 1961. Variability in level of infestation in the field prevented exact genetic analysis, but evidence suggested that a few major genes conditioned resistance. The appearance of susceptible plants in the F_2 of a cross between two resistant parents indicated to them that genes for resistance were not the same in these parents.

Tufts and Day (66) in 1934 reported on resistance to root-knot nematode H. marioni in several species of fruit trees, including the discovery of resistance in Shalil type peach, Prunus persica L. (Batsch), in California.

In 1936, Hutchins (38) in Georgia confirmed that the Shalil peach showed complete resistance to root-knot.

Weinberger et al. (72) crossed a resistant Shalil with three susceptible varieties and another resistant stock of Yunnan type with one susceptible variety. All of the 247 F₁ seedlings were resistant. Their conclusion was that resistance was dominant in both Shalil and Yunnan types.

Sharpe et al. (58) showed that resistance in Shalil and Yunnan peach to M. incognita was inherited as a monofactorial dominant character, and they suggested that resistance to M. javanica was controlled by two or more dominant genes. Their data indicated that resistance to M. incognita and M. javanica was inherited differently and independently. Seedlings resistant to M. incognita and M. javanica were susceptible to M. arenaria and M. hapla.

Bailey (3) and Romshe (55) tested species of tomato in greenhouse and field experiments for resistance to root-knot. Lycopersicon esculentum Miller, L. hirsutum Humb. and Bonpl., L. glandulosum Muller and L. pimpinallifolium (Jusl.) Miller were susceptible. Bailey described L. peruvianum Miller as tolerant and Romshe indicated it was resistant.

McFarlane et al. (46) used artificially inoculated beds to screen material from interspecific crosses of L. peruvianum and L. esculentum. All of the F₁ and F₂ were highly to moderately resistant. They concluded that resistance was dominant to susceptibility.

Watts (69) used L. peruvianum as a source of resistance in his genetic studies of resistance to root-knot; and concluded that, in at least early stages of plant growth, resistance was controlled by two dominant factors. He found that some plants resistant in early stages of growth could become galled if inoculated a second time at a later stage, a fact he attributed to different genes acting at different stages of plant growth.

Frazier and Dennet (27) in a cross of L. esculentum x L. peruvianum reported the F₁ completely resistant. The F₂ progeny segregated in a 3 to 1 ratio in favor of resistance. Despite the excellent fit to the 3:1 ratio, they suggested that one or two dominant genes with modifiers were responsible for resistance.

The work of Gilbert and McGuire in 1952 (28) on inheritance of resistance to root-knot nematode marked the beginning of such research in tomatoes using Chitwood's classification. Using a species of nematode identified as M. incognita they obtained F₂ populations which segregated 3 resistant to 1

susceptible, but some were 13:3 in favor of resistance. They attributed resistance to probably one major gene with modifiers.

Barham and Sasser (4) utilized the same L. peruvianum x L. esculentum cross as previous workers, and reported that the progeny from this cross were resistant to M. incognita, M. arenaria and M. javanica, but not to M. hapla. They also found that resistance was conferred by one or more dominant genes.

Gilbert and McGuire (29) later attempted to determine the mode of inheritance to M. incognita and concluded that resistance was controlled by a single dominant gene.

Barham and Winstead (5) in 1957 found that a single gene was responsible for resistance to M. javanica, M. arenaria, M. incognita and M. incognita acrita. Since the resistant L. peruvianum parent carried a higher level of resistance than the F₁, they concluded that resistance was incompletely dominant. This conclusion was reached despite an F₂ progeny which segregated in a ratio of 3 resistant to 1 susceptible.

Hernandez et al. (36) used five different crosses with an L. peruvianum source of resistance and showed that resistance to the M. incognita group in Louisiana lines of tomatoes was governed by a single dominant gene.

Hare (34) found that resistance to M. incognita in pepper Capsicum annuum L. was controlled by a single dominant gene.

The same gene controlled resistance to M. incognita acrita and possibly M. javanica and M. arenaria.

Resistance in sweet potato to M. incognita was studied by Cordner et al. (16). They reported that in resistant x resistant crosses approximately 50% of the F_1 were resistant, 30% were intermediate and 20% were susceptible. In resistant x susceptible crosses the number of resistant, intermediate and susceptible were approximately equal. Susceptible x susceptible crosses resulted in about 10% resistant, 25% intermediate and 65% susceptible F_1 progeny.

Smith (59) tested the reaction of cotton Gossypium hirsutum L. varieties and F_2 progenies to root-knot nematode at two locations in Georgia. There were differences between varieties and locations in galling. He found that the mean reaction of 10 F_2 hybrid progenies was like that of the more susceptible parent.

Wright (77) conducted a genetic study with the F_2 and F_3 progenies of a cross between the moderately resistant 'Clevewilt 6' and susceptible 'Deltapine 15' varieties of cotton. He concluded that the reaction to root-knot M. incognita was quantitative in nature and probably controlled by two or three major genes, with partial dominance for resistance.

Resistance to root-knot nematode in soybeans has been reported by various authors beginning as early as 1900 (9, 50, 67). Although well documented, it is difficult to determine

from such papers exactly which species of nematode were involved in early testing, and since screening trials after 1949 were repetitive of these tests only the latest literature is reviewed here.

Holston and Crittenden (37) tested eight soybean varieties in a field infested with M. incognita acrita. Resistance was not found but 'Illini' appeared tolerant despite having a large number of egg masses. This suggested to the authors that macroscopic examination of roots would detect tolerance but not resistance.

Crittenden (18) screened 50 varieties for resistance to M. incognita acrita. Ten varieties showed resistance; 'Laredo', 'Mukden', 'Anderson', 'Monroe', 'Blackhawk', 'Peking', 'Mendota', 'Haberlandt', 'Habaro' and 'Mandarin 507'. The first five mentioned varieties had the highest levels of resistance to M. incognita acrita, but were susceptible to M. hapla.

Further screening trials were conducted by Crittenden (20) which included crops other than soybeans. Resistance was not found to M. incognita acrita in barley Hordeum vulgare L., rye Secale cereale L., wheat Triticum aestivum L., bird's foot trefoil Lotus corniculatus L., tomato Lycopersicon esculentum and cantaloupe Cucumis melo L. Resistance was found in oats Avena sativa L., asparagus Asparagus officinalis L. as well as soybeans. Soybean varieties found to be resistant and their

average galling index were: Blackhawk, 1.5; FC 33 243, 1.3; Habaro, 1.8; Haberlandt, 1.8; 'Jackson', 1.4; Laredo, 1.2; Mandarin, 1.9; Mendota, 1.6; Monroe, 1.5; Mukden, 1.5; Peking, 1.5. Ratings were from 0 to 5, with indices below 2 being resistant and 2 or above being susceptible.

The list of varieties resistant to M. incognita has increased recently due to the efforts of plant breeders who have developed resistant varieties. Current varieties possessing various degrees of resistance include 'Delmar', 'Dyer', 'Forrest', Jackson, Bragg, 'Hill', 'Hutton', 'Cobb' and 'Hardee'.

Hare (35) in 1965 reviewed the literature on the inheritance of resistance of plants to nematodes. He noted that resistance had been demonstrated to be controlled by from one to three genes with many cases ascribed to minor genes. Resistance from a specific gene was for a particular nematode or up to four different species. Much of the resistance was relative. According to Hare, by the nature of most plant parasitic nematodes their movement from one area to another is restricted and new physiological races that break resistance would be slow to spread. This makes resistance one of the most profitable avenues for research on control of nematodes.

The existence of races in root-knot nematodes was a generally accepted fact before 1949 and was one of the reasons

Chitwood undertook a study of the morphology of the root-knot nematodes. He was able to separate these races of root-knot nematodes into species based on morphology alone. Later, Sasser (56) was able to separate the same species using host differentials. The question then arose of the existence of races within the new species as classified by Chitwood.

Martin (44) showed that differences in parasitism on cotton among isolates of M. incognita and M. incognita acrita ranged from no parasitism in the case of some isolates to severe parasitism in the case of other isolates. A total of 21 isolates were used; 7 from tomato L. esculentum, 6 from okra Hibiscus sabdariffa L., 4 from hairy vetch Vicia villosa Roth, 2 from cucumber Cucumis sativus L. and 2 from Lamium amplexicaule L.

Dropkin (22) studied the varietal response of soybeans to Meloidogyne spp. Soybean varieties exposed to a single population of root-knot nematode differed both in galling and egg mass production. A single variety exposed to different populations of nematodes showed varied response in galling and egg mass production. He asserted that egg mass production was the most sensitive indicator of the parasites' welfare. However, small egg masses were found in both heavily and lightly galled varieties, and abundant large egg masses were found in lightly as well as heavily galled plants. According to Dropkin,

the great sensitivity of soybean varieties to differences among these nematodes combines with the sensitivity of the nematodes to differences among hosts to make soybeans excellent tools for separation of genetically different populations.

Sasser (57) experimented with Meloidogyne spp. from various geographical areas on ten host differentials. He stated that all of the species of root-knot nematode investigated, which included M. incognita, M. arenaria, M. hapla, M. exigua and M. javanica were composed of biotypes which can be detected by qualitative and quantitative differences in their abilities to parasitize certain hosts.

Martin and Birchfield (45) in Louisiana found that a race of M. incognita failed to develop mature females on 'Centennial' sweet potatoes Ipomoea batatis L. although this cultivar was considered very susceptible to the M. incognita commonly found in soils planted to sweet potatoes in Louisiana. They also reported that a root-knot resistant selection from the Louisiana sweet potato breeding program was recorded to be severely infested with root-knot nematode in Maryland, even though the species in Maryland was also keyed to M. incognita.

Williams et al. (74) referred to the race of root-knot nematode discovered by Martin and Birchfield as the 'Wartelle' race. They noted that this race was severely pathogenic to

Bragg soybeans, a cultivar previously considered to have a moderately high level of resistance to M. incognita.

The actual mechanisms of resistance in plants to root-knot nematode are not completely understood although many workers have addressed themselves to this problem in an attempt to find such mechanisms.

Barrons (7) in 1939, made a microscopial study of rootlets from resistant and susceptible pole beans and found that as many root-knot larvae entered the roots of resistant plants as entered susceptible plants. He hypothesized that resistance was due to substances of the plant which counteract the giant cell inducing effect of the salivary secretions of nematode larvae.

Barron's results were confirmed by Christie (14) who found no correlation between suitability of the host and freedom with which larvae enter its roots. However, Christie seemed to disagree with Barrons in stating that unsuitability of the host was not necessarily accompanied by a corresponding reduction in severity of galling. He did note, nevertheless, a direct correlation between suitability of the host and rate of parasite development; especially with females which did not reach maturity or did so more slowly in unsuitable hosts.

Dean and Struble (21) reported on reaction of sweet potato and tomato roots to root-knot nematode. They found

no differences in number of larvae entering resistant and susceptible sweet potato roots. However, necrosis occurred in cells surrounding nematodes in resistant sweet potato roots but did not occur in susceptible roots. Most of the nematodes in resistant roots died before reaching maturity. Root systems of resistant tomatoes were invaded by fewer larvae than those of susceptible tomatoes. Nematodes entering resistant roots produced extensive necrosis of host tissue and, just as in sweet potato, most of the invading larvae died. It would appear, then, that the mechanism of resistance in sweet potato is hypersensitivity; while in tomato there is both a barrier to entrance and hypersensitivity reaction.

Peacock (53) listed five ways in which a chemical might contribute to resistance to nematode attack: (1) by masking an attractant substance or by actively repelling the nematode, (2) by killing the nematode on entry or retarding its development, (3) by neutralizing the effect of nematode saliva on giant cell formation, (4) by changing the composition of the cell wall so that the nematode saliva is no longer effective, and (5) by upsetting the sex ratio of the nematode either physiologically or by eliminating the females. He also demonstrated that excised L. peruvianum root tips maintained their resistance to root-knot nematode, indicating that resistance did not depend upon translocation of metabolites from aerial parts of the plant.

Crittenden (19) studied the histology and cytology of soybeans infested with M. incognita acrita. He found that in susceptible varieties numerous large giant cells with many enlarged nuclei were formed, while in resistant varieties there were only a few relatively small giant cells and each contained only a few nuclei.

Further work was conducted by Dropkin and Nelson (23) on the histopathology of root-knot nematode infestations in soybeans. They described giant cell formation in a favorable host variety as follows: intense cell multiplication about the larval head is followed by hypertrophy of cells immediately surrounding the mouth and cell wall dissolution proceeding outward from hypertrophied cells, resulting in multinucleate units, the giant cells.

Rhode (54) offered several possible explanations for resistance including production of toxic secretions by the host plant, lack of nematode stimulating secretions, inability of the roots to furnish proper nutrition, hypersensitivity of cells and failure of the plant to produce giant cells. He stated that resistance to root-knot nematodes, which requires elaborate modification of root tissue in the form of giant cells, is much more common than resistance to migratory surface feeders. In general, resistance showed up after infestation and was most often based on failure of the host

to respond to nematode secretions in a manner favorable to nematode development.

Veech and Endo (68) reported on the morphology in root-knot nematode resistant Delmar and susceptible 'Lee' soybeans. During the first few days activity was similar, but then syncytia developed at the site of nematode feeding in Lee. At the time corresponding to syncytia induction in the susceptible host the most common response in the resistant host was cell necrosis. In Lee, 94% of the roots developed galls while in the Delmar variety only 16% of the roots had galls, indicating that resistant plants produced fewer syncytia.

Godfrey (30) found that active root-knot infestations did not occur at temperatures below 10°C and 16°C seemed to be the critical temperature above which root-knot nematodes became fully active. In regard to soil moisture, he stated that moisture had little effect on root-knot development since it could develop under any moisture conditions favorable to plant growth.

Jones (40) reported that the optimum temperature for root-knot development on tomatoes was 25 to 30°C, which is also the optimum temperature for growth of tomatoes. His results showed an increase in galling with low soil moisture and relatively high temperature. On nematode survival, Jones noted that in detached galls larvae could survive for 30 days

in soils ranging in moisture from 10 to 100%. Galls in air dry soil protected nematodes for 10 days.

Thomason and Lear (65) showed that maximum egg production of M. incognita acrita was from 25 to 32°C. Viable eggs were produced from 15 to 35°C.

Dropkin (24) found that temperature affected the ability of certain soybean varieties to support growth and reproduction of M. incognita acrita. The variety 'Chief' supported nematodes better at 35 than at 24°C, but 'Adams' supported nematodes better at 24 than at 35°C.

A method was sought by Barrons (6) to accurately and economically determine root-knot resistance in beans Phaseolus vulgaris, cowpeas Vigna sinensis and lima beans Phaseolus lunatus. He attempted to show correlations between artificially inoculated greenhouse tests with seedlings and field tests conducted under natural infestations. Inoculum consisted of chopped root-knot tissue from diseased bean and tomato plants. He found that best classifications of infestations in the greenhouse could be made between 20 and 30 days after planting. A classification system of 1 to 5 was used based on galling of roots with 1 being resistant and 5 highly susceptible. Greenhouse experiments agreed with field tests for beans and cowpeas, but lima beans, which were resistant in the field, gave susceptible reactions in the greenhouse.

Bailey (3) used seedlings in greenhouse experiments to determine resistance in beans. Ground roots from infested plants were used as inoculum. He found that it was necessary to use chemicals to control damping-off and root rot organisms whose activities prevented plant growth and root galling. He stated that the number of plants per pot affected root-knot classification making it advisable to grow a fixed number of seedlings per pot.

Webster (70) reported that greenhouse testing was more rapid and severe than field tests. Higher root-knot indices were obtained in the greenhouse on lima beans in a shorter time than in field tests, and with a lower number of egg masses added.

Smith and Taylor (60) proposed the term root-knot index for data obtained by classifying degree of infestation according to percentage of roots having root-knot galls. In their system of 0 to 4, 0 = no infestation, 1 = 1 - 25%, 2 = 26 - 50%, 3 = 51 - 75%, 4 = 76 - 100% infestation. They compared this method to another, called relative root-knot index, in which plants were classified according to a standard established in that particular study. In this system 0 = no infestation, 1 = light, 2 = medium, 3 = heavy and 4 = very heavy infestation. They recommended the root-knot index for studies in which comparisons were to be made between tests or years because the data is comparable on a percentage basis.

MATERIALS AND METHODS

Two soybean strains, one resistant and one susceptible to the Wartelle race of root-knot, were chosen as parents. These were: (1) D69-6344 - a strain possessing a high degree of resistance and having white flowers and brown pubescence, and (2) D69-8178 - a strain with high susceptibility, blue flowers and gray pubescence.

Reciprocal crosses were made by hand pollination at Baton Rouge. A large number of backcrosses were also attempted. F₂ seed were furnished by Dr. E. E. Hartwig of the Delta Branch of the Mississippi Agricultural Experiment Station.

1972-73 greenhouse tests - Soil obtained from the Wartelle farm was thoroughly mixed and divided into portions of approximately 80 liters each. Samples were taken from each portion and the number of root-knot larvae determined by the USDA Nematology Laboratory at Louisiana State University in Baton Rouge. Small amounts of root-knot infested soil were added to a methyl bromide fumigated mixture (1 part Olivier silt loam: 1 part sand: 1 part vermiculite) to obtain a mixture suitable for both plant and nematode development, and having approximately 300 nematode larvae per 500 ml of soil.

As a means of efficiently handling the expected large amount of plant material, six plantings were made at two-week intervals. Plastic pots of 8-liter capacity were used and were filled with about 6 liters of nematode infested soil. At each planting date 50 pots were planted with a single F_2 seed, 3 pots with a single F_1 , and 2 pots each of the parents were planted for checks. A total of 300 F_2 , 18 F_1 , and 12 resistant and susceptible parents were planted.

All plants were grown for 60 days under a photoperiod extended to 15 hours by fluorescent lights. The plants were dug, tops removed, and root samples gently washed to remove soil. A 7X stereoscopic microscope was used to examine root samples for root-knot nematode egg masses. Root infestation was rated on a scale of 0 to 6 where 0 = no roots with egg masses, 1 = 1 to 9% of the roots with egg masses, 2 = 10 to 19%, 3 = 20 to 29%, 4 = 30 to 39%, 5 = 40 to 49%, 6 = 50 to 100% of the roots with egg masses.

A selected group of F_2 plants was treated somewhat differently in that the plants remained intact, and were replanted immediately after being examined for egg masses. These F_2 plants produced some of the F_3 lines evaluated in field tests.

1973 field tests - Forty-five F_3 lines from the F_2 screening tests plus additional F_3 lines from F_2 plants whose

reaction was untested were planted in root-knot infested soil on the Wartelle farm in May. Also planted at this time were reciprocal F_1 progenies and BC_1 progenies. The average root-knot larvae count at planting was approximately 80 per 500 ml of soil.

Forty-four F_3 lines and the F_1 and BC_1 progenies were dug on August 24. Each plant was examined for egg masses as described for previous tests. Eighteen F_3 lines which appeared by their vigor to have a high degree of resistance or to be escapes were left in the field until October. This insured that they had every opportunity to be exposed to root-knot nematodes and also allowed the production of seed by resistant lines.

1973-74 greenhouse test - A second experiment was conducted in the greenhouse to determine the reaction of resistant and susceptible parents and their F_1 under varying populations densities of root-knot nematode larvae. Nematode infested soil was prepared using the same procedure previously described. Pots were prepared in which the number of nematode larvae in 500 ml of soil increased from 100 to 1000 in multiples of 100. A completely randomized design with two replications was used. Several seed of D69-6344, D69-8178 or F_1 were planted in the appropriate pots and thinned to 3 plants per pot after emergence. Plants were grown for 60 days and

rated for root-knot infestation using the same procedure described for the 1972-73 greenhouse tests.

RESULTS AND DISCUSSION

Greenhouse tests - F_1 plants showed considerable variation in egg mass indices which ranged from 1 to 6 (Table 1). There appeared to be no difference between reciprocal F_1 progenies. Reaction of resistant and susceptible parents, however, was very consistent. The arithmetic mean of the F_1 , resistant parent and susceptible parent was 3.8, 1.4 and 5.8, respectively. There was no difference between the mid-parent egg mass index (3.6) and the mean index of the F_1 (3.8).

Results of the greenhouse test to evaluate the effect of population density on resistance are shown in Table 2. The response of the susceptible parent resulted in a consistent egg mass index of 6 regardless of nematode density. The resistant parent increased slightly in egg mass rating at higher nematode populations but the increase was not significant. However, significant variation did occur in the F_1 . It ranged from an egg mass index of 1.8 at 100 nemas per 500 ml of soil to an index of 6.0 at 1000 nemas per 500 ml of soil. Resistance appeared to be incompletely dominant at high nematode population densities, but susceptibility was partially dominant to resistance at high nematode densities.

Table 1. Classification of parents and their F₁ and F₂ progeny according to their reaction to the Wartelle race of root-knot nematode.¹

Parent ² or generation	Observed number of plants/egg mass index ³							Mean egg mass index s
	0	1	2	3	4	5	6	
D69-6344	0	7	5	0	0	0	0	1.4 $\pm$.3
D69-8178	0	0	0	0	0	2	10	5.8 $\pm$.3
F ₁	0	1	3	3	4	5	2	3.8 $\pm$ 1.2
F ₂	0	36	34	25	25	50	116	4.3 $\pm$ 2.0

¹Initial inoculum level was 300 nematode larvae per 500 ml of soil.

²Prefix 'D' refers to breeding lines selected at Stoneville, Mississippi.

³0 = no roots with egg masses, 6 = 50 to 100% of the roots with egg masses.

Table 2. Response of D69-6344¹ (res), D69-8178 (sus), and F₁ to varying population densities of the Wartelle race of root-knot nematode.

No. of nemas in 500 ml of soil	Egg mass index ²		
	D69-6344	D69-8178	F ₁
100	0.5a ³	6.0a	1.8a
200	0.4a	6.0a	3.0ab
300	0.4a	6.0a	5.1cef
400	0.6a	6.0a	4.2bce
500	0.6a	6.0a	4.8cef
600	0.6a	6.0a	4.5bce
700	1.0a	6.0a	4.8cef
800	0.8a	6.0a	4.0bc
900	0.8a	6.0a	5.5ef
1000	1.2a	6.0a	6.0f
Mean	0.7	6.0	4.4

¹Prefix "D" refers to breeding lines selected at Stoneville, Mississippi.

²0 = no roots with egg masses, 6 = 51 to 100% of roots with egg masses.

³Means within a column followed by the same letter are not significantly different at the 5% level according to the Duncan's Multiple Range Test.

The 300 F_2 seed planted in individual pots resulted in 286 F_2 plants. Egg mass indices ranged from 1 to 6 with no plants receiving a rating of 0. The frequency distribution of the F_2 plants by egg mass index is presented in Table 1. By grouping plants into classes of resistant, intermediate and susceptible, phenotypic ratios could be obtained which fit either a one or two gene model. However, the range in reaction of the F_1 plants, under 300 nematode larvae densities, demonstrated that heterozygous plants could have been classified into any egg mass index from 1 to 6. This indicated that any attempt to fit the F_2 data to genetic ratios would not be possible. Despite this handicap, the F_2 data did indicate that inheritance of resistance was qualitative in nature.

1973 field test - All F_1 plants had an egg mass index of 6. Only seven plants in the backcross progeny were identifiable as true backcrosses, so these data were not used. Five of the F_3 lines produced too few plants to acceptably determine their reaction to root-knot nematode. Other lines were eliminated from consideration because an area of the F_3 plots was low in nematodes in late summer as shown by counts of root-knot larvae from soil samples and lack of galling on susceptible parents. The remaining F_3 lines were grouped into the following three classes: 18 with all plants susceptible, 23 segregating and 7 with all plants resistant. The segregating F_3 lines had

fewer plants with indices of 3 or 4 than expected, probably because, as indicated by the F_1 field data, the heterozygotes tended to be susceptible under field conditions. This restricted the grouping of plants within segregating lines into resistant and susceptible classes.

The proportion of susceptible, segregating and resistant lines in the F_3 did seem to indicate that resistance was controlled by two genes rather than one, but is inclusive due to irregularity of nematode distribution in the field which restricted the amount of reliable data obtained.

The data thus far have not characterized with complete certainty the nature of genes carrying resistance to the Wartelle race of root-knot nematode in soybeans. The data indicate, however, that susceptibility is partially dominant to resistance at high nematode population densities and incompletely dominant at low nematode densities. It also showed that a small number of genes, probably no more than two, are responsible for resistance.

SUMMARY

A study was conducted to determine the nature of inheritance of resistance to the Wartelle race of root-knot nematode in a cross between resistant D69-6344 and susceptible D69-8178 soybeans. Greenhouse screening trials of F_1 , F_2 and parents were carried out in 1972-73. Reaction of F_3 lines and additional F_1 plants was evaluated in field tests on naturally infested soil in 1973. Infestation of plants with root-knot nematode was determined by egg mass indices, a rating system based on percent of roots containing root-knot nematode egg masses.

F_1 plants were variable in response to root-knot in the greenhouse, giving a resistant reaction at low population densities of nematodes and a susceptible response under higher nematode densities. In field tests F_1 plants were all susceptible. Egg mass indices of the F_2 plants ranged from 1 to 6 with no plants receiving a 0 rating. Although inheritance of resistance appeared to be qualitative, variability of the F_1 indicated that determination of segregation ratios in the F_2 generation was not possible. Some support for a one or two gene hypothesis for resistance was obtained from the proportion of susceptible, segregating and resistant lines in the F_3 .

The data indicated that inheritance of resistance in soybeans to the Wartelle race of root-knot nematode is controlled by a small number of genes, probably no more than two.

RESISTANCE IN SOYBEANS TO FIVE LOUISIANA ISOLATES
OF ROOT-KNOT NEMATODE

INTRODUCTION

In breeding soybeans for root-knot nematode resistance, it is important for a breeder to know the level of resistance possessed in the available germ plasm to as wide a range of isolates of root-knot nematodes as possible. If there is more than one race of root-knot nematode in the area for which the breeder is attempting to develop varieties, screening for resistance may have to be conducted for each of the races. One cultivar or breeding line could have a high level of resistance to one race of nematode and be susceptible to another race.

According to several authors (22, 26, 56) physiological races of Meloidogyne incognita exist, and reports of such races have come from Louisiana (44, 45, 74) as well as from other Southern states. If such races were proven to exist, it would be questionable as to whether or not the source of resistance (D69-6344) which was used in the inheritance study and in a breeding program would still have wide enough application to be useful.

A study, therefore, was undertaken with the objectives of: (1) determining if isolates of root-knot nematodes in Louisiana could be separated into physiological races based on their ability to attack selected strains of soybeans, and (2) determining how D69-6344 would react to these isolates in comparison to other strains of soybeans reported to be resistant.

MATERIALS AND METHODS

Five isolates of root-knot nematode were collected from various parts of Louisiana in 1972. The isolates were identified by using farmers' names or area designations. These were: Wartelle, Dessele, Vanderlick, St. Landry and Shreveport. Each of the isolates had been identified through previous work as Meloidogyne incognita (44, 74).

Eighteen strains of soybeans were selected for the experiments. Sixteen were cultivars (most no longer grown) which had been reported to have some degree of resistance to M. incognita, and included the following: 'Delmar', 'Laredo', 'Forrest', 'Bethel', 'Bragg', 'Habaro', 'Mendota', 'Hill', FC 33 243, 'Mukden', 'Monroe', 'S-100', 'Mandarin 507', 'Palmetto', 'Blackhawk', and 'Peking'. D69-6344, known to have resistance to the Wartelle isolate, was also included. 'Lee 68' was the susceptible check.

The Wartelle, Desselle and Vanderlick isolates were taken from soils planted to soybeans, the Shreveport isolate from cotton and the St. Landry isolate from sweet potatoes. All isolates were maintained on susceptible soybeans from September, 1972, to January, 1973. The Shreveport isolate, which had a low number of nematodes when collected, did not

reproduce rapidly on soybeans and therefore did not have sufficient larval populations to use as inoculum in the first series of tests.

To obtain soil for screening, soil containing a nematode isolate was mixed with sterilized soil (methyl bromide) so that the number of root-knot larvae was 300 per 500 ml. Six liters of this nematode infested soil was placed into 8-liter plastic pots and planted with several seed of the appropriate soybean cultivar or strain. Plants were thinned to three per pot after emergence.

Each isolate was conducted as a separate experiment in a randomized complete block design with three replications (pots). The experiments were planted in January, 1973, with four isolates and repeated in October, 1973, with five isolates. In this paper the first planting was referred to as winter tests and second planting as fall tests.

All plants were grown for 60 days, then dug, tops removed and root samples rated for root-knot nematode infestation using a 7X stereoscopic microscope. The degree of infestation was based on egg mass numbers where 0 = no roots with egg masses, 1 = 1 - 9%, 2 = 10 - 19%, 3 = 20 - 29%, 4 = 30 - 39%, 5 = 40 - 49%, and 6 = 50 to 100% of roots with egg masses.

Upon completion of the first series of tests in early March, the isolates were maintained, through the summer months,

on susceptible soybeans in containers outdoors. The experiments were then repeated, but with the addition of the Shreveport isolate which had increased in nematode numbers to be a sufficient inoculum.

Appropriate analyses of variance were conducted for each experiment. Data were also combined within each planting and between plantings for analysis. The Duncan Multiple Range Test was used for comparisons of treatment means.

RESULTS AND DISCUSSION

Winter tests - There were highly significant differences in egg mass indices between soybean strains for each isolate, indicating variation in levels of resistance to these isolates of root-knot nematode (Table 1). Significant differences occurred between the four isolates in each soybean strain tested, showing that each of the root-knot isolates differed in its ability to attack these strains (Table 2). Differences were present between isolates whether the strain of soybean was resistant or susceptible. Strain x isolate interaction was significant, but mean squares for both strains and isolates were significantly larger than the mean square for interaction.

Some strains (Bragg, Forrest, Habaro, FC 33 243) were susceptible to one or more isolates and resistant to other isolates. Delmar, Laredo, D69-6344 and Bethel seemed to have the highest levels of resistance which was consistent over isolates.

As an average of strains the Vanderlick isolate had the lowest egg mass rating, Wartelle and St. Landry isolates were not significantly different, and the Dessele isolate had a significantly higher egg mass index than the other three isolates.

Table 3. Response of 18 soybean strains to 4 Louisiana isolates of root-knot nematode in greenhouse tests indicating differences between soybean strains, January-February, 1973.

Strain	Egg mass index ¹				Mean
	Wartelle	Vanderlick	Dessele	St. Landry	
D69-6344	2.4 abc ²	0.9 a	1.3 a	1.0 a	1.6 a
Laredo	1.9 a	1.2 ab	2.6 ab	1.0 a	1.7 a
Bethel	2.5 abc	1.0 ab	2.5 ab	2.0 ab	2.0 ab
Delmar	2.0 ab	0.9 a	2.7 ab	2.7 ab	2.1 ab
Forrest	4.0 cde	1.6 abcd	2.5 ab	2.9 abc	2.7 bc
Habaro	2.0 a	2.4 abcde	5.0 de	2.1 ab	2.9 bc
FC 33 243	1.9 a	2.2 abcde	5.6 dc	2.6 ab	3.1 cd
Mandarin 507	2.7 ab	1.8 abcd	4.6 cde	3.0 bc	3.1 cd
Bragg	4.2 cdef	1.1 ab	5.1 de	2.6 ab	3.2 cd
Mendota	3.8 bcde	2.7 abcde	4.0 bcd	2.8 abc	3.3 cd
Hill	4.0 cde	2.7 abcde	4.1 bcd	3.3 bc	3.5 cd
Palmetto	4.5 def	2.5 abcde	3.0 abc	3.8 bcd	3.5 cd
Monroe	3.2 abcde	3.2 cdef	6.0 e	3.8 bcd	4.0 de
Mukden	4.3 cdef	3.5 def	5.4 de	4.6 cde	4.5 e
Blackhawk	4.6 def	4.1 ef	6.0 e	3.6 bc	4.6 ef
Peking	4.3 cdef	2.9 bcde	6.0 e	5.9 e	4.8 ef
S-100	4.7 ef	2.9 bcde	6.0 e	5.5 de	4.8 ef
Lee 68	6.0 f	4.9 f	5.7 e	5.4 de	5.5 f

¹0 = no roots with egg masses, 6 = 50-100% of roots with egg masses.

²Means within a column having a letter in common are not significantly different at the 5% level according to the Duncan Multiple Range Test.

Table 4. Response of 18 soybean strains to 4 Louisiana isolates of root-knot nematodes in greenhouse tests indicating differences between nematode isolates, January-February, 1973.

Strain	Egg mass index ¹			
	Wartelle	Vanderlick	Dessele	St. Landry
D69-6344	2.4 c ²	0.9 a	1.3 b	1.0 ab
Laredo	1.9 b	1.2 a	2.6 c	1.0 a
Bethel	2.5 c	1.0 a	2.5 c	2.0 b
Delmar	2.0 b	0.9 a	2.7 c	2.7 c
Forrest	4.0 d	1.6 a	2.5 b	2.9 c
Habaro	2.0 a	2.4 b	5.0 c	2.1 ab
FC 33 243	1.9 a	2.2 a	5.6 c	2.6 b
Mandarin 507	2.7 b	1.8 a	4.6 c	3.0 b
Bragg	4.2 c	1.1 a	5.1 d	2.6 b
Mendota	3.8 b	2.7 a	4.0 b	2.8 a
Hill	4.0 c	2.7 a	4.1 c	3.3 b
Palmetto	4.5 d	2.5 a	3.0 b	3.8 c
Monroe	3.2 a	3.2 a	6.0 c	3.8 b
Mukden	4.3 b	3.5 a	5.4 c	4.6 b
Blackhawk	4.6 c	4.1 b	6.0 d	3.6 a
Peking	4.3 b	2.9 a	6.0 c	5.9 c
S-100	4.7 b	2.9 a	6.0 d	5.5 c
Lee 68	6.0 c	4.9 a	5.7 bc	5.4 b
Mean	3.5 b	2.4 a	4.3 c	3.2 b

¹0 = no roots with egg masses, 6 = 50-100% of roots with egg masses.

²Means within a row having a letter in common are not significantly different at the 5% level according to the Duncan Multiple Range Test.

Fall tests - There were again highly significant differences between egg mass indices of strains within each isolate, indicating the considerable variation in levels of resistance among strains. Highly significant differences between isolates within each soybean strain showed again the differential reaction of strains to isolates. There was no strain x isolate interaction.

As an average of isolates, D69-6344 had the lowest egg mass rating, although it was not significantly lower than Delmar, Laredo or Bethel (Table 3). These 4 strains had average egg mass indices less than 2.0, the highest rating usually considered resistant. However, other strains with an average rating above 2.0 did have lower indices for some isolates. These included Forrest, resistant to the Shreveport isolate; and Bragg, resistant to the Vanderlick and Shreveport isolates. Only 5 of the 18 strains (Mukden, Palmetto, S-100, Peking and Lee 68) were rated susceptible to the Shreveport isolate, as compared to 14 susceptible strains when all 5 isolates were averaged.

As an average of strains, only the Shreveport isolate had a significantly lower egg mass index (Table 4). The remaining 4 isolates did not differ significantly; and in fact the average rating of these isolates were very close, ranging from 4.0 to 4.4. The Shreveport isolate was obviously a less pathogenic

Table 5. Response of 18 soybean strains to 5 Louisiana isolates of root-knot nematodes in greenhouse tests indicating differences between soybean strains, October-November, 1973.

Strain	Egg mass index ¹					Mean
	Wartelle	Vanderlick	Dessele	St. Landry	Shreveport	
D69-6344	0.7 a ²	0.8 a	0.7 a	0.5 a	0.1 a	0.5 a
Delmar	1.5 ab	1.7 a	1.3 a	1.8 ab	0.8 ab	1.4 ab
Laredo	1.8 ab	1.9 a	1.8 ab	1.5 ab	0.2 a	1.4 ab
Bethel	2.6 abc	0.8 a	2.0 ab	1.8 ab	0.2 a	1.5 ab
Bragg	3.2 abcd	1.2 a	4.0 bcd	2.2 abc	0.5 a	2.2 bc
Forrest	2.3 abc	2.8 ab	3.3 abc	3.6 bcd	1.3 abcd	2.7 c
Hill	3.8 bcde	5.1 bc	3.3 abc	2.9 abc	1.0 abc	3.2 cd
FC 33 243	4.0 bcde	2.9 ab	6.0 d	4.5 cd	1.3 abcd	3.8 de
Mendota	3.5 bcde	5.7 c	4.6 cd	5.4 cd	1.5 abcd	4.1 de
Habaro	3.5 bcde	5.7 c	5.5 cd	6.0 d	1.0 abc	4.3 ef
Mukden	4.6 cde	4.1 bc	6.0 d	5.7 d	2.3 abcd	4.5 efg
Palmetto	5.5 de	4.5 bc	6.0 d	3.8 bcd	2.9 abcd	4.6 efg
Monroe	5.3 de	6.0 c	5.8 cd	6.0 d	1.0 abc	4.8 efg
Mandarin 507	5.5 de	6.0 c	5.8 cd	5.8 d	1.5 abcd	4.9 efg
Blackhawk	5.8 de	6.0 c	6.0 d	6.0 d	0.8 ab	4.9 efg
S-100	5.7 de	6.0 c	6.0 d	6.0 d	3.5 bcd	5.4 fg
Peking	6.0 e	6.0 c	5.7 cd	6.0 d	3.8 d	5.5 g
Lee 68	6.0 e	6.0 c	6.0 d	5.0 d	3.7 d	5.5 g

¹0 = no roots with egg masses, 6 = 50-100% of roots with egg masses.

²Means within a column having a letter in common are not significantly different at the 5% level according to the Duncan Multiple Range Test.

Table 6. Response of 18 soybean strains to 5 Louisiana isolates of root-knot nematodes in greenhouse tests indicating differences between nematode isolates, October-November, 1973.

Strain	Egg mass index ¹				
	Wartelle	Vanderlick	Dessele	St. Landry	Shreveport
D69-6344	0.7 ab	0.8 b	0.7 ab	0.5 ab	0.1 a
Delmar	1.5 b	1.7 b	1.3 ab	1.8 b	0.8 a
Laredo	1.8 b	1.9 b	1.8 b	1.5 b	0.2 a
Bethel	2.6 c	0.8 a	2.0 bc	1.8 b	0.2 a
Bragg	3.2 d	1.2 b	4.0 e	2.2 c	0.5 a
Forrest	2.3 b	2.8 bc	3.3 cd	3.6 d	1.3 a
Hill	3.8 c	5.1 d	3.3 bc	2.9 b	1.0 a
FC 33 243	4.0 c	2.9 b	6.0 d	4.5 c	1.3 a
Mendota	3.5 b	5.7 d	4.6 c	5.4 d	1.5 a
Habaro	3.5 b	5.7 c	5.5 c	6.0 c	1.0 a
Mukden	4.6 b	4.1 b	6.0 c	5.7 c	2.3 a
Palmetto	5.5 d	4.5 c	6.0 d	3.8 b	2.9 a
Monroe	5.3 b	6.0 c	5.8 bc	6.0 c	1.0 a
Mandarin 507	5.5 b	6.0 b	5.8 b	5.8 b	1.5 a
Blackhawk	5.8 b	6.0 b	6.0 b	6.0 b	0.8 a
S-100	5.7 b	6.0 b	6.0 b	6.0 b	3.5 a
Peking	6.0 b	6.0 b	5.7 b	6.0 b	3.8 a
Lee 68	6.0 b	6.0 b	6.0 b	6.0 b	3.7 a
Mean	4.0 b	4.1 b	4.4 b	4.2 b	1.5 a

¹0 = no roots with egg masses, 6 = 50-100% of roots with egg masses.

²Means within a row having a letter in common are not significantly different at the 5% level according to the Duncan Multiple Range Test.

organism on soybeans, having an average egg mass index of 1.5. This had previously been noted as it was difficult to increase the population of these nematodes on soybeans considered to be susceptible.

There were highly significant differences between strains, isolates and dates in the combined analysis (Table 5). Interactions which were highly significant included strains x isolates, strains x dates, isolates x dates and strains x isolates x dates.

The interaction of isolates and dates indicated that some isolates, as an average of all strains, showed more pathogenicity at one date than they did at the other date, i.e., more in October than January. The reason may have been due to the colder temperatures during the January study. Strains x isolates interaction indicated that some strains, as an average of dates, were more resistant to one isolate than another. The significant strain x date interaction showed that some strains, as an average of isolates, were more resistant at one date than another. The mean square for strains significantly exceeded the interaction of strains x isolates and strains x dates, which indicated that reaction of strains was consistent enough over dates and isolates to allow comparisons as an average of dates and isolates. Also, the mean square for isolates was significantly larger than the mean square for strains x isolates

Table 7. Combined analysis of variance for winter and fall test data.

Source	d.f.	S.S.	M.S.	F
Experiments	(7)	214.0		
isolates	3	69.9	23.3	21.4**
dates	1	90.5	90.5	83.1**
I x D	3	53.6	17.9	16.4**
Error (a)	28	30.5	1.1	
Replications	35	244.5		
Strains	17	1459.2	85.8	45.4**
S x I	51	160.5	3.2	5.3**
S x D	17	134.8	7.9	13.4**
S x I x D	51	136.0	2.7	4.6**
Error (b)	472	279.2	0.6	
Total	647	2414.2		

**Significant at the 1% level.

interaction which indicated that valid conclusions could be drawn concerning isolates as an average of dates and strains.

As an average of dates and isolates, D69-6344, with an egg mass index of 0.9, had significantly fewer egg masses than any other strain (Table 6). However, three other strains were classified as highly resistant on the basis of having had average egg mass indices of less than 2.0. These were Delmar, Laredo and Bethel. Of the top four strains, only D69-6344 and Laredo were highly resistant to all four isolates (Table 7). Delmar was rated moderately resistant to the St. Landry isolate, and Bethel was moderately resistant to the Wartelle and Dessele isolates.

Forrest and Bragg as an average of isolates and dates were moderately resistant, although Bragg did have a high level of resistance to the Vanderlick isolate. Strains which appeared to have low levels of resistance were Hill and FC 33 243. Remaining strains were all highly susceptible.

Averaged over strains and dates, the Dessele isolate had a significantly higher egg mass index, the Wartelle and St. Landry isolates were intermediate, and the Vanderlick isolate had a significantly lower egg mass index than did other isolates (Table 6).

On the basis of two dates data, D69-6344 appeared to have the highest consistent level of resistance to the isolates of

Table 8. Response of 18 soybean strains to 4 Louisiana isolates of root-knot nematode, combined data indicating differences between strains.

Strain	Egg mass index ¹				
	Wartelle	Vanderlick	Dessele	St. Landry	Mean
D69-6344	1.3 a	0.9 a	0.9 a	0.7 a	0.9 a
Laredo	1.9 a	1.7 b	2.0 b	1.3 ab	1.7 b
Delmar	1.7 a	1.4 ab	1.9 b	2.1 c	1.8 b
Bethel	2.6 b	0.9 a	2.2 b	1.8 bc	1.9 b
Forrest	2.9 bc	2.4 c	3.1 b	3.3 de	2.9 c
Bragg	3.5 cd	1.1 ab	4.4 c	2.3 c	2.9 c
Hill	3.9 de	4.3 de	3.6 b	3.1 d	3.7 d
FC 33 243	3.3 bcd	2.7 c	5.9 e	3.9 ef	3.9 d
Mendota	3.6 cd	4.7 ef	4.4 c	4.5 fg	4.3 e
Habaro	3.0 bc	4.6 e	5.3 de	4.7 gh	4.4 e
Palmetto	5.2 fgh	3.8 d	5.0 cd	3.8 e	4.5 e
Mandarin 507	4.6 fg	4.6 e	5.5 de	4.9 gh	4.9 f
Mukden	4.5 ef	3.9 d	5.8 e	5.3 hi	4.9 f
Monroe	4.6 fg	5.0 efg	5.9 e	5.3 hi	5.2 fg
Blackhawk	5.4 h	5.4 fg	6.0 e	5.2 ghi	5.5 gh
Peking	5.4 h	5.0 efg	5.8 e	6.0 j	5.6 h
S-100	5.3 gh	5.0 efg	6.0 e	5.8 ij	5.6 h
Lee 68	6.0 i	5.6 g	5.9 e	5.8 ij	5.8 h

¹0 = no root with egg masses, 6 = 50-100% of the roots with egg masses.

²Means within a column having a letter in common are not significantly different at the 5% level according to the Duncan Multiple Range Test.

Table 9. Response of 18 soybean strains to 4 Louisiana isolates of root-knot nematode, combined data indicating differences between isolates.

Strain	Egg mass index ¹			
	Wartelle	Vanderlick	Dessele	St. Landry
D69-6344	1.3 b ²	0.9 a	0.9 a	0.7 a
Laredo	1.9 b	1.7 b	2.0 b	1.3 a
Delmar	1.7 a	1.4 a	1.9 b	2.1 b
Bethel	2.6 d	0.9 a	2.2 c	1.8 b
Forrest	2.9 b	2.4 a	3.1 bc	3.3 c
Bragg	3.5 c	1.1 a	4.4 d	2.3 b
Hill	3.9 b	4.3 c	3.6 b	3.1 a
FC 33 243	3.3 b	2.7 a	5.9 d	3.9 c
Mendota	3.6 a	4.7 b	4.4 b	4.5 b
Habaro	3.0 a	4.6 b	5.3 c	4.7 b
Palmetto	5.2 b	3.8 a	5.0 b	3.8 a
Mandarin 507	4.6 a	4.6 a	5.5 b	4.9 a
Mukden	4.5 b	3.9 a	5.8 d	5.3 c
Monroe	4.6 a	5.0 b	5.9 c	5.3 b
Blackhawk	5.4 a	5.4 a	6.0 b	5.2 a
Peking	5.4 b	5.0 a	5.8 c	6.0 c
S-100	5.3 b	5.0 a	6.0 c	5.8 c
Lee 68	6.0 b	5.6 a	5.9 ab	5.8 ab
Mean	3.8 b	3.5 a	4.4 c	3.9 b

¹0 = no root with egg masses, 6 = 50-100% of the roots with egg masses.

²Means within a row having a letter in common are not significantly different at the 5% level according to the Duncan Multiple Range Test.

root-knot tested. Delmar, Laredo and Bethel ran a rather poor second, with indices twice that of D69-6344, and also seemed to lack consistency over isolates. As a source of resistance to M. incognita in a breeding program D69-6344 would be the best of the strains tested in these experiments. In addition to its high level of resistance, due probably to two genes, it is the result of selection and therefore not highly unsuited agronomically to production in the South.

Concerning the question of races of root-knot nematode, there was a differential response of soybean strains at both dates and as an average of dates between isolates tested. The Shreveport isolate, although tested at only one date, was definitely less pathogenic on soybeans than the other four isolates. Differences between other isolates indicated physiological differences between these also. However, there was only one example of a strain being highly susceptible to one isolate and highly resistant to another. This occurred in Bragg, which as an average of dates, was susceptible to the Dessele and resistant to the Vanderlick isolate. Other differences within strains were significant, but were not as large.

The Shreveport and Vanderlick isolate should be considered as separate races of the root-knot nematode M. incognita, and although other isolates did evidence some physiological

differences, the Wartelle, Dessele and St. Landry isolates would be difficult, if not impossible, to separate using these soybean strains as differentials.

Results of these experiments were based entirely upon egg mass indices which in this work were closely correlated to galling. There were some inconsistencies with regard to resistance as reported here and performance in the field, particularly with reference to Bragg soybeans. Bragg had an egg mass rating of 4.4 under the Dessele and 3.5 under the Wartelle isolate, which seemed to indicate a higher level of resistance to the Wartelle isolate. However, Bragg yielded well when planted in soil infested with the Dessele nematode, but yielded poorly when planted in soil infested with the Wartelle isolate. This pointed out the importance of other factors influencing reaction to root-knot in the field. It suggested that the severe yield reductions experienced with Bragg in the Wartelle soil may have been due more to a disease complex rather than root-knot disease alone. This is not to say that resistance in D69-6344 was due to a disease complex (a possibility, however), because there were highly significant differences in the ability of root-knot nematodes to attack D69-6344 and Bragg, even when the Wartelle isolate was not considered. The matter of a disease complex as concerns Bragg's response to the Wartelle isolate is one worthy of further study.

REFERENCES

1. Allard, R. W. 1954. Sources of root-knot nematode resistance in lima beans. *Phytopathology* 44:1-4.
2. Atkinson, G. F. 1889. A preliminary report upon the life history and metamorphosis of a root-gall nematode, Heterodera radicicola (Greef) Muller, and the injuries caused by it upon the roots of various plants. *Sc. Contrib. Agr. Exp. Sta. Alabama Polytechnic Inst.* 1:177-226.
3. Bailey, D. M. 1941. The seedling test method for root-knot-nematode resistance. *Proc. Amer. Soc. Hort. Sci.* 38:573-575.
4. Barham, W. S., and J. W. Sasser. 1954. Inheritance of resistance to Meloidogyne spp. in tomatoes. *Proc. Assoc. South. Agr. Workers* 53:150.
5. _____, and N. N. Winstead. 1957. Inheritance of resistance to root-knot nematodes in tomatoes. *Proc. Amer. Soc. Hort. Sci.* 69:372-377.
6. Barrons, K. C. 1938. A method of determining root knot resistance in beans and cowpeas in the seedling stage. *J. Agr. Res.* 57:363-370.
7. _____. 1939. Studies of the nature of root knot resistance. *J. Agr. Res.* 58:263-271.
8. _____. 1940. Root-knot resistance in beans. *J. Hered.* 31:35-38.
9. Bessey, E. A. 1911. Root-knot and its control. *USDA Bur. Pl. Ind. Bull.* 217.
10. _____, and L. P. Byars. 1915. The control of root-knot. *USDA Farmers Bull.* 648.
11. Bird, A. F. 1960. Additional notes on the attractiveness of roots to plant parasitic nematodes. *Nematologica* 5:217.

12. Chitwood, B. G. 1949. "Root-knot nematodes"--Part I. A revision of the genus Meloidogyne Goeldi, 1887. Proc. Helminthol. Soc. Wash. 16:90-104.
13. Christie, J. R., and F. E. Albin. 1944. Host-parasite relationships of the root-knot nematode, Heterodera marioni I. The question of races. Proc. Helminthol. Soc. Wash. 16:90-104.
14. _____. 1946. Host-parasite relationships of the root-knot nematode, Heterodera marioni. II. Some effects of the host on the parasite. Phytopathology 36:340-52.
15. Collins, J. L., and H. R. Hagan. 1932. Varietal resistance of pineapple roots to the nematode Heterodera radiculicola (Greef) Muller. J. Jered. 23:503-511.
16. Cordner, H. B., F. B. Struble, and L. Morrison. 1954. Breeding sweetpotatoes for resistance to the root-knot nematode. Plant Dis. Reprtr. Suppl. 227:92-93.
17. Crittenden, H. W. 1954. Factors associated with root-knot nematode resistance in soybeans. Phytopathology 44:388. (Abstr.)
18. _____. 1955. Root knot nematode resistance of soybeans. Phytopathology 45:347. (Abstr.)
19. _____. 1958. Histology and cytology of susceptible and resistant soybeans infected with Meloidogyne incognita acrita. Phytopathology 48:461. (Abstr.)
20. _____. 1961. Studies of the host range of Meloidogyne incognita acrita. Plant Dis. Reprtr. 45:190-191.
21. Dean, J. L., and F. B. Struble. 1953. Resistance and susceptibility to root-knot nematodes in tomato and sweetpotato. Phytopathology 43:290. (Abstr.)
22. Dropkin, V. H. 1959. Varietal response of soybeans to Meloidogyne - a bioassay system for separating races of root-knot nematodes. Phytopathology 49:18-23.
23. _____, and P. E. Nelson. 1960. The histopathology of root-knot nematode infections in soybeans. Phytopathology 50:442-447.

24. Dropkin, V. H. 1963. Effect of temperature on growth of root-knot nematodes in soybeans and tobacco. *Phytopathology* 53:663-666.
25. Endo, B. Y., and J. A. Veech. 1969. The histochemical localization of oxidoreductive enzymes of soybeans infected with the root knot nematode Meloidogyne incognita acrita. *Phytopathology* 59:418-425.
26. Franklin, Mary T. 1971. Taxonomy of Heteroderidae. In B. A. Zuckerman, W. F. Mai, and R. A. Rohde (ed.) *Plant Parasitic Nematodes*. Academic Press. New York and London. p. 139-160.
27. Frazier, W. A., and R. K. Dennett. 1949. Isolation of Lycopersicon esculentum type tomato lines essentially homozygous resistant to root knot. *Proc. Amer. Soc. Hort. Sci.* 54:225-236.
28. Gilbert, J. C., and D. C. McGuire. 1952. Root knot resistance in commercial type tomatoes in Hawaii. *Proc. Amer. Soc. Hort. Sci.* 60:401-411.
29. Gilbert, J. C., and D. C. McGuire. 1956. Inheritance of resistance to severe root knot from Meloidogyne incognita in commercial type tomatoes. *Proc. Amer. Soc. Hort. Sci.* 68:437-442.
30. Godfrey, G. H. 1926. Effect of temperature and moisture on nematode root-knot. *J. Agr. Res.* 33:223-254.
31. _____. 1931. Some technique used in the study of the root knot-nematode, Heterodera radicicola. *Phytopathology* 21:323-329.
32. Golden, J. K., W. M. Powell, and F. F. Hendrix, Jr. 1972. The influence of storage temperature on recovery of Pythium spp. and Meloidogyne incognita from field soils. *Phytopathology* 62:819-823.
33. Goodey, T. 1932. On the nomenclature of the root-gall nematodes. *J. Helminthol. Soc. Wash.* 10:21-28.
34. Hare, W. W. 1956. A major gene for resistance to root-knot nematodes in pepper. *Phytopathology* 46:14. (Abstr.)

35. Hare, W. W. 1965. The inheritance of resistance of plants to nematodes. *Phytopathology* 55:1162-1167.
36. Hernandez, T. P., J. C. Miller, and J. M. Giamelva. 1965. Inheritance of resistance to root-knot nematodes, Meloidogyne incognita group, in tomatoes. *Proc. Amer. Soc. Hort. Sci.* 87:412-414.
37. Holston, E. M., and H. W. Crittenden. 1951. Resistance in soybeans to root-knot nematodes. *Phytopathology* 41:562. (Abstr.)
38. Hutchins, L. M. 1936. Nematode-resistant peach rootstocks of superior vigor. *Proc. Amer. Soc. Hort. Sci.* 34:330-338.
39. Isbell, C. L. 1931. Nematode-resistance studies with pole snap beans. *J. Hered.* 22:191-198.
40. Jones, L. H. 1932. The effect of environment on the nematode of the tomato gall. *J. Agr. Res.* 44:275-285.
41. Kofoed, C. A., and W. A. White. 1919. A new nematode infection of man. *J. Amer. Med. Assoc.* 72:567-569.
42. Lider, L. A. 1954. Inheritance of resistance to a root-knot nematode, (M. incognita var. acrita) Chitwood, in Vitis spp. *Proc. Helminthol. Soc. Wash.* 21:53-60.
43. Lordello, L. G. E. 1955. Nematodes attacking soybean in Brazil. *Plant Dis. Reptr.* 39:310-311.
44. Martin, W. J. 1954. Parasitic races of Meloidogyne incognita and M. incognita var. acrita. *Plant Dis. Reptr. Suppl.* 227:86-88.
45. _____, and W. Birchfield. 1973. Further observations on variability in Meloidogyne incognita on sweetpotatoes. *Plant Dis. Reptr.* 57:199.
46. McFarlane, J. S., E. Hartzler, and W. A. Frazier. 1946. Breeding tomatoes for nematode resistance and for high vitamin C content in Hawaii. *Proc. Amer. Soc. Hort. Sci.* 47:262-270.
47. McGuire, D. C., and R. W. Allard. 1958. Testing nematode resistance in the field. *Plant Dis. Reptr.* 42:1169-1172.

48. McGuire, D. C., R. W. Allard, and J. A. Harding. 1961. Inheritance of root knot nematode resistance in lima beans. *Proc. Amer. Soc. Hort Sci.* 78:302-307.
49. Minton, N. A. 1962. Factors influencing resistance of cotton to root-knot nematodes (Meloidogyne spp.). *Phytopathology* 52:272-279.
50. Neal, J. C. 1889. The root knot disease of the peach, orange and other plants in Florida. USDA Div. of Entom. Bull. 20:1-31.
51. Nirula, K. K., C. L. Khushu, and B. T. Raj. 1969. Resistance in tuber-bearing Solanum species to root knot nematode Meloidogyne incognita. *Amer. Potato J.* 46:251-253.
52. Orton, W. A. 1908. The development of farm crops resistant to disease. Yearbook of Agr. (U.S. Dep. Agr.) U.S. Gov. Printing Office, Washington, D. C. p. 453-464.
53. Peacock, F. C. 1959. The development of a technique for studying the host-parasite relationship of the root-knot nematode Meloidogyne incognita under controlled conditions. *Nematologica* 4:43-55.
54. Rohde, R. A. 1965. The nature of resistance in plants to nematodes. *Phytopathology* 55:1159-1162.
55. Romshe, F. A. 1942. Nematode resistance test of tomatoes. *Proc. Amer. Soc. Hort. Sci.* 40:423.
56. Sasser, J. N. 1954. Identification and host-parasite relationships of certain root-knot nematodes (Meloidogyne spp.). Univ. of Maryland Agr. Exp. Sta. Bull. A-77.
57. _____. 1966. Behavior of Meloidogyne spp. from various geographical locations on ten host differentials. *Nematologica* 12:97-98.
58. Sharpe, R. H., C. O. Hesse, B. F. Lownsbery, V. G. Perry, and C. J. Hansen. 1969. Breeding peaches for root-knot nematode resistance. *J. Amer. Soc. Hort. Sci.* 94:209-212.
59. Smith, A. L. 1941. The reaction of cotton varieties to Fusarium wilt and root-knot nematode. *Phytopathology* 31:1099-1107.

60. Smith, A. L., and A. L. Taylor. 1947. Field methods of testing for root-knot infestation. *Phytopathology* 37:85-93.
61. Stevenson, F. J., and H. A. Jones. 1953. Some sources of resistance in crop plants. In A. Stefferud (ed.) *Plant Diseases. Yearbook of Agr. (U.S. Dep. Agr.)* U.S. Gov. Printing Office, Washington, D. C. p. 192-216.
62. Tanveer, M., and A. T. Saad. 1971. Reaction of some cultivated crops to two species of root-knot nematodes. *Plant Dis. Reprtr.* 55:1082-1084.
63. Taylor, A. L., and B. G. Chitwood, 1951. Root knot susceptibility of Lycopersicon peruvianum. *Plant Dis. Reprtr.* 35:97.
64. Taylor, A. L., and E. M. Buhner. 1958. A preliminary report on distribution of root-knot nematode species in the United States. *Phytopathology* 48:464. (Abstr.)
65. Thomason, I. J., and B. Lear. 1961. Rate of reproduction of Meloidogyne spp. as influenced by soil temperature. *Phytopathology* 51:520-524.
66. Tufts, W. P., and L. H. Day. 1934. Nematode resistance of certain deciduous fruit tree seedlings. *Proc. Amer. Soc. Hort. Sci.* 31:75-82.
67. Tyler, J. 1941. Plants reported resistant or tolerant to root knot nematode infestation. U.S. Dep. Agr. Misc. Pub. No. 406. 91 pp.
68. Veech, J. A., and B. Y. Endo. 1970. Comparative morphology and enzyme histochemistry in root knot resistant and susceptible soybeans. *Phytopathology* 60:896-902.
69. Watts, V. M. 1947. The use of Lycopersicon peruvianum as a source of nematode resistance in tomatoes. *Proc. Amer. Soc. Hort. Sci.* 49:233-234.
70. Webster, R. E. 1950. A comparison of greenhouse and field methods for evaluating lima beans for resistance to root knot nematodes. *Proc. Amer. Soc. Hort. Sci.* 56:395-400.

71. Weimer, J. L., and L. L. Harter. 1925. Varietal resistance of sweetpotatoes to nematodes, Heterodera radicumicola (Greef.) Muller, in California. *Phytopathology* 15:423-426.
72. Weinberger, J. H., P. C. Marth, and D. H. Scott. 1943. Inheritance study of root knot nematode resistance in certain peach varieties. *Proc. Amer. Soc. Hort. Sci.* 42:321-325.
73. Wiles, A. B. 1957. Resistance to root-knot nematode in cotton. *Phytopathology* 47:37. (Abstr.)
74. Williams, Curtis, Wray Birchfield, and E. E. Hartwig. 1973. Resistance in soybeans to a new race of root-knot nematode. *Crop Sci.* 13:299-301.
75. Winstead, N. N., and J. N. Sasser. 1956. Reaction of cucumber varieties to five root-knot nematodes (Meloidogyne spp). *Plant Dis. Reprtr.* 40:272-275.
76. Winstead, N. N., and R. D. Riggs. 1959. Reaction of watermelon varieties to root-knot nematodes. *Plant Dis. Reprtr.* 43:909-912.
77. Wright, S. L. 1956. Inheritance of resistance to root knot nematode in cotton. Unpublished manuscript of Master of Science thesis, Louisiana State University, Baton Rouge, La.

Vita

Donald James Boquet was born the son of Mr. and Mrs. Ferdinand Boquet on October 7, 1945, at Bourg, Louisiana. He attended elementary school at Bourg from 1950 to 1958, Houma Jr. High from 1959 to 1960, then South Terrebonne High in Bourg until graduation in 1963. He received a Bachelor of Science degree in Agriculture from Nicholls State University in January, 1968. From January, 1968, to January, 1969, he attended Louisiana State University as a graduate student in the Department of Agronomy. In January, 1969, he married Annie Santangelo of Tampa, Florida. In February, 1969, he was drafted into the armed service in which he served until January, 1971. Upon release from active duty he returned to Louisiana State University where he completed requirements for the Master of Science Degree in Agronomy in 1971. He is at this time a candidate for the Doctor of Philosophy Degree in the Department of Agronomy.